CHAPTER-II
REVIEW OF LITERATURE

Review of literature provides a sound base for any scientific investigation. Any research study, demands an acquaintance with the studies done already on a particular subject, in order to develop a clear picture of the problem in hand and to comprehend the study correctly. It also helps us to elucidate the correct methodology to be used in the study.

In this chapter, the literatures related to this study are presented under the following heads.

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2.1. SCENARIO OF CEREAL PRODUCTION

2.1.1 Rice

Rice is one of the important cereals in the world. It is commonly used as milled (white) rice produced by removing the hull and bran layer of the rough rice kernel (paddy) (Perdon et al., 2001).

Rice production in India is an important segment of the national economy. India is the world’s largest producer of white rice, accounting for 20% rice production in the world. Rice is India’s pre-eminent crop, and is the staple food of the people of the eastern and southern parts of the country.

India is the second largest rice producing country in the world next to China. In India 65% of rice consumed is after parboiling. Rice is the largest consumed calorie source among the food grains. With a per capita availability of 73.8 kg it meets 31% of the total caloric requirement of the population. More than 200 commercial rice varieties of indica subspecies are grown in about 44 million hectares (2006-2007) with 53% irrigated area (2003-2004). The average yield of rice is 2.08 tones/ha (2006-07). The production of about 91 million tons rice (2006-07), is estimated as one-fifth of world production. The combination of increasing cropping intensity today helped India self-sufficient in rice production (Patil and Singh, 2008).

India’s production went up from 176 million tones in 1990-91 to 218 million tones in 2009-2010 which works out to about 24% increase in 20 years. The per capita production is about 185 kg per year. But increase in Tamilnadu is very much lower at 8% from 7.4 million tones in 1990-1991 to only 8.0 million tones in 2009-2010 for a population of about 67 million people, which work out to a per capita production of only 120 kg per year (Directorate of Economics and Statistics, 2010).

The total food protein and energy production per hectare were found higher in rice than in wheat. In the developing and underdeveloped countries, cereals supply more than 50% of protein and in the ensuing years, it will, probably, remain the dominant source of protein for nearly two third of world (Jamuna, 1996).
2.1.2 Millets

Based on the last five year records (2007-2011), India ranks the first and eleventh place in top global consumption and per capita consumption of millets respectively. During 2010-2011, the world production of millet was 360 lakhs MT. In India the millet production was 125 lakhs MT during the year 2010-2011 (en.wikipedia.org/wiki/millet).

In Tamilnadu, small millets comprising of six crops were cultivated in a total area of 7, 18, 936 ha with a total production of 17.47 lakh tones in 2008-2009. The percentage of millet contribution to total cereal area was around 27.05 and in terms of production of cereal it was 25.21% in 2008-2009. Over a period of past ten years from 1999-2000 to 2008-2009, no uniform trend was observed in the area under millets. However the area was hovering around 7.68 lakh ha. Similarly there was a variation in the production of millets over the past ten years from 6.78 lakh tones in 2002-2003 to 17.47 lakh tones in 2008-2009 (Directorate of Economics and Statistics, 2010). During the year 2010-2011 the millet production was 19.15 lakhs MT (www.tn.gov.in).

Foxtail millet ranks second in the total world production of millets and it continues to have an important place in the field of agriculture all over the world providing approximately six million tons of food to millions of people, mainly on poor or marginal soils in the Southern Europe and in the temperate subtropical and tropical Asia (Marathee, 2003).

Foxtail millet was and is, by far, the most important millet in China, although the growing areas declined, from 1986 to 1990, as maize production has increased. China produced more than 90 per cent of the world’s foxtail output, according to 1981 to 1985 estimate. Foxtail millet requires warm weather and matures quickly in the hot summer months. Generally, grown in semi-arid regions, it has low water requirement. The genus *Setaria italica* is widely distributed in warm and temperate areas (Dendy, 1995).

Little millet (*Panicum. Syn. Panicum miliare* is a auct. non Lam) is a species of millet, in the family Poaceae. Millet is being cultivated in the temperate zones of Asia, China, East Asia and also in the tropics of the continent; India, Indochina and
Malaysia. The plant can be cultivated in India up to 2000 m above sea level. It can withstand both drought and water logging. The largest cultivation is in central India. Usually, it is planted by using a seed drill. It can also, if necessary, be planted spoiled. The green plant can also be used in part as cattle feed. The straw can be mixed with clay or cement in construction works. The harvest yield is normally from 230 to 400 kg/ha. Little millet is cooked like rice and sometimes it is also milled and baked. The protein content of this grain is 7.7% (German Wikipedia; Heywood, 1978).

Little millet covers area (13012 ha) of the total cultivable area under millets. It is, generally, grown in less fertile soil as a mixture crop with pulses throughout the year regardless of the seasons. In Dharmapuri district the millet production was 79.91 MT during the year 2010-2011 (www.tn.gov.in).

2.2 PROCESSING AND CHEMICAL COMPOSITION OF CEREALS

2.2.1 Raw brown rice

Rice is harvested in the form of a covered grain, termed as paddy or rough rice. The grain contained the kernel (caryopsis) enveloped in a protective covering called husk or hull, which constitutes about 18-22 per cent of grain by weight. The weight distributions of different components were pericarp 1-2 per cent, seed coat and aleurone 5 per cent, starchy endosperm 89-91 per cent and embryo 2-3 per cent. Since rice is processed and consumed mainly in whole kernel form, the physical attributes of the intact endosperm was always of highest importance. The changes in the constituents of rice, like amylose, amylopectin, protein, fat, minerals and vitamins were governed by genetic as well as environmental factors (Pillaiyar, 1988).

Unpolished whole grain rice that is produced by removing only the hull or husk using a mortar and pestle or rubber rolls. It may be distinctly brown, reddish or purplish. The embryo may or may not be left intact depending on the hulling process. It becomes milled or white rice when the bran layer is stripped of in the milling or 'whitening' process. Thus, the distinguishing factor should be its unpolished feature and not the color. It has a mild nutty flavour, is chewier than white rice and becomes rancid more quickly, but is far more nutritious. Any rice, including sticky rice, long-grain rice, or short-grain rice, may be eaten as brown rice (Dinesh Babu et al., 2009).
Brown rice (hulled rice) is composed of surface bran (6–7% by weight), endosperm (E90%) and embryo (2–3%) (Chen et al., 1998).

Brown rice is loaded with vitamins and minerals that are not available in white rice. Its bran layer contains a very important nutrient and rich in fiber and essential oils. Fiber has been involved in the prevention of major diseases such as gastrointestinal and heart diseases. The essential oils in the bran have also been found to prevent heart diseases because these decrease serum cholesterol, which is a major risk factor in heart disease (Jeyanth and Mohamed, 2009).

Soaad and Rayees (1981) reported that nutrient contents and distribution of protein, fat, ash, fibre, Nitrogen Free Extract (NFE) in seven Iraqi rice and it’s by products. The results indicated that the protein content of both brown and milled rice has a significant negative correlation with NFE. Bran contained the maximum Ca, K, Mg and P whilst milled rice contained the lowest levels in all the tested varieties.

Juliano (1985) compiled the proximate composition of paddy, brown rice, milled rice and bran. The protein-content (N x 5.951) was found to be 5.8-7.7, 7.1-8.3, 6.3-7.1, 11.3-14.9 and 11.2-12.4 per cent with paddy, brown rice, milled rice, bran and polish respectively. Crude fat content in the order of paddy, brown rice, milled rice, bran and polish were 1.5-2.3, 1.6-2.8, 0.3-0.5, 15.0-19.7 and 10.1-12.4 per cent respectively.

According to Gomez (1979), the protein content of the brown rice ranged between 4.3 and 18.2 per cent with a mean of 9.5 per cent.

Ramarathnam and Kulkarni (1983) studied the effect of aging on the fatty acid composition of some Indian varieties of brown rice. The changes in fatty acid composition of ten varieties of Indian brown rice indicated that there was slight increase in linoleic acid; while palmitic and oleic acid levels declined during the storage of 120 days.

Vitamins are generally present in higher levels in brown rice than in raw milled rice. Distribution of vitamins in different milling fractions varies from 2.9-6.1 μg/g in brown rice while that of milled rice and bran vary between 0.1 and 1.1 and between 12 and 24 μg/g respectively. The paddy, as such, contains 2.6-3.3 μg/g of thiamine. Vitamins, such as, riboflavin and niacin are not in free form. The riboflavin
content of unmilled raw rice ranges between 0.05 and 0.09 mg/100 g and niacin in the range of 4.9 and 6.4 mg/100g (Pillaiyar, 1988).

Ajayi and Agun (1989) observed the effects of soaking temperature and steaming period on some quality parameters of rice on ‘Os6’ rice variety. These parameters include grain breakage, swelling capacity and test water absorption ratio. The steeping temperature was found between 55°C and 75°C while the steaming period ranged from 60 to 120 min at atmospheric pressure for a 16-hr steeped paddy, and the results showed favorable parboiling conditions with an acceptable product at 65-75°C soaking temperature and steaming times between 90 and 110 min. The higher the soaking temperature the lower the breakage, swelling capacity and water absorption ratio. The authors also found that a longer steaming period lowers the breakage, swelling capacity and water absorption ratio.

During milling, brown rice is subjected to abrasive or friction pressure to remove bran layers resulting in high, medium or low degrees of milling depending on the amount of bran removed (Chen and Siebenmorgen, 1997; Chen et al., 1998).

Milling brings about considerable loss of nutrients and affects the edible properties of milled rice (Chen et al., 1998 and Doesthale et al., 1979). As most cereals, rice does not show a homogeneous structure from its outer (surface) to inner (central) portions (Itani et al., 2002).

Commercial brown and yellow milled rice submitted to inappropriate storage conditions were characterized and utilized to develop instant flours that were used in the preparation of atoles. The grains were classified as long-thin; the average size was 2.13 x 6.79 mm. The milling yields obtained in laboratory with paddy rice were 70% brown rice and 60% milled rice. Brown rice and yellow milled rice had similar amylase contents, 22.5 and 25.6% respectively. Gel consistency was soft with low gelatinization temperature (63-68 degrees C) for both samples. Instant flours were prepared by soaking the grain in water, and then steaming, drying and milling it. The highest values for water absorption index were obtained from yellow milled instant rice flour. Protein and ash contents of brown and milled rice were unaffected by hydrothermal process, and the lipid content showed only little changes (Martínez et al., 1997)
Pandey and Gupta (2000) observed the milling characteristics of eighteen varieties of paddy grown in India and estimated their physical characteristics namely length, width and thickness of brown rice and milled rice. The brown rice yield varied from 75.1% to 79.60%, whereas, the milling yield ranged from 67.01% to 75.45% at a constant time of polishing.

Three Indian rice cultivars, varying in length to breadth ratio, were parboiled and evaluated for their milling characteristics by Hardeep and Singh (2001). The raw and parboiled rice samples were milled for 0, 20, 40, 60, 80 and 100 sec in the McGill no.2 rice miller and tested for the degree of milling, ash distribution pattern and conductivity. Parboiled rice samples, from all the three rice cultivars, showed a lower degree of milling as compared to raw rice for the same milling duration. Parboiling lead to a significant increase in the ash content and conductivity values in all the three rice cultivars.

Gbabo et al., (2008) analyzed the effect of variety, pressure and specific volume of steam on the head rice yield of milled parboiled rice. The samples were milled after drying and tempering to 13% moisture content. The highest head rice yield of 93.3% was obtained with the higher process pressure ($5.5 \times 10^4 \text{N/M}^2$).

Sowbhagya and Zakiuddin (1991) studied the effect of presoaking on cooking time and texture of raw and parboiled rice. Milled rice (IR 2, year old) needed about 15 min to cook in excess boiling water. Parboiled rice (normal, roasted, parboiled) required longer time (21 to 32 min) for cooking, depending upon parboiling conditions. Presoaking, at room temperature, for 15 min of raw and 2 to 3 hr of parboiled rice reduced the cooking time by 50 % for raw and 25-40 % for parboiled rice as compared to unsoaked controls. Presoaking of raw rice caused an increase in the length (about 20%) of cooked raw rice but a reduction in thickness (about 5 %) as compared to unsoaked cooked control.

According to Yamakura et al., (2005), high temperature presoaking (at 55°C) effectively improved the nutritional qualities and biofunctionality of brown rice by decomposing residual protein to free amino acids like serine, glycine, and γ-amino butyric acid (GABA).
The kernels of brown rice, however, are more resistant to water infusion than are white rice kernels which usually have cracks that help water to diffuse inside. The bran on the brown rice kernels restricts water diffusion (and therefore water penetration) into the kernels, so most of the absorption happens near the embryo and the periphery of the grains and does not infiltrate into the cracks (Horigane et al., 2006). For this reason, the presoaking step is almost essential when cooking brown rice kernels to improve the eating quality after cooking.

Bett-Garber et al., (2007) determined the influence of the amount of water during cooking on flavor and texture attributes, three water-to-rice ratios of low (less than recommended), recommended, and high (more than recommended). The recommended amount used was based on amylose content and cook type for the cultivar. Four diverse cultivars were compared: Delimont (aromatic long-grain), Saber (conventional long-grain), Neches (waxy long-grain), and Bengal (conventional medium-grain). A descriptive sensory panel evaluated flavor and texture attribute intensities. The water-to-rice ratio did not significantly affect flavor attributes across all cultivars. The amount of water affected II of the 14 texture attributes evaluated. Of these II, initial starchy coating, slickness, stickiness between grains, cohesiveness, and uniformity of bite greater amounts of water at cooking, whereas hardness, stickiness to lips, springiness, and chewiness decreased in intensity.

Cereals and millets generally hydrate at a moderate rate and their hydration behaviour differs in native and in processed state. Singh et al., (2010) studied the hydration of paddy, milled rice, parboiled rice, wheat, millets and equilibrium moisture content (EMC) on soaking at room temperature. Paddy hydrated very slowly, hydration rate was slow in brown rice but fast in milled rice and highest in waxy rice. In most of the rice varieties, maximum absorption occurred at the end of 30 min. In wheat hydration rate was slow and its EMC was highest (43%). Maize grits of big size hydrated slowly compared to small grits. In coarse cereals EMC varied from 28 to 38%. Foxtail millet hydration was slow whereas that of finger millet was fast.

Milling and polishing are important operations during the production of white rice. The degree of milling and polishing has a significant effect on the nutritional aspects of white rice, especially on minerals, due to non-uniform distribution of
nutrients in the kernels. Information on the distribution of nutrients in rice will greatly help in understanding the effect of milling and aid in designing procedures that improve technological and sensory properties of rice while retaining its essential nutrients as much as possible. Jianfen et al., (2008) selected, three kernel shapes (short-, medium- and long-grain) of rice for the study of milling characteristics and distribution of zinc (Zn) and phytic acid using abrasive milling and X-ray fluorescent microscope imaging approaches. The results give us the possibility to process brown rice to obtain low PA contents and a relatively high Zn.

Rice is an important staple food in Asian countries. In the rural areas it is also a major source of micronutrients. The bioavailability of zinc from rice, is low because it is present as an insoluble complex with food components such as phytic acid. Jianfen et al., (2008) investigated the effects of soaking germination and fermentation reducing the content of phytic acid, while maintaining the sufficient levels of zinc, in the expectation of increasing its bioavailability. Fermentation treatments were most effective in decreasing phytic acid (56-96% removal), followed by soaking at 10ºc after preheating (42-59%). Steeping of intact kernals for 24 h at 25ºC had the least effect on phytic acid removal (<20%). In-vitro solubility, as a percentage of total zinc in soaked rice, was, significantly, higher than in untreated brown rice while in steeped brown rice, it was lower (p<0.05).

For brown rice, many studies have focused on the effects of parboiling (Sujatha et al., 2004; Heinemann et al., 2005; Derycke et al., 2005) and germinating (Watanabe et al., 2004; Genkawa et al., 2007; Kim et al, 2007) on the physical properties of the brown rice, but few reports have addressed how soaking affects the digestive properties of cooked rice. It is possible that the swelling and gelatinization of the residual starch during cooking, both of which are determined by the moisture content and the level of water diffusion inside the kernels, could affect the rate and extent of digestion of the cooked rice.

Brown rice kernels (japonica type) were soaked in water at different temperatures (25 or 50ºC) before cooking to a moisture content of 20 or 30%. Soaked brown rice was cooked in either the soaking water (SW) or in distilled water (DW) (rice solids to water ratio 1:1.4). Color, texture, and in vitro digestive properties of the cooked rice were examined (Jung and Seung, 2009). When the soaking temperature
was higher (50°C vs. 25°C), water absorption and starch leaching were greater. To reach 20% moisture, the rice required 1 hr of soaking at 50°C but 2 hr of soaking at 25°C. Both the moisture content of the soaked rice and the soaking temperature affected the texture of the cooked brown rice. Rice that attained 20% moisture content during soaking was harder and less adhesive when cooked compared with rice that attained 30% moisture content. The rice soaked at 50°C was slightly softer but more adhesive when cooked than rice soaked at 25°C. The soaking temperature and moisture content of the rice kernels also affected the digestive properties of the cooked rice. The rice soaked at 50°C was slightly softer but more adhesive when cooked than rice soaked at 25°C. The soaking temperature and moisture content of the rice kernels also affected the digestive properties of the cooked rice. The cooked brown rice that had attained 30% moisture before cooking was digested to a greater extent than rice that had attained 20% moisture. Even at equal moisture content, the rice soaked at the higher temperature (50°C) was digested more readily. It was assumed that the amount of soluble material leached during soaking differed according to the soaking temperature and moisture content, which subsequently affected the texture and digestive properties of the cooked brown rice. This result indicated that the soluble material leached during soaking made the cooked rice harder and less digestible, perhaps due to interactions between these molecules and the gelatinized rice during cooking.

2.2.2 Parboiled brown rice

It is estimated that about one-fifth of world’s rice and more than half of the Indian production undergoes parboiling process. The parboiling process has disrupted the organized constituent of rice. Rice starch was gelatinized during parboiling and the total amylose content of the rice remained unchanged (Ali and Bhattacharya, 1972).

Apart from India, Bangladesh, Pakistan, Nepal and Sri Lanka are also following the process of parboiling. Parboiled rice is also consumed in many other countries of Asia and Africa, particularly among the descendants of Indian origin (Borasio and Gariboldi, 1967).

Parboiling, literally, means partial boiling. In practice, it means boiling (i.e, cooking) of the rice within the husk (so as to retain its size and shape) after which it is dried. In other words, parboiling (or hydrothermal treatment, as some recent workers call it) is nothing but rice precooked in paddy form. The process involves soaking, steaming and drying the rice with husk intact. About one fifth of the world production
and more than half of the paddy produced in India were reported to be parboiled (Bhattacharya, 1985).

Cooking implies hydration and gelatinization of starch. So, the two components of the process are water and heat, when starch is out in water at room temperature, it hydrates slowly, ultimately coming to an equilibrium at around 30% moisture (wet basis). No appreciable change occurs when this slurry is heated, until at a particular temperature the granules suddenly start to swell and hydrate very rapidly. At the same time, the slurry becomes viscous and also more translucent. This phenomenon is called gelatinization temperature range. This range, usually, lies between 50°C and 80°C (Gariboldi, 1984).

Among cereals, rice is the only grain, which is preferred as whole kernel for cooking and consumption. Unfortunately, rice is highly prone to breakage due to cracks in rice developed during harvesting and threshing, which cannot be retrieved by any other means except pre-milling process known as “Parboiling” (Pillaiyar, 1993).

Unlike other cereals, rice is mostly cooked as whole milled grains for consumption. Generally, the paddy is either milled as such which yields ‘white rice’ or ‘raw rice’ or is given a pre-milling cooking treatment called ‘parboiling’ which after milling gives parboiled rice. Bhattacharya and Swamy (1967) reported that the milling quality of parboiled rice is strongly dependent on the conditions of its drying. While proper drying can, practically, avoid breakage of rice entirely. Improper drying could lead to even 100% breakage. Drying, thus, plays the most crucial role in the technology and economics of parboiling.

During the process of parboiling, the husk opens slightly due to swelling of the kernel. This makes the dehusking operations easier, thereby increasing the shelling capacity of the mill. As a matter of fact, the improvement in the milling quality sometimes more than off-sets the cost of processing, and often the parboiled rice is sold at a cheaper rate than raw rice. This improved milling quality arises from healing of kernal defects as a result of realignment and cementing of the grain constituents upon cooking of the starch during parboiling (Bhattacharya and Subbarao, 1966).
In India, parboiled brown rice is the staple food of people in the coastal states of eastern and southern parts of the country. Parboiling is a very ancient process which originated in India and is still followed widely in the country. Parboiling has been carried out by small, home-scale methods for centuries. Large-scale methods were adopted for commerce from the early part of the present century. The need to eliminate the pronounced defects of these processes inspired the development of a few improved processes in India during the last few decades. Several highly mechanized, patented processes have been adopted in the west after the nutritional and technological value of parboiling became widely known. The two commonest large-scale methods being practiced in India and elsewhere are the so-called single boiling and double-boiling methods. The oil content of bran was reported to increase further with increase in the temperature and duration of soaking as well as with increasing pressure of steaming. Contrary to these findings, in an experiment with carefully controlled degrees of polishing and after calculating the complete oil balance, it was observed that neither the temperature of soaking nor the duration of steaming during parboiling influenced the oil content of the bran when calculated for precise degrees of milling (Ghose et al., 1960).

Parboiling also causes some minor disadvantages during milling. Firstly, due to hardening of the grains, parboiled rice requires a greater force or longer time to mill. Secondly, polishing of parboiled brown rice leads to some problem of rice stickiness and clogging of the mill screen. The resultant rice also has a rather unattractive appearance (Raghavendra et al., 1967).

Parboiling resulted in rupturing of protein bodies and decreasing the solubility. It was noted that the solubility of untreated rice was 73.4 per cent while that of parboiled rice was only 31.1 to 22.2 per cent (Juliano, 1985).

Destruction of some natural antioxidants by parboiling treatment is also found during hydrolytic rancidity (Sowbhagya and Bhattacharya, 1976).

Parboiled rice has also been claimed to be more resistant to infestation by insects and moulds. It is considered that the greater hardness and the smooth surface of the gelatinized grain provide a safe cover from insect attacks. After parboiling, the finished rice acquires a color varying from light yellow to medium amber. This discoloration is chiefly due to non-enzymatic browning of the maillard type, as it is
largely inhibited by bisulphate. A part of the bran might be embedded in the endosperm during parboiling, which would add to the color of the rice, more so because this layer itself is darkened by maillard reaction, being rich in free sugars and amino acids. Parboiling, actually, lowers the total B₁ (thiamine), content of the original, but whatever remains is much better protected against milling loss (Subbarao and Bhattacharya, 1966). Other vitamins (riboflavin, niacin), minerals (Ca, P, Fe) and even protein are also, protected in the same way.

Increase in oil content of bran was attributed to the outward movement of the oil during parboiling which was further accelerated with an increase in temperature and duration of soaking as well as the increase in the pressure of steaming (Vasan et al., 1971).

The storage behavior of rice is improved by parboiling. Hydrolytic rancidity, due to splitting of fat to free fatty acids, is completely checked as a result of inactivation of rice lipase. However, parboiled rice is more prone to oxidative rancidity leading to deterioration of aroma and flavour (Houston, 1972).

Polishing of parboiled brown rice leads to the problem of rice stickiness and clogging of the mill screen. This problem is, usually, overcome by addition of a little husk during polishing, or by milling the paddy directly in huller. This property is related to the greater surface oil content of milled parboiled rice (Abdul and Bhattacharya, 1978).

Bhattacharya and Ali (1985) reported that water-soluble vitamins, such as thiamine and nicotinic acid, were found more in milled parboiled rice than in raw rice. There was no change or little change in the constituent of brown rice after parboiling. The parboiling process had reduced the loss of minerals like phosphorus, calcium, iron, manganese and molybdenum.

Heinemann et al., (2005) studied the chemical composition of commercial samples of brown, parboiled brown, parboiled milled and milled rice, and the contribution of each mineral to the Recommended Dietary Allowances (RDA). The results showed protein (N* 5.7) and crude fat contents in all rice forms similar to
literature data with some differences in ash contents, mainly between milled samples. Parboiled rice showed 18% ash enrichment in comparison with milled rice, and higher contents of K and P. The brown rice analysed showed concentrations of P, Mn and Na lower than those reported in literature, indicating the usefulness of selecting, nutritionally, promising varieties for commercial production. Macronutrients, which are the most affected by parboiling and milling, showed a low contribution to the RDA in all forms of rice.

The effects of soaking temperature and steaming period on some of the quality parameters of rice were studied for ‘Os6’ rice variety. These parameters include grain breakage, swelling capacity and test water absorption ratio. Steeping temperature between 55°C and 75°C and steaming period from 60 to 120 min at atmospheric pressure for a 16 hr steeped paddy showed favourable parboiling conditions with an acceptable product at 65-75°C soaking temperature and steaming times between 90 and 110 min. The higher the soaking temperature the lower the breakage, swelling capacity and water absorption ratio. It was also found that a longer steaming period lowers the breakage, swelling capacity and water absorption ratio (Ajayi and Agun, 1989).

Paddy was normally parboiled by soaking in water to saturation level (30-31% m.c), draining and steaming of soaked paddy. Other processes like pressure-boiling (steaming of partially soaked paddy at fairly high pressure, 2.5 kg/cm or higher) and dry-heat parboiling (roasting of fully soaked paddy) have also been developed (Manisha and Ali, 1998).

Durakova and Menkov (2004) analyzed the moisture sorption characteristics of rice flour. Moisture equilibrium data (adsorption and desorption were determined for rice flour using the static gravimetric method at 10, 20 and 30°C). Equilibrium moisture content decreased with an increase in temperature at any given aw. The results showed that temperature did not appear to affect monolayer moisture and the heat of sorption decreased with increasing moisture content.

Lambeerts et al., (2006) studied the effects of the soaking and steaming steps in rice parboiling on color changes and the levels of reducing sugars in rice were studied. Brown rice was soaked to different moisture contents (MC, 15, 20, 25, and
The color parameters indicated that during soaking, red and yellow bran pigments diffused from the bran into the endosperm. The increase in brightness brought about by soaking rice was attributed to migration of rice compounds (e.g., lipids) from the inner to the outer bran layers (rice surface). The levels of reducing sugars in brown and milled soaked rice samples increased with increasing brown rice MC after soaking. The total color difference between parboiled and non parboiled rice increased with increasing MC after soaking and depended on the intensity of the steaming conditions as reflected in the degree of starch gelatinization. Parboiling affected yellowness more than redness in mildly steamed brown rice and most in intermediately steamed brown rice. Severe steaming of brown rice affected redness more than yellowness. Reducing sugars were formed and lost during steaming, suggesting Maillard reactions during steaming.

**Parnsakhorn and Noomhorm (2008)** selected Thai rice varieties with high amylase content (Chainat 1, Supanburi 1) and low amylase content (Koa Dok Mali 105) were used to produce parboiled brown rice. They studied brown rice with the initial moisture content of 13±1% (w.b.) was soaked at two different initial soaking temperatures of 70 and 80°C. The soaking time was 1h, 2h, 3h and 4h, followed by steaming at temperature of 100°C for 10, 15 and 20 min. The samples were then shade dried at 30±1°C and 60±5 %RH to a final moisture content of 13±1% (w.b.). Physicochemical properties were determined and sensory analysis was performed for selected processing conditions. Head rice yield, yellowness (b-value), whiteness, hardness, water absorption, vitamin E and vitamin B2 were measured and compared with those of commercial parboiled paddy. Results revealed that the head rice yield, color (b-value), cooking time and hardness of parboiled brown rice were decreased whereas whiteness and water absorption were increased compared with commercial parboiled paddy. Qualitatively, parboiled brown rice showed intermediate values between milled rice and commercial parboiled paddy. Sensory analysis revealed high acceptance of cooked parboiled brown rice from the panelists. However, presence of vitamin B2 decreased and vitamin E disappeared after parboiling process on brown rice. Head rice yield was lower for parboiled brown rice when compared to that of parboiled paddy but greater than the head rice yield of non-parboiled rice.
Ondier et al., (2011) studied the effects of temperature and relative humidity (RH) on the equilibrium moisture contents (EMCs) of rough rice, brown rice, and head rice from non-parboiled and a parboiled rice. Rice hulls attained the lowest EMC followed by rice bran, brown rice, broken kernels, and head rice; this held for both parboiled and non-parboiled samples.

Zakiuddin and Bhattacharya (1982) studied the pressure parboiling of rice. The long time and hard texture of pressure-parboiled rice have been investigated. Paddy, adjusted to various moisture contents (12-30%), was steamed under different pressures (0-3kg/cm²) for different times (5-80 min). Translucence index (per cent rice area are not covered by white belly), gelatinization index (equilibrium moisture content attained by paddy immediately after steaming when soaked in water at room temperature, or immediate EMC-S), retrogradation index (per cent fall in EMC-S of rice after drying and milling as compared to immediate EMC-S), cooking resistance index (per cent fall in water uptake during cooking of parboiled as compared to that of raw rice), colour and headrice recovery were studied. The degree of each property increased with the increase in the moisture content, pressure and time of steaming.

Whatever be the parboiling system the paddy had to be dried in two stages, first steamed paddy should be brought to 16-20 per cent moisture and tempered to 3-4 hours and then dried to 13-14 per cent for milling. Otherwise the parboiled paddy also resulted in breakage during milling (Bhattacharya, 1993).

Varadharaju et al., (2001) determined the milling and cooking qualities of conduction parboiled paddy samples of ‘ADT 36’, ‘IR 20’ and ‘CO 45’. The initial moisture content and contact time contributed for more head rice recovery and gelatinization percentage. Hardness increased by 50 to 60%, whereas, the whiteness decreased due to parboiling compared to that of control. The cooking time decreased by 1 to 2 min and there was no appreciable change in water uptake and swelling index.

Three Indian rice cultivars varying in length to breadth ratio were parboiled and evaluated for their milling characteristics. The raw and parboiled rice samples were milled for 0, 20, 40, 60, 80 and 100 sec in the Mc Gill No.2 rice miller and tested for the degree of milling, ash distribution pattern and conductivity. Parboiled
rice samples from all the three rice cultivars showed a lower degree of milling as compared to raw rice for the same milling duration. Parboiling lead to a significant increase in the ash content and conductivity values in all the three rice cultivars (Hardeep and Narpinder, 2001).

The oil content of raw and parboiled brown rice remained unchanged, when milled to the same degree. Parboiled rice contained less oil than raw rice whereas the oil content of parboiled bran was more than raw bran (Pillaiyar, 1988).

Panumat et al., (2011) determined changes in physical quality of rice in each stage of the process of parboiling brown fragrant rice; the process consists of soaking, steaming, drying, hulling and parboiled brown rice drying, respectively. The physical quality study included grain temperature, moisture content, head rice yield, color of milled rice, size and weight of milled rice, elongation ratio and viscosity of starch. This study found that the steaming stage caused the most changes in physical properties, followed by paddy drying, parboiled brown rice drying, soaking and paddy hulling, respectively. Since the steam (high temperature and humid) caused swelling and gelatinization of the starch while other stages were less involved in mechanical and heat treatments. This study has provided the useful information for development of parboiled rice process in industrial scale with respects to maintaining its nutritional qualities.

Morteza and Jamuna (2010) studied the effect of cooking on nutritional quality of raw and parboiled rice. The physicochemical characteristics of raw and parboiled rice significant difference were observed in 1000 kernal weight, porosity and gel consistency. Parboiled rice was a better source of iron, thiamine and riboflavin and most digestible with respect to starch. The changes observed were due to the process of parboiling.

Bhaskar et al., (1989) studied the effect of phosphate and citrate on cooking time of ‘Pankaj’ variety of raw and parboiled rice. The process involved rinsing of the rice in sodium bicarbonate followed by cooking in disodium phosphate and calcium citrate solution and finally drying in a cabinet dryer. The treated rice cooked faster (3.7 times for raw rice and 1.2 times for parboiled rice) than the untreated rice. The process, presumably, caused loosening of the protein structure of raw rice and thus increasing its rate of water uptake. The swelling, colour and appearance were slightly superior to those obtained from cooking with untreated rice.
Rice is often modified by parboiling to improve its quality. Parboiling is the hydrothermal treatment applied to rough rice. As a result, the properties of the rice are changed which in turn improves the milling quality, nutritional value and storage stability of the grain. Rice quality may also be improved by germination. During germination, high molecular weight polymers are hydrolysed which decreases the molecular size and produces bio-functional substances. Kanokkan and Onanong (2009) determined the changes in pre-germinated brown rice and parboiled pre-germinated brown rice. Alkali digestibility, rice colour, reducing sugar content and pasting properties were measured to observe resultant changes in rice properties. The research suggested that the optimal soaking time for pre-germinated rough rice was 14 h at 30°C to obtain three levels of subsequent embryo growth lengths, 0.5 mm (minimum), 1 mm (optimum) and 2 mm (maximum) at respective incubation times of 14, 18 and 24 h. At these conditions the water content of pre-germinated rough rice was more than 30% (w/w), which was sufficient for the parboiling process. Gelatinization temperature of rice (GT) was recorded from the alkali spreading value of the brown rice. The results showed all pre-germinated brown rice had high GT (74.5-80°C) whereas all parboiled pre-germinated brown rice had lower GT (<70°C). The yellowness (p value) of all pre-germinated and all parboiled pre-germinated brown rice was significantly increased compared to normal brown rice (P<0.05). The reducing sugar contents of all pre-germinated and all parboiled pre-germinated brown rice were increased compared to brown rice upon prolonging incubation times (P<0.05).

2.2.3 Millets

Millets are small seeded annual cereal grains. These are very hardy crops and can be grown successfully in infertility lands. These crops are less prone to diseases and pests. It is stable cereals like wheat and rice. Some of them are even better with regard to average protein, fat and mineral content (Gopalan et al., 1997).

All the millets are rich in calcium, iron, folic acid, niacin, potassium, magnesium and zinc (Parvathy and Thayumanavan, 1995).

In the developed countries, coarse cereals are mainly used as animal feed whereas in the developing countries 68-98% of coarse cereals are used for human consumption. They are put to many uses in our diet depending upon the taste and
cultural preferences. Currently, millets are consumed in Northern China, India, Africa and Southern Russia as about 80 per cent of the crop is consumed directly as human food (Sindhu and Khetarpaul, 2001).

Grains are the storehouses of many chemical components including nutrients, phytochemicals, and non-nutritive plant protective functional constituents. The nutritive value of millets is comparable to other cereals with slightly higher contents of protein and minerals (Gopalan et al., 2002).

The term “millet” is applied to various grass crops whose seeds are harvested for human food or animal feed (Crawford and Lee, 2003).

Millet consumption is very low in India when compared to other cereal grains. Minor millets like foxtail, kodo and little millets are easily available throughout the year. It is cheaper than the other cereals and major millets (www.fao.org). Millets are particularly low in phytic acid and rich in dietary fibre, iron, calcium and B-vitamins. It also contains higher proportions of unavailable carbohydrates and release of sugar from millet is low. Over the past three decades cultivation and production of nutritious cereals in decreasing significantly, because of poverty, shifting consumption pattern from a balanced diet, widespread prevalence of nutritional deficiencies and also low consumption of nutritious cereals (Seetharaman and Rao, 2004).

Millets are rich in vitamins, minerals, sulphur-containing amino acids and phytochemicals, and hence are termed as nutri-cereals. They have higher proportions of non starchy polysaccharides and dietary fibre. Millets release sugars slowly and thus have a low glycemic index. They have been designated as ‘nutritious millets’ (Bala, 2004).

Mineral content of millets are high compared to other cereal grains. But the high content to phytic acid (0.50-0.70%) in millets presents grounds for concern in view of its interference with several minerals. The oxalate contents (21-29 mg/100 g dry weight) in millets are low (Ravindran, 2003).
Millets, generally, have high content of minerals (calcium and iron) and B complex vitamins as compared to other cereals (Jood and Khetarpaul, 2005).

Minor millets include six main grain crops; namely finger millet, kodo millet, little millet, foxtail millet, proso millet and barnyard millet. Millet is nutritionally equivalent or superior to other cereals. The protein content in millet is very close to that of wheat as both contain about 11 per cent protein by weight (Veena et al., 2005).

Millets are a small-seeded annual coarse cereal grown throughout the world. Millets include five genera: Panicum, Setaria, Echinochloa, Pennisetum and Paspalum. The cultivated species include foxtail millet (Setaria italica) and barnyard millet (Echinochloa frumentacea). Foxtail millet, considered a crop for poor people, is grown mainly in China, Bangladesh and India. It requires warm weather and matures quickly in the hot summer months. Practically devoid of grain storage pest, foxtail millet has a long storage life (Anju and Sarita, 2010).

The sensory properties millets are also poor due to coarse nature of these grains. These are rich in polyphenols, which influence the colour and flavour of millet (Rao and Deosthale, 1988).

Bookwalter et al., (1987) analysed whole millet adjusted to 15% moisture was gradually heated to 97ºC over 12 min by passing through a steam-jacketed paddle conveyer to inactive lipid enzymes. Both processed and unprocessed millet were milled to 50% and 80% extraction flours. The 80% flour contained germ fractions which resulted in much higher protein, lipid, thiamine, riboflavin, niacin, iron, zinc, available lysine and protein efficiency ratios than the 50% flour. After 49ºC storage, peroxide and fat acidity values were lower and flavor scores higher for processed than for unprocessed millet flours. No differences between processed and unprocessed flours were found in birefringence, water absorption and solubility, viscoamylograph values, or in their use in several traditional foods.

Foxtail millet (Setarica italica) is the second most widely planted species of millet and the most important in East Asia. It has the longest history of cultivation among the millets having grown in China since sixth millennium B.C. In China,
foxtail millet is the most common millet and one of the main food crops, especially, among the poor in the dry Northern part of that country. In Europe and North America it is planted at a moderate scale for hay and silage and to a more limited extends for bird seed (Daniel and Maria, 2000).

Fourteen varieties of foxtail, two varieties each of proso and barnyard, one variety of little and kodo millets were analysed for their proximate composition, and studied for milling, popping and malting characteristics. The yield of the polished grains varied from 63.7 to 73.5%. Under similar popping conditions (19% moisture and 250°C), the yield and volume expansion of the popped grains varied from 47 to 94% and 4.8 to 11.6 ml/gm respectively. Slurries of flours from well popped samples exhibited higher cold paste and lower hot paste viscosity. Foxtail and proso millet emalts had higher α-amylase activity and lower hot paste viscosity than the other millet malts (Malleshi and Desikachar, 1985).

Kulkarni et al., (1992) analyzed the chemical composition and protein quality of Italian millet. The chemical composition of three varieties (local, K-221-1, RS-118) of Italian millet. The local variety was found to be superior in fat, ash, calcium and least in tannin followed by RS-118 which was rich in protein, crude fibre and ionisable iron.

Dietary fibre which is present as soluble and insoluble form is proved to play an important role in the management of metabolic disorders like diabetes mellitus, hyperlipidemia, improve bowel motility and in turn reduce the incidence of colon cancer. Millets in general are rich in dietary fibre content (9 to 15%). It was reported that Little millet recorded a highest proportion of soluble fibre of 5.7 per cent (Hadimani and Malleshi, 1993 and Veena et al., 2005), followed Proso and Foxtail millets were shown to contain lowest proportions of soluble fractions of dietary fibre (4.4 and 3.4% respectively). Reports thus indicated higher proportion of dietary fibre in millet indirectly emphasizing the potential of grain as health food.

Kulkarni et al., (1992) assessed the tannin content of five minor millets viz., Proso, Kodo, Italian, Little and Barnyard millet. Lowest level was recorded in Barnyard millet (102.96 mg) followed by Italian millet (129.29 mg), Little millet
Proso millet (156.65 mg) and Kodo millet (167.10 mg). Dehulling of the seeds reduced the tannin levels by 65 – 80 per cent.

Protein content in pearl, proso and foxtail millets are comparable with those in wheat, barley and maize. The starch in some foxtail millet varieties were shown to be 100 per cent amylopectin and the starches contained in foxtail, proso and barnyard millets are known to be more digestible than maize starch. The protein in foxtail millet is known to be deficient in lysine, and its amino acid scores are comparable to that of maize. It was also observed that in different grain varieties, the higher the protein content, the lower the content of lysine in the protein. It is relatively high in leucine and methionine. Little millet has reasonably good levels of protein but very poor amino acid values. The total ash content of foxtail millet is good and is much higher than the more commonly consumed cereal grains including sorghum, however dehulling of the grain, like in other millets, causes considerable nutrient losses. The fat content of degummed millets ranged from 1.1 per cent to 5.0 per cent, mild grains contains nearly 70 per cent of total fat of the whole seeds. Kodo millet is also reasonably low in fat. Little millet has the highest fat content of all the millets (Hadimani and Malleshi, 1993).

Saroja and Vijaya (1997) studied the effect of cooking and germination on the nutritive value of Tenai (Setaria italica). It revealed that germination of thenai for 3 days before cooking increased the nutritive value. Even though a further increase in the nutritive value was noticed with increase in germination time, appearance of roots makes the millet unsuitable for consumption.

Pawar and Machewad (2006) reported Foxtail millet grains were soaked in distilled water (1:5, w/v) for 12 h at room temperature, dehulled; dehulled and soaked; and dehulled, soaked and cooked in distilled water (1:3, w/v), and the effects of removal of polyphenols and phytate on the in vitro protein digestibility (IVPD) and availability of iron and zinc were measured. The results showed that polyphenols and phytate were decreased significantly up to 50.92 and 49.89%, respectively. The IVPD, however, increased up to 38.71%. The iron and zinc contents decreased up to 18.79 and 18.61%, respectively, but the ionizable iron and zinc were increased up to 55.45
and 80.18%, respectively. This indicated the suitability of simple processing techniques for improvement of availability of nutrients from foxtail millet.

Chemical characteristics of a sample of foxtail millet bran and its oil, focusing on the approximate composition of foxtail millet bran and the fatty acid profile, physicochemical properties and tocopherol composition of foxtail millet bran oil, are determined by Shaohua et al., (2010). The results indicate that the millet bran constituted 9.39 ± 0.17% crude oil, 12.48 ± 0.41% crude protein, and 51.69 ± 2.14% crude fiber. The saturated fatty acids included palmitic acid (6.4%) and stearic acid (6.3%).

Kamara et al., (2009) examined the chemical composition and physicochemical properties of two varieties defatted foxtail millet flour grown in China. The seeds were obtained, milled and sieved to produce flour. The flours were tagged DFMFW and DFMFY for defatted foxtail millet flour white and defatted foxtail millet flour yellow, respectively. The protein contents of DFMFW and DFMFY were 11.92 and 11.39, respectively. DFMFY had higher mineral elements, ash and fat content than DFMFW. Essential amino acids was above the recommended amount by Food Agricultural organization/World Health Organization (FAO/WHO) for humans. Defatted foxtail millet flour could be used in food formulation with less fear of retrogradation.

Little millet (Paniun sumatranse) is grown throughout India to a limited extend upto an altitude of 2-100 cm but is of little importance else where. The seeds of little millets are smaller than those of common millets. Millets are rich in nutraceuticals, available at low cost, can be cultivated in dry areas and have protective effect against degenerative diseases (Lupien, 1990).

Little millet has reasonably good levels of protein but very poor amino acid values. In general, minor millets are considered to be more nutritious than rice, both in terms of macro and some micronutrients. For example, samai is a minor millet consumed, occasionally, by villagers and it was once one of their staple foods and crops. One hundred grams of the edible portion of the millet contains 7.7 grams of protein, 4.7 grams of fat, 7.6 grams of fibre and 67 grams of carbohydrate. It also had 17 mg of calcium, 220mg of phosphorus and 9.3 mg of iron (Kumaran et al., 1998).
Minor millets are important food crops of a large group of people in rural, tribal and hilly areas in India. Presence of husk and bran over the edible endosperm is the major processing problem. This is usually removed by hand pounding, since mechanical dehusking or polishing units suitable for processing little millet are not available yet. Ravindra et al., (2009) studied postharvest processing methods for little millet using two types of mills and different pretreatment interventions. Rubber roll sheller and abrasive grain polisher (Mill-1) yielded little millet brown rice with 62.2% head rice yield, 3.8% of broken with 66.2% dehusking efficiency. The dehusking efficiency was significantly higher in direct boiling in water for 20 min and sun drying (T3). Head rice yield using Mill-1 ranged from 67.0 to 73.0% and 48.7 to 67.9% in provender mill (Mill-2). The mean milling efficiency values varied from 44.8-57.8%. Among the treatments, T3 recorded significantly highest milling efficiency (60.6%). Treatments such as parboiling, steaming and application of 2% lime (Calcium oxide) solution showed differences in dehusking efficiency. The cost incurred to convert one kilogram of little millet into rice in Indian rupees was Rs. 0.23 and Rs. 8.65 in Mill-1 and Mill-2 respectively. It can be concluded that pretreatment of little millet is a must for complete removal of husk. Provender mill had more advantages as it can be used for milling of other cereals and millets cost effectively. To reduce milling losses and to bring good returns, little millet should be parboiled and dried before milling.

According to Ushakumari et al., (2004) millet is a minor cereal of high nutritional value, but its consumption is limited; this is thought to be mainly due to the non-availability of ready-to-use or ready-to-eat millet products. It is suggested that processing millet to prepare ready-to-eat foods may increase its economic and nutritional value. Studies were, therefore, conducted to evaluate the functional properties of popped, flaked, roller dried and extrusion cooked millet for potential use as ready-to-eat products. Foxtail millet grains were either subjected to HTST treatment to prepare popped millet or decorticated in rice-milling machinery then processed further to prepare flaked, extrusion cooked and roller-dried products. Nutrient composition and some functional properties of the products were determined, including solubility and swelling power in water, oil absorption capacity and pasting characteristics. Carbohydrate and lipid profiles of the products were also studied. SEM examined changes in starch granule structure caused by heat treatment. The
degree of starch gelatinization was highest in roller-dried millet followed by popped, flaked and extruded products. These results suggest that the investigated cereal processing technologies could be successfully applied to foxtail millet to prepare ready-to-eat or ready-to-use products, and thereby increasing its consumption level.

Sarita et al., (2001) developed two convenience mixes, suitable for five different types of baby foods, based on proso millet (*Panicum milliaceum*). Malting and popping were used as processing techniques. Malted convenience mix was further used as multipurpose flour for development of different baby foods. These five baby food products were sweet gruel, salty gruel, halwa, burfi and biscuits. The nutritional quality of mixes was analysed for moisture, crude proteins, energy and total ash contents of malted and popped convenience mixes. Iron and ascorbic acid contents of malted convenience and popped convenience mix were also determined.

The possibilities of obtaining fibre-rich oat products with multifunctional properties are discussed, with particular reference to studies carried out on various oat cultivars and oat products in order to examine the influence of processing (extrusion or autoclaving) on Resistant Starch (RS) formation. It was shown that RS could be formed in oat products subjected to appropriate extrusion or autoclaving (25% moisture) conditions and that oat extrudates with effective concentration of RS could be obtained by extrusion of oats mixed with corn starch or high amylose corn. RS generation was also influenced by fat content, with low fat content cultivars most suitable for RS formation. It was also possible to add commercial RS and/or other biologically active additives, such as insulin, to produce oat-based functional foods. Results of invitro and invivo trials are also summarized, which demonstrate the beneficial effects of oat products on gastrointestinal health (Gebhardt et al., 2004).

The composite flour containing kodo (*Paspalum Scrobiculatum*) and barnyard Millet (*Echinochloa colona*) flour, whole wheat flour and defatted soy flour of four different combinations was prepared and studied the impact of Millet flour blend incorporation on characteristics of composite flour. The Millet flour blend and composite flour were analyzed for its particle size distribution, sedimentation value, falling number, wet and dry gluten content, bulk density, water absorption capacity (WAC), oil absorption capacity (OAC), swelling power (SP), thermal properties,
pasting properties, retrogradation properties (level of syneresis) and chemical parameters such as moisture content, total carbohydrate, crude fiber, protein, fat, starch, amyllose, amylopectin and reducing sugar content using standard procedures. Results indicated that wet and dry gluten content, bulk density, WAC, SP decreased significantly (p<0.05); level of syneresis and OAC, conclusion gelatinization temperature, gelatinization range (R), protein and crude fiber content were increased significantly at p<0.05 with increased proportion of Millet flour blend. Thus the analyzed properties of composite flour were significantly modified while increasing the level of incorporation of Millet flour blend (Poongodi and Jemima, 2009).

2.3 DEVELOPMENT OF TRADITIONAL SOUTH INDIAN FOOD

2.3.1 Idli

Idli, a popular fermented breakfast food consumed in the Indian subcontinent is made mainly from rice and black gram. It is very popular because of its textural and sensory attributes (Steinkraus et al., 1967 and Reddy et al., 1981).

Several workers have tried to use different proportions of blackgram with rice for idli making (Joseph et al., 1961; Khandwala et al., 1962; Padhye and Salunkhe, 1978; Balasubramanian and Viswanathan, 2007).

The fermented flour is steam cooked to make idli. Black gram has been reported to play a major role in idli fermentation as a source of microorganisms and as a fermenting substrate (Radhakrishnamurthy et al., 1961).

The organisms produce lactic acid and carbon dioxide, which make the batter anaerobic and leaven the product (Reddy and Salunkhe, 1980).

Idli is a popular breakfast food in South India which is prepared by fermenting a mixture of parboiled rice and dehulled blackgram. The ratio of rice and blackgram varies from 4:1 to 1:4 and more often it is 3:1. Vanveen et al., (1968) used 1:1 ratio to study the effect of fermentation in idli containing more protein. The average PER for casein diet, fermented idli were 2.81, 1.84, 1.99 and 1.70 respectively. They
concluded that the fermentation did not improve the PER significantly and there was not much increase in moisture content during fermentation. The riboflavin content of raw unfermented mixture was 0.137 mg/100g, heated mixture was 0.077 mg/100g and steamed product was 0.075 mg/100g, indicating a significant loss in riboflavin content. Soybean, green gram and bengal gram can be substituted for black gram, wheat or maize can be substituted for the rice to yield Indian dhokla (Ramakrishnan, 1979; Steinkraus, 1996).

Fermented foods make a significant contribution to human diets of many regions in the world. Fermentation is a relatively inexpensive technology of food preservation, which improves nutritional value of foods and enhances sensory properties (Steinkraus, 1996).

Venkatasubbaiah et al., (1985) observed yeast flora responsible for gas production during idli batter fermentation. Of several yeast strains identified, Torulopsis holmii had a higher fermentation rate when compared to other strains. Organoleptic tests indicated that idlis, prepared from batter fermented by T. holmii are better in taste, flavor, texture and over all acceptability.

Sowbhagya et al., (1991) studied the influence of variety, parboiling and aging of rice on the texture of idli and observed that the variety having an amylose content of 22 per cent and above either raw or parboiled were suitable for idli preparation, while low amylose and waxy rice yielded hard and sticky textural idli. Aged rice had better appearance and texture compared to fresh rice idlis.

Singaravadivel (1997) analyzed the suitability of different proportions of rice blackgram for the preparation of dry idli mix using curd as inoculum for fermentation. The results revealed that the black gram and rice in the ratio of 1:1 and 1:2 were acceptable compared to other ratios of 1:3, 1:4 and 1:5. The water requirement for dry mix idli was in the ratio of 1:2 which was acceptable compared to 1:1.6, 1:1.8 and 1:2.2. Kumar et al., (2005) had studied rice with a lesser degree of polishing and found better fermentation properties, resulting in a higher batter volume, higher microbial counts, lower shear value and softer idli. However, during sensory analysis
Idli prepared with low polish rice achieved significantly lower scores for appearance and colour, compared with idli prepared using highly polished rice. However, idli quality was influenced by rice variety and degree of polishing.

Idli is a traditional fermented rice and black gram based food. Idli batter is prepared by soaking polished parboiled rice and decorticated black gram for 4 h at 30±1°C in water. The soaked mass was ground using a grinder with adequate amount of water. The blend ratios of 2:1, 3:1 and 4:1 (w/w) batter were allowed for fermentation for different periods with the addition of 2% (w/w) of salt. During fermentation, maximum production of riboflavin and thiamine were found to be 0.76 mg/100 gm and 0.73 mg/100 gm in 3:1 blend ratio of idli batter; and the folic acid content was found to be at a maximum of 0.75 mg/100 gm of idli batter after 10 h of fermentation. (Debasree and Parimal, 2011).

Geetha and Geetha (2012) studied new rice variety for idli making. The new rice variety TRY3 gives 45 medium sized idlis from one kilogram of rice (the idli batter mix was prepared with rice and blackgram in 4:1 ratio respectively) compared to the presently popular variety CR1009 (37 idlis). The rice variety preferred for idli making, exhibited high amylose and intermediate alkali spreading value. High viscosity and set back values indicated that in TRY3, swelling granules is high and facilitates higher breakdown to a greater extent and more quantity of batter. The organoleptic evaluation and consumer preference test was confirmed that the idlis made out of new variety rice TRY3 was superior in taste, palatability and stomach filling compared to the market variety CR1009.

Balasubramanian and Viswanathan (2007) studied the texture of cooked idli to judge and optimize the production process of good textured idli with the selection of the ingredients and the process. Owing to the difference in raw materials, composition, process and region, the fermentation periods are slightly different for idli making. Among the texture-profile analysis test attributes of idli, majority of the parameters are positively correlated with gumminess and chewiness, which determine the softness of idli. Based on the results of principal component analysis (PCA), the firmness is the prime factor to illustrate idli texture followed by chewiness, gumminess, cohesiveness and springiness.
Sahana and Fauzia (2003) prepared fermented cereal from indigenous raw material like parboiled rice and Bengal gram. The approximate analysis, microbiology, edibility of cereal product has been done. It was found to be a high nutritive value and acceptable as a food.

Three idli-like products were prepared by replacing either rice or black gram (Phaseolus mungo) used in conventional idli batter. Panicum miliaceum (bhagar), rajmah (Phaseolus vulgaris), black gram dhal and horse gram (Dolichos biflorus) were used as legume ingredients. After fermentation for 12 hr at 30ºC, the steam cooked idli-like products were examined for acceptability and palatability. It was found that the products made from bhagar and either black gram dhal or rajmah were satisfactorily acceptable. However, bhagar combined with horse-gram, failed to achieve the expected acceptability (Sarasa and Nath, 1985).

A study was conducted by Susheelamma (1989) for replacing the blackgram dhal with the seed coat of linseed (Linum usitatissimum L.) containing a mucilaginous polysaccharide which rendered an aqueous suspension of the seeds lightly viscous in nature. Polysaccharides obtained from raw or roasted seeds were tested along with rice, rice semolina and defatted peanut or sesame flour as sources of surface active proteins in steamed pudding (idli) type preparations. A larger quantity of polysaccharide from roasted seed was required to stabilize porous texture, which also increased bulk-density of the idlis.

Preparing idli, conventionally, is a cumbersome process and to replace this ready mix with suitable microorganisms for fermentation was attempted. The dry mix was prepared by mixing dry flour of rice and black gram in 2:1 (w/w) ratio with 2 per cent salt. The dry mix was slurried with water in 1:2 (w/w) ratios and allowed for fermentation by inculcating two efficient pure cultures viz. PPRC 1 and PPRC 2. Both the pure cultures fermented the dry mix faster. The batter fermented for 10-12 hours had yielded a spongy texture idli with normal taste and flavour. The qualities of the idli was similar to that of prepared from normal wet ground method (Singaravadivel and Dakshinamurthy, 1997).

The traditional Indian instant mixes of idli and dosai based on cereal, legume combinations are now being manufactured by blending various ingredients in required
proportions along with chemical leavening agents. Instant *idli* and *dosai* mixes have been prepared, based on the black gram and rice flours in suitable proportions along with yeast or chemical leavening agents, thereby eliminating the need for soaking, wet grinding and fermentation (Arya, 1990).

Anshu and Neelam (1997) attempted to find out the effect of natural fermentation on phytic acid content and *in vitro* digestabilities of starch and protein of rice-blackgram dhal whey blends mixed in different proportions. The phytic acid content of various rice-blackgram dhal blends without and with whey ranged from 205.57 to 301.96 and from 172.67 to 226.82 mg/100g respectively. Phytic acid content decreased to the extent of 26 to 37 per cent over the control value. Whey incorporation and fermentation improved the starch and protein digestibility of all rice-blackgram dhal mixture. A significant negative correlation was observed between phytic acid and starch and protein digestability.

Masa (Waina) is a Nigerian yeast fermented puff batter of millet or rice cooked in a pan with individual cup like depressions resembled Indian idli and tasted like dosa which is poor in protein quality. An attempt was made to improve its protein quality by the addition of cowpea or groundnut with millet or rice and its chemical and nutritional qualities were evaluated by Iro Nkama and Malleshi (1998). Phosphorus and calcium concentration were low and magnesium and sodium concentrations were high. Significant improvement in lysine, threonine and isoleucine were observed for some masa samples. The biological value, apparent digestibility and net protein utilization of all masa samples showed improved nutritional qualities. Supplemented masa was nutritionally better than masa made from millet or rice alone.

Nagaraju and Manohar (2000) investigated changes in rheological properties and particle size during fermentation of idli (a fermented food made from rice and black gram); dimensional parameters of batter formed using a specially developed automated idli processing unit and the effects of rice:black gram ratio (2:1, 3:1 and 4:1) on idli quality were also studied. Shear stress and shear rate values obtained for different idli batters during fermentation (23 h at ambient temp.) showed good agreement with the power law model with yield stress. Consistency index was observed to increase with increasing rice: black gram ratio at all fermentation times.
However, a small increase in mean particle size occurred between 4 and 13 h of fermentation. Height of batters showed little variation between batter types while diam. decreased with increasing ratio rice: black gram ratio. A rapid volume increase was observed in batters after 4 h fermentation; rate of volume increase progressed steadily until approximately 13 h and then slowed down.

Idli is a popular breakfast and hospital food in South India, which is prepared by fermenting a mixture of soaked and milled parboiled rice and dehulled black gram (*Phaseolus mungo*). Vanveen *et al.*, (2008) investigated; no appreciable increase in methionine was found after 24 hours of fermentation, when idli would normally be steamed. The PER and digestibility in rats were the same as of the unfermented mixture. The riboflavin content was decreased. Because of the presence of *Streptococcus faecalis* in the fermented batter, the presence of pharmacological active amines such as tyramin was expected but they were not detected. It seems that the nutritive advantage of this interesting food may lie mainly in its increased acceptability, but not in an increased nutritive value.

*Bong and Vasudeva* (2009) carried out pasting profile of coarse rice, fine rice as well as black gram individually, in combination, in flour as well as in batter form, before and after fermentation by Brabender Viscoamylograph. Cold paste viscosity (CPV) was highest in fine rice, lowest in black gram and intermediate in coarse rice. Breakdown (BD) was least in fine rice, highest in coarse rice and black gram lay in between. Values of total setback indicated the strong reason for use of coarse rice in parboiling as well as in idli and dosa preparations.

*Neeta et al.*, (1989) studied microbial and biochemical changes occurring during dhokla fermentation to find out optimum concentrations of microbial metabolites that impart typical aroma, flavor and texture to the product. During the course of fermentation from zero to 18 hr. The product exhibited the best sensory qualities at the 16th hr of fermentation.

*Manoharan and Prathapkumar* (2012) selected the ingredients for optimum desirable product characteristics and to identify the optimum ratios of ingredients and fermentation time with respect to sensory attributes using Response Surface
Methodology (RSM). The sensory attributes included were color, appearance, texture, taste and overall quality. Preliminary trials were conducted using five variants of rice and common black gram dhal before framing a model using Central Composite Rotatable Design (CCRD). From the study they found that a desirable score of 0.7439 was obtained for sensory attributes of idli made with the ratio of 3:1.475 for IR20 idli rice and ADT3 variety black gram (with husk removed after soaking) fermented for 10.2 h. Principal Component Analysis (PCA) helped to discriminate the samples and attributes within the data matrix, depending upon their inter relationships.

Soyabean protein was isolated and utilized in the preparation of food items like idli and vada. Soya protein isolate was incorporated upto 60 per cent which increased the protein content of the idli mix upto 8 per cent. The black gram flour in the idli mix was entirely replaced by soya protein isolates with 0.5 per cent guar gum which improved the organoleptic properties (Ramalingam, 1994).

Singh et al., (1995) studied the effect of substituting rice with extrusion cooked (75, 100 and 125C) rice flour at 10, 20, 30 and 40% level on the quality of idlis was investigated. Both the levels of substitution and temperature of extrusion had significant effects on the specific gravity, acidity and pH of the idli batter, and textural and sensory quality of the idlis. The idlis prepared from idli mix containing rice substituted by 20-30% of rice flour extruded at 125ºC were most acceptable.

Idli is a traditional cereal/legume-based naturally fermented steamed product with a soft and spongy texture, which is highly popular and widely consumed as a snack food item in India. The predominant fermentation microflora are lactic acid bacteria and yeasts, which cause an improvement in the nutritional, textural and flavour characteristics of the final product. Renu et al., (2000) determined the levels of flavour components of stored idli batter prepared from specific starter cultures. Desirable flavour compounds such as ketones, diols and acids were found to be present up to 8 days of storage, whereas undesirable flavours like sulphurous and oxazolidone compounds, ethanone and thiazole appeared in the batter after 6 days of storage.
Raw rice and parboiled rice are mostly used for the preparation of several processed rice products. The matured and well filled grains are dried in the sun for 3 to 4 days to reduce the moisture to 13 to 14 percent. The non-waxy or non-glutinous rice was found suitable for the preparation of cooked rice, popped and puffed rice, beaten rice, idli and dosai cakes etc. Beaten rice soaked in water (2 times of its weight) for about 30 minutes under the lid cover gave excellent swelling properties. Kalyani-2 was rated best for preparation of beaten rice (Das Bhaskar and Avijit, 2010).

2.3.2 Pittu

Pittu is a rice flour-based product, which is a white-coloured South Indian traditional product. It posses granule in nature, a soft hand feel and slightly chewy texture and a typical pleasant, flavor and aroma.

For the preparation of rice flour, the broken rice was cleaned and washed before soaked in water for 3 hour with (rice to water ratio: 1:1). The soaked rice was ground using the wet milling process. The starch slurry was filter pressed and dried by hot air at 50°C for 15 hours. The milled flour was ground and sifted through 100-mesh screen before stored at 4°C in sealed plastic containers until use (Sriwararak, 2010).

Nura et al., (2011) determined the preparation of the flour, rice grains were dry-milled (Good and Well, Malaysia) using a rice mill with a 200 μm sieve. Rice flour sample was placed in a sieving machine (Fritsch Analysette 3, Germany) with 200 mm diameter sieves of particle sizes 63, 80, 100, 125, and 140 μm. Rice flour with each particle size was fortified with the premix at the level of 1000 IU of vitamin A, 0.16 ppm of folic acid, and 42 ppm of iron based on Malaysian Food Regulation 2007.

A study was conducted to evaluate the performance of four types of rice flour milling machinery currently used in Sri Lanka namely, pin (disk) mill, plate mill, roller mill and hammer mill. The machines were evaluated for their performance with a view to recommending the suitable machinery or machinery combination for the Sri Lankan rice flour milling industry. Their performances were evaluated in terms of particle size obtained after milling, temperature increase during milling, moisture content of milled rice flour, string continuity on extrusion and cost of production. The
pin mill performed best as a single machine among the four types of rice flour milling machinery. However, the particle size of rice flour obtained was 300 pm. which is inadequate for the preparation of extruded products. A combination of three passes through the pin mill produce a particle size of 212 pm and the flour was suitable for extruded products after preparation of dough with warm water at 60 °C. The study also showed that rice flour produced by a combination of pin (two passes) and plate mill (single pass) is suitable for extruded products after preparation of dough with water at ambient temperature as well as warm water at temperature 60 °C. The temperature increase during milling, moisture content of milled rice flour and cost of production per 1 kg of rice flour by this combination are 59.5°C. 12.3% and LKR 2.84 respectively (Bandara, 2011).

The raw grains of kodo and barnyard Millet were cleaned, winnowed and soaked in water for 24 hours. The soaked grains were steamed for 20 minutes, shade dried to moisture content of 10-12 g% and milled into flour (Poongodi and Jemima, 2009).

Bhuvaneswari (2008) millets like kodo millet, foxtail millet and little millet were selected for the development of pittu. The pittu was evaluated for sensory characteristics like, appearance, colour, flavour, texture and taste using ‘Numerical scoring method’ with a three point score level with the help of semi-trained panel members which was compared with the known standard. Sensory scores reveal that pittu prepared with the selected three millets were equally acceptable as the standard one prepared with rice.

Millet flour samples were produced from pearl millet using four different methods. In the first method, 500 g of millet grains were thoroughly cleaned by removing unviable seeds. The grains were then washed with cold tap water and thoroughly rinsed with distilled water, followed by drying in a cabinet solar drier at a temperature range of 52-59°C for 8½ h. The dried grains were milled using a 2 bench-top attrition mill (Christy Hunt Agriculture Ltd, South Humberside, England). The resultant flour was sieved into a particle size of 100 μm. The flour was then packaged in a low density polyethylene bag and stored using plastic containers with lids in a refrigerator at 8°C (Ocheme and Chinma, 2008).
Anju and Sarita (2010) reported the preparation of biscuits, Foxtail millet and barnyard millet grains were cleaned free from dust and foreign particles and were subjected to grinding in a commercial roller mill (Saboo millstones, Rajasthan, India). Thereafter it was passed through a 20 mesh sieve (ASEW, New Delhi, India) to obtain the flour.

Karuppasamy et al., (2011) studied the development and evaluation of millet based convenience mix. The combination of sorghum and maize based mixes were C₁(40:60, sorghum:maize), C₂(50:50), C₃ (60:40). All these combinations (C₁, C₂ and C₃) of mixes were used to prepare the various products like uthiripittu, kuzhapittu and rotti. Among the combinations C₂ mix (50:50, sorghum:maize) was found to be better based on the nutrient content and organoleptic evaluation of the products.

Nazni and Sureshkumar (2011) formulated Low cost weaning foods namely ladoo, kheer, halwa and puttu were developed in the laboratory using germination and malting processes. The experimental formulations were based on germinated kodomillet, pulses (Green gram and Bengalgram) and roasted groundnut in the ratio of 75:25. All the formulations were evaluated thrice for their acceptability by a panel of judges using a hedonic scale. Nutrition education about weaning foods through demonstration method are given to the selected Adhidravidar mothers and its impact was assessed. Results showed that all the experimental formulations were found to be acceptable obtaining moderately to extremely good scores ranging from 7.00 to 8.30. About 17.7 per cent increase in knowledge among the Adhidravidar mothers was brought attained after the demonstration study about the weaning foods. Thus, the study helps to increase the nutritional knowledge about weaning foods among the selected Adhidravidar mothers.

The glycaemic response (index) to four commonly consumed breakfast items of Kerala, namely puttu, idiappam, appam and tapioca was studied in six non-insulin dependent diabetic Malayalee men. All the breakfast items were isoenergetic and had almost similar nutrient composition. The glycaemic response to breakfast items as compared to that of glucose was determined by comparing the areas under the 2 hour glucose response curves. The mean peak rise over fasting levels was significantly lower (P<0.05) only after puttu consumption whereas the mean area under curve was significantly lower (P<0.05) after consumption of puttu, idiappam and tapioca when
compared to the oral glucose tolerance test. The mean glycaemic response to puttu was found to be the lowest (0.79) of the breakfast items tested, followed by that of idiappam and appam. Tapioca elicited a glycaemic response almost similar to that of glucose load. The differences observed in the glycaemic response to different breakfast items may be due to differences in carbohydrate chemistry or physical form of food (particle size) and also dependant on method of processing (Latha and Sumathi, 1997).

2.3.3 Porridge

OGI Porridge-Ogi is one of the fermented cereals produced from maize / sorghum / millet is consumed as porridge by a very large number of Nigerians. It is the most traditional food for weaning infants and the major breakfast cereal for adults. Porridge is a dish which has become associated with Scotland. The first evidence for dishes resembling porridges is pre-historic. Neolithic farmers cultivated oats along with other crops (Okeiyi and Futrell, 1983).

Millet grains were cleaned and soaked in clean tap water in a covered container. The soaked grains were allowed to ferment at room temperature (37°C) for 24 h. After fermentation, the water was drained and the grains rinsed with 500 ml of water and oven dried at 80°C for 3 h. The sample was milled and sieved with 30 mm particle size sieve. One hundred and fifty grams of flour was reconstituted with 500 ml of clean tap water. The slurry was heated slowly with constant stirring for 10 min to obtain smooth textured porridges. One tablespoon of sugar was added to the sample. The porridge were kept separately in thermos flask (to keep warm and prevent them from congealing) for sensory evaluation (Lombor et al., 2009).

Complementary foods were formulated from millet, soybeans and crayfish and evaluated for proximate composition and organoleptic properties. The different flours were combined in ratios of 78.5:20:1.5, 81.6:15:3.4 and 84.6:10:5.4 (protein basis) of millet, soybeans and crayfish. Nutrend, a commercial complementary food, served as control. Porridges were prepared from the composite blends for organoleptic evaluation. Standard methods were used to analyze the composite flour for proximate composition. The composite flours contained higher moisture, protein and carbohydrate than the control. The protein and carbohydrate levels of the blends
ranged between 15.9-16.7% and 67.5-68.75% respectively. Composite blend sample 84.6:10:5.4 was generally preferred over the others and control. Sample 84.6:10:5.4 was also more tasteful than the others including the control. The study showed that porridges prepared from blends of millet, soybeans and crayfish are nutritionally adequate to support child growth and well being (Lombor et al., 2009).

Several indigenous fermented foods and beverages were produced at household level in Swaziland. The fermented products include fermented maize (sancoti), fermented porridges (incwancwa), non alcoholic cereal beverage (emahewu) and alcoholic beverage from millet (nyawotsi). Incwancwa was a fermented thin porridge. It was prepared similar to emahewu, except that it was thicker than emahewu, and was usually taken with a spoon. The porridge is prepared from corn meal (mealie) or sorghum meal. The mealie meal was mixed with water, and allowed to ferment naturally for 24 hr. A portion from previously fermented meal may be added to the new batch to initiate and speed up the fermentation process. The fermented porridge was then cooked before consumption as sour porridge. Incwancwa was commonly eaten as a cereal breakfast meal in many households of Swaziland. Singwangwa (fermented porridge from leftovers) was prepared by mixing a previous product (porridge) with emahewu. This was done to prevent spoilage of porridge, and to improve its taste. When scraps of porridge remain, they were mixed with emahewu to prevent their spoilage and enhance digestibility (Masarirambi et al., 2009).

Porridges produced from cereals are eaten in many parts of the world particularly in developing countries where they are part of the basic diet. Some examples include Ogi in Nigeria; Uji in Kenya and Kenkey in Ghana. Enyiokwolla, a porridge produced from millet is a popular diet among the idomas and Tivs in Benue State, Central Nigeria. It is usually taken as a breakfast diet with Okpa or Akpukpa, a steamed pudding produced from bambara groundnut. Enyiokwolla production involves the cleaning of whole millet grains followed by milling of the cleaned grains into flour. The flour is then made into slurry by adding cold water. Boiling water is added to the slurry to produce a gelatinized product; enyiokwolla. It may be further heated if the thickness is not satisfactory. The nutritional quality of the porridge (enyiokwolla) will be improved by modifying the processing method by soaking and germinating the grains before milling into flour by Ocheme and Chinma (2008). The
effects of soaking and germination on some physicochemical properties of millet flour and the sensory properties of porridges produced from the flour were studied. Millet flours were prepared from untreated, soaked, germinated and soaked-germinated grains. There were significant (p<0.05) increase in protein, ash, dry matter, water absorption capacity, hygroscopicity and swelling power of flour as a result of soaking and germination. Fat, phytic acid, least gelation capacity and viscosity of flour samples decreased significantly (p<0.05) as a result of soaking and germination. Porridge prepared from un germinated millet flour had higher sensory score, though all the porridges were accepted.

Lei and Jalobsen (2004) explained Koko, a fermented millet porridge, is consumed regularly in North Ghana, as a light meal or a snack food. The fermented liquid phase produced during koko production, known as Koko Sour Water (KSW), is also regularly consumed as a beverage. It is suggested that these African fermented millet products may have the potential as the probiotic foods have.

Thaoge et al., (2003) determined the microbiological safety, the nutritional quality and viscosity of a traditional African weaning porridge, the effects of fermentation, cooking, addition of sorghum malt (amylase rich flour) and re-cooking on pearl millet porridge, and on micro flora and survival of an inoculated pathogen (10^6 cfu Escherichia coli ATCC 25922). Fermentation inhibited the growth of microorganisms in the porridge and re-cooking the fermented porridge after sorghum ARF addition further eliminated the fungi and coli forms that were introduced with the sorghum ARF (<10^5 cfu/g). The re-cooked, fermented millet plus sorghum ARF porridge prevented the proliferation of E. coli, reducing the numbers to <10^4 cfu/g within 18hr. The porridge could be supplied to the children under 3yr with the daily required protein using 1.4 feedings/day, and required energy with 4 feedings /day.

Ojijo and Shimoni (2004) studied the rheological properties of the fermented finger millet thin porridge. Apparent viscosity and yield stress of fermented finger millet pastes were investigated as a function of cooking time, flour solids concentration and temperature. All the viscosity curves demonstrated shear thinning behavior and could be accurately predicted using the Cross equation. Static yield stress decreased with increasing temperature during boiling for 1 h, but increased
when boiling was only carried out for 10 min. A linear increase in yield stress was not affected by solids concentration, temperature dependence of yield stress derived from Cross equation parameters was biphasic in pastes boiled for 1 h, the critical temperature was approximately 40°C.

Zhou (2004) determined the rheological properties of instant porridge during gelatinization and retrogradation using a texture analyzer, DSC and a dynamic rheometer. The results were used to determine how factors, such as raw materials, time, etc., affect the quality of instant porridge, and to provide a scientific basis for the large-scale commercial production of instant porridge. It is found out that proper raw materials contribute significantly for the improvement in the quality of instant porridge. It is also reported that time plays a remarkable role in the quality of instant porridge.

Onyango et al., (2004) observed Uji-an East African thin porridge prepared from a composite flour blend of corn+ finger millet, corn + sorghum, cassava + finger millet or cassava + sorghum by spontaneous or backs lop fermentation in a submerged culture. In this study, the potential of different mixtures of lactic acid bacteria and backslap starter cultures to acidify and form flavour compounds in uji was investigated. The use of pure single or mixed cultures did not improve the flavour profile of fermented uji. Ethanol, 1-pentanol, 1-hexanol, lactic acid and ethyl acetate were synthesized prior to fermentation and synthesis of these compounds continued during fermentation.

Haraldsson et al., (2005) determined the Iron availability and degradation of (1→3, 1→4)-β-D-glucan (β-glucan) in three whole grain porridges made from two optimized barley malts and unprocessed barley were studied in a dynamic gastrointestinal model. The results indicated the potential for using high temperature, steeping with lactic acid, to yield improved iron availability combined with reduced degradation of β-glucan in the small intestine, to maintain the beneficial properties of barley.
Fombang et al., (2005) determined the use of sorghum as a food, compared to corn. It was noted sorghum proteins become more indigestible with wet cooking. The effects of varying doses of γ-irradiation of dry and wet sorghum and corn flours on solubility and digestibility of proteins when cooked as porridge. The 2 condensed-tannin-free sorghum cultivars (BR7, a red glume variety from South Africa, and Madjeri, a white glume variety from Cameroon) and a white corn hybrid (PAN 6043 from South Africa) were used. Dry flours (moisture content 8%) were prepared by cleaning the grains, followed by milling. Wet flours were prepared by mixing dry flour with distilled water at 30% solids content. Both flour types were irradiated at 0, 10 and 50 kGy using a 60 CY-rays source. Portions of irradiated and non-irradiated flours were then cooked into porridges. Higher doses of irradiation decreased sorghum digestibility possibly as a result of cross-linking, maillard reactions and protein aggregation. Polyphenols appeared to influence the effect of irradiation on protein digestibility. The digestibility of corn porridge prepared from irradiated dry flour was unaffected whereas the digestibility of porridge prepared from wet irradiated corn flour decreased.

Twenty-four healthy subjects in Sweden were randomly assigned to eat either a breakfast of rye porridge or the same amount of calories in the form of refined wheat bread for three weeks. After a wash-out period of 3-4 weeks, they switched to the other breakfast choice. At three points during each three-week diet, researchers recorded appetite ratings (hunger, satiety, and desire to eat) for 24 hours. They found that the whole grain rye porridge resulted in higher satiety, less hunger, and less desire to eat for four hours after breakfast, but that the differences did not extend into the afternoon. The satiety effect persisted throughout the three weeks of the diet (Hanna et al., 2011).
2.3.4 Products from rice and millets

Brown rice is often added to various bakery products such as bread, cake, or cookies, because of its nutritional superiority over white rice. As a foodstuff, however, brown rice is less popular than milled white rice, due to its poor eating quality. It is reported that brown rice has more nutritional value (Piggot et al., 1991).

A quick-cooking brown rice product was developed using the centrifugal fluidized bed drier (“CFB”) concept. The high heat transfer rates in the CFB equipment provided a dry quick-cooking brown rice in about 5 min drying time, after precooking. Preparation time for the finished product was 10–15 min, about one-fourth that required for raw brown rice. Protein, vitamins, and mineral contents were comparable to raw brown rice and higher than white rice. Selected processing conditions were successfully used on a continuous CFB unit, producing about 40 lb/hr finished product. It was observed that less kernels were broken and more yield was reported (Roberts et al., 2006).

Rice is a staple food for over half of the world’s population. Germinated brown rice (GBR) is considered whole food because only the outermost layer i.e. the hull of the rice kernel is removed which causes least damage to its nutritional value. Swati and Md. Khalid (2011) reviewed brown rice can be soaked in water at 30 °C for specified hours for germination to get GBR. Soaking for 3 h and sprouting for 21 h has been found to be optimum for getting the highest gamma-amino butyric acid (GABA) content in GBR, which is the main reason behind the popularity of GBR. The intake of GBR instead of white rice ameliorates the hyperglycemia, boosts the immune system, lowers blood pressure, inhibits development of cancer cells and assists the treatment of anxiety disorders. Germination process could be used as enzymatic modification of starch that affects pasting properties of GBR flour. GBR would improve the bread quality when substituted for wheat flour. It is concluded that GBR has potential to become innovative rice by preserving all nutrients in the rice grain for human consumption in order to create the highest value from rice.

Guraya and Patindol (2011) reported generally, instant or quick-cooking rice products are prepared by first hydrating and/or precooking raw rice followed by drying the treated rice to desired moisture content. These methods of instantization
require significant amounts of water and energy, adding cost to the product and often affecting product quality. Moreover, most of these processes have been developed for white rice. Relatively few quick-cooking brown rice technologies have been developed. Because the bran layers contain most of the nutrients in the rice kernel, the development of quick-cooking brown rice products acceptable to the consumer would be highly desirable. They reduced the cooking time of brown rice by puncturing the water-resistant bran layers to produce microscopic holes. This would allow water to penetrate more quickly into the starchy endosperm of the kernel, resulting in faster cooking time. The process could be accomplished by bombarding brown rice with high-velocity, abrasive tiny particles. This would create micro perforations (i.e., nicks, holes, or cuts) on the water resistant outer layer of brown rice. A sandblaster is typically used to remove rust from metal parts or to smooth the surface. They propelled brown rice flour against the brown rice with pressurized air in the sandblaster, which created micro perforations. They stored the brown rice for 10 months and studied the shelf stability.

Rice can be a major source of inorganic arsenic for many sub-populations. Rice products are also used as ingredients in prepared foods, some of which may not be obviously rice based. Organic brown rice syrup (OBRS) is used as a sweetener in organic food products as an alternative to high-fructose corn syrup. Jackson et al., (2012) determined the concentration and speciation of arsenic in commercially available brown rice syrups and in products containing OBRS, including toddler formula, cereal/energy bars, and high-energy foods used by endurance athletes. Cereal bars and high-energy foods containing OBRS also had higher arsenic concentrations than equivalent products that did not contain OBRS.

Fourteen varieties of foxtail, two varieties each of proso and barnyard, one variety each of little and kodo millets were analysed for their proximate composition, and studied for milling, popping and malting characteristics. The yield of the polished grains varied from 63.7 to 73.5%. Under similar popping conditions (19% moisture and 250° C), the yield and volume expansion of the popped grains varied from 47 to 94 % and 4.8 to 11.6 ml/gm respectively. Slurries of flours from well popped samples exhibited higher cold paste and lower hot paste viscosity. Foxtail and proso millet
Maltes had higher α-amylase activity and lower hot paste viscosity than the other millet malts (Malleshi and Desikachar, 1985).

Chhavi and Sarita (2012) formulated composite bread by utilising finger millet flour and foxtail millet flour and further to evaluate these breads for sensory, nutritional qualities, and glycemic response. Two genotypes of finger millet VL-146 and PRM-601 and one local cultivar of foxtail millet were studied. The finger millet flour (FMF) and foxtail millet flour (FTF) were individually blended in various proportions (30 to 60%) into refined wheat flour (RWF). These blends were then used in the preparation of composite breads. The refined wheat flour bread (RWF) served as the control. One bread from each millet flour blend was selected finally for further investigation on the basis of sensory scores. As the 30% millet flour substitution was most preferred among the three millet samples, it was selected for further evaluation. Nutrient composition of the selected breads showed that composite bread formulated using FTF showed significantly higher crude protein, crude fat, total ash, phosphorus and insoluble dietary fibre. The composite bread formulated using FMF contained significantly higher calcium, soluble dietary fibre, tannin and phytic acid. However, the control (RWF) bread contained significantly higher carbohydrate, physiological energy and starch. Millet flour incorporated breads had low glycemic indices and were acceptable and nutritious.

Foxtail millet (Setaria italica) is a type of minor millet. Minor millets are small seeded annual grasses cultivated for food, feed, forage and other industrial uses. The term minor millets includes at least 12 to 14 species of the grass family and those with potential to become important crops in semi arid production systems. The foxtail millet was popped and their nutrient analysis was made. Fermented foods were prepared from the popped millet. The foxtail millet was pretreated with sodium chloride, sugar, citric acid. The millet was soaked and popped in mechanically popping machine. The grain was treated with salt and citric acid showing higher popping percent when compared to sugar treated grains. During soaking and popping (300°C), anti nutrient (phytic acid, tannin) abilities were found decreased. Physico chemical characters analysis were made. Physical characters (length, breadth, volume, moisture, acidity, porosity) are mostly similar in all types of treated foxtail millet, but chemical parameters (carbohydrate, starch, amylase, fat, free fatty acid, protein and...
fiber) varies for each type of treated millet. Popped foxtail millet kamu were used to prepare health drink and dried cakes and the organoleptic evaluation was made (Gurupavithra, 2009).

Anju and Sarita (2010) prepared biscuits based on foxtail millet and barnyard millet and to evaluate their sensory quality and acceptability, nutritional value and glycemic index by comparing with biscuits made from refined wheat flour. The biscuits made from millet were prepared using 45% of millet flour and 55% of refined wheat flour. All the three types of biscuits were found to be acceptable by a trained panel and diabetic subjects. The shelf life study indicated that the biscuits made from both types of millet flour can be successfully stored for a period of 60 days in a thermally sealed single polyethylene bag at room conditions. The millet flour and biscuits had higher content of crude fibre, total ash and total dietary fibre than refined wheat flour and biscuits. Biscuits from foxtail millet flour had the lowest GI of 50.8 compared to 68 for biscuits from barnyard millet flour and refined wheat flour. Thus, besides its traditional use in making chapatti and porridge, millet can be exploited for the development of low GI therapeutic food products like biscuits.

Yenagi et al., (2010) reported the traditional fermented breakfast food ‘paddu’ made with little millet has light and fluffy textural quality of cooked starch and is highly acceptable for taste and texture as compared to that made with rice. Small seeded little millet showed an advantage over rice due to several technological features like less water uptake, less soaking, grinding, and baking time and high product yield. Introduction of paddu in restaurants was acceptable to the consumers and was found sustainable in hotels. Indigenous papads such as ‘nere happala’ and ‘mudde happala’ prepared from the gelatinized mass of three days soaked millets, viz.,ragi (finger millet), little millet and foxtail millet without addition of any chemical additive like ‘happla khara’ enhanced the characteristic aroma and sour taste with good expansion of fried papad. Incorporation of 50% whole grain foxtail millet or ragi flour to standard recipe with change in proportion of fat yielded acceptable cookies of different types with good spreading quality, crispy texture and sweet taste. Muffins of foxtail millet and ragi were light, puffy and highly acceptable for taste. Incorporation of millet flour in cookies and muffins increased the protein, fibre, and micronutrient contents. Millet based products showed good potential to
enter bakery industry especially in rural sector as a nutritious snack item for school children. Thus, ethnic millet *papads*, fermented breakfast food ’*paddu*’ and bakery products have good scope for marketing and income generation through rural women entrepreneurs. Value addition to millets is a highly strategic intervention in the popularization of nutritionally rich crops.

Poongodi *et al.*, (2010) studied influence of millet flour blend on physical, functional, nutritional, cooking and organoleptic characteristics of noodles prepared from composite flour of millet flour blend, whole wheat flour and soy flour. Fiber and amyllose/ amylopectin ratio increased significantly (*p*<0.05) with increase in level of millet flour blend incorporation. Cooking time of developed noodles from composite flour (15-18 min) was significantly (*p*<0.01) higher than cooking time of branded noodles (9.3 min). Mean overall organoleptic score of developed noodle from composite flour was in the range of highly acceptable criteria (20-25). By all means, 20% level of millet flour blend incorporation was found to be acceptable. Mean glycemic index and load of developed noodle was significantly (*p*<0.01) lower than branded noodle.

Two convenience mixes suitable for five different types of baby foods based on proso millet (*Panicum milaceum*) were developed. Malting and popping were used as processing techniques. Malted convenience mix was further used as multipurpose flour for development of different baby foods. These five baby food products were sweet gruel, salty gruel, halwa, burfi and biscuits. The nutritional quality of mixes was analysed for moisture, crude proteins, energy and total ash contents of malted and popped convenience mixes. Iron and ascorbic acid contents of malted convenience and popped convenience mix were also determined. The Protein Efficiency Ratio (PER) was assayed with malted convenience mix and popped convenience mix. All the food products were organoleptically acceptable. Anon–significant difference at *p*=0.05 was observed among the scores for five food products (Sarita *et al.*, 2001).

Complementary foods, based on cereals and legumes, often contain high amounts of phytic acid, a potent inhibitor of mineral and trace element absorption. Possible use of the phytase, naturally present in whole grain cereals to degrade phytic acids in complementary foods, was investigated by Egli *et al.*, (2003). A meager 10%
whole grain rye, wheat or buckwheat was added to corn or mixtures of cereal and legume (polished rice + chick peas or whole grain wheat with low extraction rate + dehulled toasted soybeans). Phytic acid was completely degraded in a relatively short time (1.5-3 hr) when the complementary foods were incubated with cereal under optimal conditions for cereal phytase activity. To demonstrate the feasibility adapting the process for industrial use, a pilot plant scale incubation of whole grain wheat (10%) was added to the complementary food mixture containing 70% wheat with low extraction rate and 20% dehulled, toasted soybeans was performed.

**Thilakavathy and Muthuselvi (2010)** studied, development and evaluation of millet incorporated chappathi. Millet flours such as bajra, thenai, varagu and white oats were incorporated with different levels along with wheat flour and chappathies were prepared and standardized. In chappathi, minor millets thenai, bajra, varagu and white oats were incorporated at 20 per cent, 40 per cent and 60 per cent levels and the scores were given on a five point rating scale. Millet flour incorporated chappathi at 40 per cent level was most acceptable. Chappathi developed incorporating 60 per cent flours was unacceptable because of the hardness.

### 2.4 IMPORTANCE OF DIETARY FIBRE ON HEALTH

In 1987, an expert panel of nutritionists recommended that a satisfactory amount of dietary fiber ranges from 20 to 35g/day for healthy adults *(Pilch, 1987)*.

The dietary fibre requirement varies from individual to individual. But, most nutritionists recommend 12g of fibre /1000 K cal (i.e 30g of fibre/day) and the proportion of soluble to insoluble fibre should be 1:2 through varied sources *(Proskey and Vries, 1992)*.

The *American Diabetic Association (1994)* recommends a minimum of 20-35g of fiber/ day for a healthy adult depending on caloric in take (e.g.2000 cal/ 8400kj) and the diet should include 25 gm of fiber per day *(www.diabetes.org)*.

The British Nutrition Foundation has recommended a minimum fiber intake of 12-24g/day for healthy adults. Current recommendations from United National Academy Sciences, Institute of Medicine, suggest that adult should consume 20-35 of dietary fibre per day *(www.nutrition.org.uk)*.
Consumption of dietary fibre substantially alleviates coronary heart disease (CHD), diabetes and obesity (Anderson et al., 1994).

Evaluation of a high-fibre diet in hyperlipidemia: a review. Epidemiologic studies of cardiovascular mortality rates in different countries have suggested that dietary fibre may play a protective role. Within a similar population, a large intake of fibre is associated with a lower relative risk of death from coronary heart disease. Dietary fibre may be separated into at least two types: insoluble, which includes cellulose, hemicellulose, and lignin; and soluble, including pectin and gums. Laxative effects appear to predominate with insoluble fibers such as wheat bran, with little change in plasma lipid levels in most studies. Pectin, guar gum, and oat bran (soluble fibers) have been reported to have hypocholesterolemic effects in both animals and man (Ullrich, 1987).

Regular intake of dietary fibre at appropriate levels is reported to be effective in counteract many of the risk factors associated with CHD increased apolipoprotein B and consequently increase in LDL cholesterol, elevated serum cholesterol levels, high levels of blood serum fibrinogen and hypertension, obesity and diabetes. Dietary fibres also reduce high blood pressure due to high calcium (Ca) and magnesium (Mg) contents in dietary fibre (Shil, 1988; Luft et al., 1989). Soluble dietary fibre supplementation of diet reduces serum hypercholesterolemia significantly (Bell et al., 1990).

Dietary fiber has become one of the most enduring dietary interests of this decade, world wide. Interplay of the effects of the physical and chemical properties of dietary fibre has physiological importance with nutritional implications. Clinical investigations and research findings point out the favorable effect of high fibre diet in the management of disease conditions like diabetes mellitus, cardio vascular diseases, obesity and gastro intestinal disorders (Marckmann et al., 1996).

Dietary fibre exerts a buffering effect that binds excess of acid in the stomach, increases the faecal bulk and stimulates the intestinal evacuation. In addition, it
provides a favourable environment for the growth of the beneficial intestinal microbiota. Fibre can also bind diverse substances including cholesterol. It has been reported that these specific properties of DF play an important role in the prevention and treatment of obesity, atherosclerosis, coronary heart diseases, colorectal cancer and diabetes (Spiller, 2001). These physiological functions attributed to DF are influenced by the components of this DF. Basically, DF components are grouped into two major classes: polymers that are soluble in water (SDF), such as pectins and gums, and those water insoluble materials (IDF), where cellulose, hemicellulose and lignin are included.

Dietary fibre would likely include plant foods in which the fibre is relatively intact. Dietary fibre plays a crucial role in weight control, diabetes and digestion. It also helps to protect against colon cancer. Eating a variety of whole unrefined, plant based foods in the best way to provide your body with the fibre it needs. Fiber plays a major role in contributing to gut health, which is considered to be the foundation of wellness (Jenkins et al., 2002).

A nutrition, rich in fibre, has a preventive effect against constipation, colon diverticulosis, carcinoma of the large bowel and stomach, type 2-diabetes, metabolic syndrome and cardiovascular disease. In case of constipation, diverticulosis and diabetes this effect solely depends on dietary fibre. Regarding carcinomas and cardiovascular diseases, unknown factors integrated or associated with fibre-rich food may also contribute to the preventive effect (Vuksan and Korsic, 2004).

The interest in foods, rich in dietary fibre (DF), has increased in the recent decades, and the importance of this food constituent has led to the development of a large market for fibre-rich products and ingredients. A high DF intake has been related to several physiological and metabolic effects (Juana et al., 2009).

Soile et al., (2010) evaluated dietary fiber intake in children and studied associations between growth variables, serum cholesterol concentrations, and intakes of fiber, energy, and nutrients. Altogether, 543 children from a prospective randomized atherosclerosis prevention trial (the Special Turku Coronary Risk factor Intervention Project; STRIP) participated in this study between the ages of 8 mo and 9
y. The intervention children \((n = 264)\) were counseled to replace part of saturated fat with unsaturated fat. Nutrient intakes, weight, height, and serum total, HDL-, and LDL-cholesterol and triglyceride concentrations were analyzed. Children were divided into 3 groups according to mean dietary fiber intake in foods: low (lowest 10%), high (highest 10%), and average (middle 80%) fiber intakes. The results found fiber intake associated positively with energy intake and inversely with fat intake. Children with a high fiber intake received more vitamins and minerals than did children in other groups. In longitudinal growth analyses, weights and heights were similar in all 3 fiber intake groups, and fiber intake (g/d) associated positively with weight gain between 8 mo and 2 y. Serum cholesterol concentrations decreased with increasing fiber intakes. Children in the intervention group had a higher fiber intake than did the control children during the entire follow-up period.

The cereal and millet contain fibres in which soluble fibres increase transit time, delay gastric emptying, slow glucose absorption and lower serum cholesterol. Insoluble fibres decrease the intestinal transit time, increase the faecal bulk delay glucose absorption and slow starch hydrolysis. High fibre diet promotes weight loss (Schweitzer and Edwards, 1992). They increase satiety, delay gastric emptying and found to be suitable for cardiovascular patients.

Anderson et al., (2009) described dietary fiber intake provides many health benefits. However, average fiber intakes for US children and adults are less than half of the recommended levels. Individuals with high intakes of dietary fiber appear to be at significantly lower risk for developing coronary heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal diseases. Increasing fiber intake lowers blood pressure and serum cholesterol levels. Increased intake of soluble fiber improves glycemia and insulin sensitivity in non-diabetic and diabetic individuals. Fiber supplementation in obese individuals significantly enhance weight loss. Increased fiber intake benefits a number of gastrointestinal disorders including the following: gastro esophageal reflux disease, duodenal ulcer, diverticulitis, constipation, and hemorrhoids. Prebiotic fibers appear to enhance immune function. Dietary fiber intake provides similar benefits for children as for adults. The recommended dietary fiber intakes for children and adults are 14 g/1000 kcal. More
effective communication and consumer education is required to enhance fiber consumption from foods or supplements.

Mann and Cummings (2009) described that there is impressive evidence from epidemiological and experimental studies that dietary fibre derived from vegetables, fruits and wholegrain cereals protects against and may be useful in the treatment of a wide range of diseases. However, while there is some evidence of benefit of extracted and synthetic fibres in terms of lowering levels of cardiovascular risk factors, improving measures of glycaemic control and gastrointestinal function. An appropriate definition of dietary fibre is essential, given that claiming a food is high in dietary fibre is in effect making a health claim, without formally doing so. The new Codex definition acknowledges the difference between naturally occurring carbohydrate polymers which are neither digested nor absorbed in the human small intestine and synthetic or extracted polymers. However the latter two groups may also be defined as dietary fibre provided "beneficial physiological effect has been demonstrated by generally accepted scientific evidence". Given the need for a definition of dietary fibre which can be used for food labelling, setting nutrient reference values and decisions relating to health claims it is important to achieve agreement as to what constitutes a meaningful physiological effect and the level of evidence required to be certain of such effect.

The diets, which are rich in fiber content, prove to be very effective in reducing the blood sugar level. Dietary habits of different population groups, consuming an increased portion of the diet from fat, fatty, refined processed or preserved foods have increased the prevalence of non-insulin dependent diabetes mellitus. High fibre diets, containing complex carbohydrates, are slowly digested and absorbed, bringing about a reduction in post prandial glucose (Trowell, 1975).

Fibre has long been thought to be protective against colon cancer because it helps to “sweep” cancer-causing substances out of the intestines. Studies have demonstrated mixed results; however, data from the Nurse’s Health Study in 1999 indicated that women who consumed increased fibre daily were no less likely to get colon cancer than those who ate little fibre. Another study, Health Professionals Follow-up study showed similar results. In 2003, however, two studies suggested that
diets rich in fiber were indeed protective and that people who consumed them were 25 per cent less likely to develop colon cancer. Martha et al., (2004) examined the association between rectal cancer and plant food and fibre intakes. A threshold effect of approximately 5 servings of vegetables/day was needed to see a reduced risk of rectal cancer. The results suggest that plant foods may be important in the etiology of rectal cancer in both men and women.

People could likely benefit from increased fibre intake. As a less-restrictive and sensible approach to weight management, diet rich in fibre may also have other health benefits such as reduced risk of colon cancer, diabetes and heart disease. Fibre supplements added to a caloric diet have additional effects on weight reduction in overweight subjects. Bowen et al., (2005) studied and compared the effects of various commercial fibre supplements (glucomannan, guar gum and alginate) on weight reduction in healthy overweight subjects. Glucomannan induced body weight reduction in healthy overweight subjects, whereas the addition of guar gum and alginate did not seem to cause additional loss of weight.

Researchers at Imperial College London conducted a meta-analysis of 25 studies involving almost two million people (and 14,500 cases of colorectal cancer) to assess the links between colorectal cancer and both whole grains and total dietary fiber. They concluded that there is a credible "dose-response" relationship between whole grain consumption and reduced cancer risk; they estimate that eating three or more servings of whole grains per day lowers colorectal cancer risk nearly 20%. Dietary fiber also reduces this risk, but cereal/grain fiber shows stronger benefits than other types of fiber (Aune et al., 2011).

2.4.1 Cereal grains and cardiovascular diseases

Brown rice is one of the major cereals consumed in many countries. Its bran contains multiple health-promoting components, such as phytosterol, gamma oryzanol, tocopherols, and various dietary fibers. Some of these substances have hypoglycemic and hypoinsulinemic effects (Qureshi et al., 2002) that prevent chronic diseases (Meyer et al., 2000).

Brown rice bran contains several things - two major ones are fiber and essential oils. Fiber is not only filling, but is implicated in prevention of major diseases in this country such as certain gastrointestinal diseases and heart disease. The
National Cancer Institute recommends 25 grams of fiber a day, a cup of brown rice adds nearly 3.5 g, while an equal amount of white rice not even 1 g. Also, components of the oils present in rice bran have been shown in numerous studies to decrease serum cholesterol, a major risk factor in heart disease (Kuriyan et al., 2005; Most et al., 2005).

Millet protein has a beneficial influence on metabolism of cholesterol (Nishizawa and Fudamo, 1995).

Millet and other whole grains are rich source of magnesium, a mineral that acts as a co-factor for more than 300 enzymes, including enzymes involved in the body’s use of glucose and insulin secretion. Magnesium has also been shown to lower high blood pressure and reduce the risk of heart attack, especially in people with atherosclerosis or diabetic heart disease. Niacin can be of help in lowering high cholesterol. Eating foods high in insoluble fibre, such as millet can help women avoid gall stones (Luc and Gaziano, 2007).

Smith et al., (2003) studied the wholegrain foods with special reference to: whole grains as important sources of nutrients; phytochemicals present in whole grains; effects of processing on the nutritional value of wholegrain foods; health benefits of wholegrain foods (reduced risk of cancer, diabetes and obesity, hypolipaemic activity); UK health claims associated with wholegrain foods; recommended intakes and consumption patterns: and strategies to increase consumption of wholegrain foods.

Rimm et al., (1996) checked their results with fibre calculated both by Southgate’s method and by Englyst’s. They concluded that they could not, completely, exclude the possibility that some unknown factor, associated with high fibre intake is responsible, but it would need to have a strong influence. The lack of any substantial confounding by known predictors of cardiovascular disease and by other dietary factors, together with demonstrated benefits in metabolic studies, suggests that higher intake of dietary fibre, particularly from cereal and grain sources can reduce, substantially, the risk of coronary heart disease.

Until recently, the dietary focus in the prevention of coronary heart disease (CHD) has been almost exclusively centered on reducing intake of cholesterol, total
fat and saturated fat. The food industry responded vigorously with low-fat products, some of which are helpful, particularly low-fat dairy products, but others that are less so, due to the increase in refined carbohydrate content. Recent research shows that a variety of foods provide protection against CHD, which includes certain types of fatty acids, and a variety of components in fruit and vegetables, whole grains and nuts. In particular, there is now an emphasis in reducing not only the saturated fat, but also the transfat, whereas mono and omega-3 fatty acids have been shown to be protective. Many new studies have shown a link between intake of fruits and vegetables and whole grains and protection against CHD. This had been ascribed to their fibre, vitamin, mineral and phytochemical content. New recommendations to prevent heart diseases require a greater focus on total dietary pattern with a return to the use of variety of minimally processed foods (Tucker, 2004).

A number of reviewers have examined studies investigating the relationship between coronary heart disease and stroke prior to 2000. Since then, several key studies have been published. Five studies have examined the relationship between wholegrain consumption, coronary heart disease (CHD) and cardiovascular (CVD) disease and found protection for either or both diseases. The researchers concluded that a relationship between wholegrain intake and CHD is seen with at least a 20% and perhaps a 40% reduction in risk for those who eat wholegrain food habitually vs those who eat them rarely. Notwithstanding the fact that fibre is an important component of whole grains, many studies have not shown an independent effect of fibre alone on CHD events. Thus in terms of CHD prevention, fibre is best obtained from wholegrain sources. Soluble fibre clearly lowers cholesterol to a small but significant degree and one would expect that this would reduce CHD events (Flight and Clifton, 2006).

Consumption of whole grain products and dietary fibre has been shown to reduce the risk of high blood pressure and heart attack. In this meta-analysis of seven studies, including more than 1,50,000 persons, those whose diets provided the highest dietary fibre intake had a 29 per cent lower risk of cardiovascular disease compared to those with the lowest fiber intake. In addition to the matrix of nutrients in their dietary fibers, the whole grain arsenal includes a wide variety of additional nutrients and phyto nutrients that reduce the risk of cardiovascular disease (Erkkila et al., 2005).
Switching to whole grains may reduce body fat and aid heart health, according to scientists at the University of Copenhagen. In a twelve-week, randomized clinical trial, they asked 79 overweight or obese postmenopausal women to eat a calorie-restricted diet incorporating either 480 calories of refined grain foods or the same amount of whole grain foods. Those eating the diet with whole grains lost more weight (3.6kg vs 2.7kg) and saw a more significant decrease in body fat (3% reduction vs 2.1%) compared to those eating refined grains. Cholesterol levels increased 5% in the refined group, highlighting the heart benefits of choosing whole grains instead of refined (Kristensen et al., 2012).

Although whole grain consumption has been associated with a lower risk of cardiovascular disease incidence and mortality in the general population, little is known about the effect of whole grain and its components on cardiovascular risk and mortality in diabetic patients. Meian et al., (2010) followed 7822 US women with type 2 diabetes mellitus for up to 26 years to investigate intakes of whole grain and its components cereal fiber, bran, and germ in relation to all-cause and cardiovascular disease-specific mortality. Their results indicated that intakes of whole grain, especially its subcomponent bran, were inversely associated with all-cause and cardiovascular disease-specific mortality among women with type 2 diabetes mellitus. Low whole-grain intake may be considered an important modifiable risk factor for decreasing mortality and cardiovascular risk in persons with diabetes mellitus.

Tae et al., (2011) investigated; intake of whole grains has been associated with lower risks of type 2 diabetes and cardiovascular disease. Brown rice is unrefined whole grain and is produced by removing the outermost layers containing the germ and bran, which are rich in nutrients including dietary fiber, vitamins, minerals, and other unmeasured dietary constituents. The lees of brown rice (LB) are by-products of its fermentation in the process of manufacturing takju, a Korean turbid rice wine. In this study, they hypothesized that intake of LB would reduce waist circumference, a strong risk factor for cardiovascular disease in type 2 diabetic patients. A randomized, double-blind, placebo-controlled study was scheduled for 12 weeks. Thirty subjects were randomly assigned to receive a supplement prepared from
the LB or from a mixed-grain dietary product (MG). Body weight, waist circumference, body composition, lipid profiles, and other laboratory parameters were measured. The LB group showed greater reduction in waist circumference (LB: 87.9 ± 8.8 to 85.1 ± 9.0 cm; MG: 86.9 ± 8.8 to 86.0 ± 9.3 cm; P = .032). Consumption of the LB was associated with a decreased waist circumference in type 2 diabetic patients.

2.4.2 Impact of cereal on hyperlipidemia in animal model and human.

2.4.2.1 Animal model

Seung et al., (2005) studied the effect of different brown rice diets containing 1% cholesterol on cholesterol metabolism in Sprague-Dawley rats. Diets fed to rats for 28 days included corn starch alone as a control or 50% corn starch + 50% corn starch substitute, uncooked brown rice, cooked brown rice, brown rice with lactic acid bacteria and brown rice fermented by lactic acid bacteria. Rats fed with brown rice fermented by lactic acid bacteria had significantly lower levels (33-50%) of blood and hepatic triglycerides, total blood cholesterol, low density lipoprotein cholesterol and a very low density lipoprotein cholesterol, whereas the levels of high density lipoprotein cholesterol were 227% higher compared to the control group (p<0.05). These effects appeared to be related to increase in faecal wt. and excretions of triglycerides, total cholesterol and bile acids (p<0.05). The sensory properties of diets (flavour preference, overall acceptability) were improved markedly by the addition of fermented brown rice. The results suggest that fermented brown rice may have potent hypolipaemic activity and improve the sensory properties of diets.

Brown rice or unmilled rice is the whole grain of rice, from which the germ and outer layers containing the bran have not been removed. Brown rice seeds are rich in more nutritional components, such as dietary fibers, vitamins B and E, gamma (γ)-oryzanol and γ-amino butyric acid (GABA) than the ordinary milled rice grains. Shahin et al., (2009) investigated the influence of brown rice varieties containing different GABA levels on blood cholesterol in Sprague-Dawley male rats. Quantitative analysis of GABA, Gamma oryzanol, dietary fiber, protein and fat was carried out using appropriate method. Hypercholesterolemia and elevation of LDL-cholesterol was successfully ameliorated by most of the brown rice diets (p < 0.05). A significant negative correlation (p < 0.05) between serum TC level and γ-oryzanol
content of diets was observed. Moreover, a significant negative correlation ($p < 0.05$) between serum LDL-C level and dietary fiber content of diets was observed. In contrast, there was no correlation between GABA content and TC, LDL-C, HDL-C and glucose levels. Although no correlation was found between GABA content and lipid profile suppression, this study suggests that using brown rice varieties instead of polished rice in human diet can modulate the changes of blood cholesterol.

Brown rice is unpollished rice with immeasurable benefits for human health. Brown rice (BR) and pre-germinated brown rice (PGBR) are known to contain various functional compounds such as gamma-oryzanol, dietary fibre and gamma-aminobutyric acid (GABA). Roohinejad et al., (2010) investigated the experimental diets containing BR and PGBR (24, 48 h pre-germination) were the influence of pre-germination time of brown rice on blood cholesterol in Sprague-Dawley male rats. Hypercholesterolaemia and elevation of LDL-cholesterol were successfully ameliorated by the experimental diets containing BR and PGBR (24 and 48 h pre-germination). As compared to the control sample, the pre-germination time had a significant ($P < 0.05$) effect on blood cholesterol of Sprague-Dawley male rats. It was also found that the significantly ($P < 0.05$) better effect on lipid profile of hypercholesterolaemic rats was observed by prolonging the pre-germination time. As compared to non-germinated brown rice, the germinated brown rice showed the higher cardio-protective effect on hypercholesterolaemic Sprague-Dawley male rats.

Lee et al., (2010) formulated the hypothesis that whole grain consumption would have beneficial effects on lipid profiles, antioxidant status, and the inflammation state of hyperlipidemic rats compared to those resulting from a white rice (WR) diet. Forty-week-old male Sprague-Dawley rats (n = 24) were fed a high-fat diet (188.3 kJ% energy as fat) for 8 weeks to induce hyperlipidemia and were then randomly divided into 4 groups (n = 6 each) that were fed diets containing WR (control), sorghum, foxtail (FM), or proso millet for the next 5 weeks. Blood lipid profiles, hepatic antioxidant parameters, and inflammation-related measurements were determined in all of the groups. The concentrations of serum triglycerides were significantly lower in the FM and proso millet groups compared to those of the WR and sorghum groups. The concentrations of serum total, high-density lipoprotein (HDL), and low-density lipoprotein (LDL)-cholesterol were significantly
higher in the sorghum group than in the WR, FM, and proso millet groups. In conclusion, FM and proso millet may prevent cardiovascular disease by reducing plasma triglycerides in hyperlipidemic rats; in contrast, sorghum increases total cholesterol, HDL-cholesterol, and LDL-cholesterol concentrations.

**Jerzy et al., (2009)** evaluated the efficacy of an anthocyanin pigmented rice (e.g. black rice) to mitigate the onset of hypercholesterolemia in rats-fed atherogenic diets. Male Wistar ($n=10$/group) rats were fed with atherogenic diets containing 0.5% cholesterol in the presence and in the absence of bile salt (e.g. 0.05% cholic acid) along with a standardized black rice extract (BRE) (e.g. 3%, w/w). All animals were individually housed in stainless steel cages and fed with the experimental diets during a 12-h period for 10 weeks. Body weights of rats were measured every week of the experiment. After 10 weeks fed on experimental diets, rats were sacrificed and plasma total cholesterol, HDL and LDL cholesterol and triacylglycerols were measured immediately. The total cholesterol (TC) content in the liver, heart and aorta, and the concentration of triacylglycerol (TAG) were measured after lipid extraction using Folch method. Rats fed with 0.5% cholesterol containing diets which also included bile salt exhibited a considerably more severe hypercholesterolemia than counterparts fed diets containing only 0.5% cholesterol. The inclusion of the BRE in diets significantly ($p<0.05$) decreased the level of TC, LDL–TC and TAG in plasma of rats-fed control diets that either contained or were absent in bile salt ($p<0.05$). There were no differences in HDL-level. Liver crude lipids and total cholesterol levels were also significantly ($p<0.05$) decreased in experimental groups relative to the control group in both experiments. Thus, supplementation of atherogenic experimental diets with BRE effectively decreased lipid levels in hypercholesterolemic rats.

**Ausman et al., (2005)** had investigated the possible mechanisms for the hypocholesterolemic effect of the physically refined rice bran oil and examined its effect on aortic fatty streak formation. In the first experiment, 30 hamsters were fed, for 8 weeks, with chow-based diets plus 0.03% added cholesterol and 5% (wt/wt) coconut, canola or Physically Refined Rice Bran oil (CoCo, CANOLA or PRBO animal groups, respectively). In the second experiment, 36 hamsters were fed with chow-based diets of 0.05% added cholesterol, 10% coconut oil and 4% additional CoCo, CANOLA or PRBO. Early atherosclerosis (fatty streak formation) was,
significantly, found reduced (48%) only in PRBO, unlike in the other two. The lipid lowering found in PRBO is associated with decreased cholesterol absorption, but not hepatic cholesterol synthesis, and the decrease in fatty streak formation with this oil may be associated with its non triglyceride components not present in the other two diets. These results suggest that, physically, refined rice bran oil containing 2-4% nontriglyceride components, as compared to other vegetable oils, appears to be associated with lipid lowering and anti-inflammatory properties in several rodent, primate and human models.

**Amarjeet and Sekhon (1994)** studied the nutritional quality of parboiled rice. Feeding trails were conducted on albino rats for 28 days using reference casein diet, raw rice diet and the diets based on pressure parboiled rice as well as traditionally parboiled rice protein efficiency ratio (PER) was very significant for different groups. However, PER value was the highest for rats fed on casein diet, followed by raw rice diet, pressure parboiled rice diet and traditionally parboiled rice diet respectively.

Nutritive value of soy idli was studied using rat growth experiment (Akolkar and Parekh, 1983). Weaning albino rats were fed diet consisting wholly of either unfermented or fermented soy idli supplemented with lime powder and fenugreek leaves. The control group was fed 20 per cent casein diet. Fermented soy idli was found superior to unfermented soy idli in terms of body weight gain, hepatic protein and vitamin content and femur composition. Supplementation of fermented soy idli with lime and fenugreek leaves further improved the growth, liver and femur composition and were comparable with the control group (20% casein diet) and thus indicate the fact that fermented soy idli, along with lime and greens, can form a good supplement for undernourished children.

**Jaffer and Hussain (2009)** reported five groups of rats were given five different diets for 4 weeks after one week adaptation with standard casein. These diets include: casein diet as a control group (C), cooked rice (R), cooked rice with 1% exogenous cholesterol (RC), oat meal (O), and oat meal with 1% exogenous cholesterol (OC) (Different analysis was determined on animals of these groups at the end of the experiment). The rat’s weights at the end of experiment showed that weight gain of control group rats was significantly higher (p≤0.01) than other groups but
there were no differences among other groups. The concentration of serum total cholesterol for (O) group (64.6 mg/100 ml) and that of (R) group (67.7 mg/100 ml) were significantly lower ($p \leq 0.01$) than those of other groups and the control group was the highest one in all groups (112.42 mg/100 ml).

Mansour et al., (2003) evaluated the sensory properties of low-fat cookies prepared by partial replacement of butter oil with different types of carbohydrate-based fat replacer. The best 2 types were selected to determine the optimum fat replacement levels, and 4 types and a full-fat control were evaluated on an animal. Animal model was used to ascertain the effects of serum lipids (total cholesterol, low density lipoprotein (LDL)-cholesterol, high density lipoprotein (HDL)-cholesterol and triglycerides), hepatic and renal fatty acids compositions, food intake, body weight, weight gain and organ weight. Among the feeding rats, these low-fat cookies showed a significant decrease in total serum cholesterol, LDL-cholesterol, HDL-cholesterol and triglycerides concentration compared with rats fed on control cookies.

Grain sorghum is a rich source of phytochemicals that could potentially benefit human health. In this study, the male hamsters were fed with A1N-93M diets supplemented by a hexane-extractable lipid fraction from grain sorghum whole kernels. The grain sorghum lipids (GSL) comprised 0.0, 0.5, 1.0 or 5.0% of the diet by wt. After 4 weeks, the dietary GSL significantly reduced plasma non-high density lipoprotein (HDL-cholesterol concentration in a dose-dependent manner with reductions of 18, 36 and 69% in hamsters fed 0.5, 1.0 and 5.0% GSL, respectively, compared with controls. It is concluded that grain sorghum contains beneficial components that could be used as food ingredients or dietary supplements to manage cholesterol levels in humans (Carr et al., 2005).

Hypolipaemic activities of 2 allergy-free amaranth flours and oatmeal were compared in order to determine whether this pseudocereal can be a substitute for individuals allergic to cereals. Male wistar rats were fed on diets containing 1% cholesterol and 10% oatmeal or 10% of 1 of the 2 amaranth flours for 32 days. Intake of oatmeal and, to a lesser extent, amaranth flours retarded increases in plasma lipids level observed on control rats fed cholesterol. On the whole, it is suggested that amaranth flour positively affects the plasma lipid profile of rats fed on cholesterol-
containing diets, and the degree of this effect is related to the bioactive compound content and antioxidative activity of the samples. It is concluded that amaranth may be a useful hypolipaemic agent in individuals allergic to cereals (Czerwinski et al., 2004).

2.4.2.2 Human subjects

Miyoshi et al., (1986) fed 550 gm brown rice per 60 kg body weight per day fed for five healthy, normocholesterolemic males. They experienced increased fecal weight and decreased nutrient digestibility with no decrement in cholesterol levels.

Rice is a staple food in Japan and provides 43% of carbohydrate and 29% of energy intake in the Japanese population. Ehab et al., (2011) studied encompassing 83,752 Japanese men and women aged 40–79 y; rice intake was determined by self-administered food frequency questionnaire. A total of 3514 cardiovascular deaths [1640 strokes, 707 coronary heart diseases (CHD), and 560 heart failure] were documented. There was a gender difference on the effect of rice intake on the risk of cardiovascular disease (CVD). Overall, rice intake was inversely associated with CHD, heart failure, and total CVD in men but not in women. Rice intake was not associated with risk of stroke in either gender. For women, rice was not associated with reduced risk of mortality from CVD after adjusting for lifestyle and dietary variables. In conclusion, the consumption of steamed rice was associated with reduced risk of mortality from CVD in Japanese men but not women.

David et al., (1999) examined the cholesterol-lowering effects of a proprietary Chinese red-yeast-rice supplement in an American population consuming a diet similar to the American Heart Association step I diet using a double blind, placebo-controlled, prospectively randomized 12-wk controlled trial at a university research centre. They conduced that the red yeast rice significantly reduces the total cholesterol, LDL cholesterol, and total triacylglycerol concentrations compared to placebo and provides a new, novel, food-based, approved way of lowering cholesterol level in the general population.
Sanders and Reddy (1992) noted the lowered triglycerides, but not the cholesterol levels, in 18 healthy, normocholesterolemic males after short term feeding of 15g/d of defatted rice bran compared with 15g/d wheat-bran.

Full fat rice bran, when added to the prudent diets of moderately hyperlipidemic individuals, produces significant cholesterol reduction and improvement in the LDL-C; HDL-C ratio in most of these individuals. There was no significant different between the effectiveness of the rice bran and oat bran products used in this study to reduce serum cholesterol or between responses in males and females (Gerhardt and Gallo, 1998).

The effects of defatted rice bran and rice bran oil in an average American diet on blood lipid concentration in moderately hyperlipaemic persons were investigated. The results show that the defatted rice bran did not lower lipid concentration but total cholesterol concentration was, significantly, lower with the consumption of the diet containing rice bran oil than with the consumption of the control diet. Moreover, with the consumption of the rice bran oil diet, low density lipoprotein cholesterol concentration decreased by 7% (P <0.0004), whereas the high density lipoprotein cholesterol concentration remained unchanged. It is concluded that the rice bran oil, not fibre, lowers the cholesterol level in healthy, moderately hyperlipaemic adults, since no major differences exist in the fatty acids composition of the diets the hypocholesterolaemic effect is attributed to other components present in the rice bran oil, such as unsaponifiable compounds (Most et al., 2005).

Rice bran oil, which was not popular worldwide, is slowly being recognized a ‘healthy’ oil in India. It has been assessed if rice bran oil had any hypolipidaemic effects in subjects with elevated lipid levels. The results showed that the use of rice bran oil, significantly, reduced the plasma total cholesterol, and triglyceride levels compared with sunflower oil. The use of rice bran oil, as the main cooking oil, significantly reduced serum cholesterol and triglyceride levels. The use of rice bran oil together with dietary and lifestyle modifications may have implications for reducing the risk of cardiovascular diseases (Kuriyan et al., 2005).
Kestin et al., (1990) performed a double, cross-over trial of wheat, oat and rice bran in moderately hypercholesterolemic men. The HDL-C to cholesterol ratio with 12 g fiber/day from rice bran or oat bran, but LDL-C fell significantly only with oat bran. Dietary fiber lowers atherogenic serum lipids and blood pressure and improves the glucose metabolism. They compared 24 mildly hypercholesterolemic men for the effects of adding 11.8g dietary fiber/d from each of three cereal brans (wheat, rice and oat) to a low-fiber diet for 4 week each. A double-blind, crossover design incorporated brans into bread and muffins. Plasma total-and low-density-lipoprotein-cholesterol concentrations were significantly lowered only in oat bran. Comparison with wheat bran, showed the ratios of plasma high-density-lipoprotein cholesterol to total cholesterol and of apolipoprotein A-I to B were significantly increased with oat bran (both by 4.7%, P less than 0.05), and rice bran (2.3%, P less than 0.05 and 3.9%, P less than 0.05 respectively). Oat and rice bran exert a small but potentially useful effect on plasma lipoprotein risk factors for cardiovascular disease.

Radha and Vijayalakshmi (2006) evaluated the role of fibre rich millets in controlling hyperlipidemia among the selected cardiovascular patients. Fibre rich millets namely varagu (Paspalum soorbitum), thenai (Panicum miliare) and samai (Setaria italica) to find out its effect on lipid profile. One hundred cardiovascular patients in the age group of 36-75 years were selected. Among these patients, 38 were selected for the clinical trial with an experimental group of 10. Supplements of 60g of varagu and samai and 90g of thenai were given to the experimental subjects for a period of 60 days. Both for the control and experimental groups the initial and final values for the different lipids were estimated before and after supplementation. The supplementation of millets resulted in a reduction of 7.71-10.09 and 1.37-12.25 mg/dl of total and LDL cholesterol. Further, HDL cholesterol increased by 0.82-1.40 mg/dl. VLDL cholesterol and triglycerides reduced by 1.40-10.25 and 7.91-50.58 mg/dl respectively.

Cardiovascular diseases represent an enormous, medical, social and economic burden to the public. Supplementation of antioxidant has a significant fall in total cholesterol, triglycerides, low density lipoprotein cholesterol and very low density lipoprotein cholesterol. Appropriate antioxidant therapy could be useful to prevent various cardiovascular Complications. Thilagamani and Uma (2011) envisaged to
developed antioxidant rich supplement and find its effect on lipid profile of young women at risk for cardiovascular disease. A formulation with Italian millet flour (an under exploited millet, botanical name *Setaria italica*), whole wheat flour, coriander leaves and groundnut oil in the ratio of 3:1:1:1 was selected owing to its high acceptability and nutritional contribution and was given daily for a period of 90 days. On statistical analysis of lipid values before and after supplementation, total cholesterol and low density lipoprotein cholesterol showed significance at one percent level. Triglycerides, high density lipoprotein cholesterol and very low density lipoprotein cholesterol did not show any significant changes for the selected sub-sample.

**Lupton et al., (1994)** compared the effects of adding barley bran flour and barley oil extract to a fat modified diet on serum lipids in persons with hypercholesterolemia. The subjects were 79 men and women with hypercholesterolemia and the subjects mean age was 48.2 yrs. All the participants were instructed to follow the National Cholesterol Education programme (NCEP) step I diet and were randomly assigned to one of three treatment groups; 20g added cellulose, 3g added barley oil extract or 30g added barley bran flour. They concluded that the addition of barley bran flour or barley oil enhances the cholesterol-lowering effect of the NCEP step 1 diet in individuals with hypercholesterolemia.

**Hallfrisch et al., (2003)** studied the ability of varying levels of barley fibre to lower blood pressure as part of a wholegrain diet. Totally 21 non-hypertensive males (aged 28-62yr) with mild hypercholesterolemia followed the American Heart Association Step 1 diet for 2 wk and then consumed experimental wholegrain diets providing 0, 3 or 6 gm/day soluble barley fibre for 5 wk in a Latin square design. Experimental diets used were: brown rice + whole wheat (BR/WW; providing insoluble fibre); barley diet (providing 6 g soluble barley fibre/day): or a combined BR/WW + barley diet (providing 3 g soluble barley fibre/day). Consumption of the step I diet did not influence the blood pressure values, but systolic, diastolic and mean arterial pressure were reduced by all and whole grained diets, regard less of fibre source (soluble or insoluble). Consumption of the diet providing 6g soluble fibre / day resulted in lower urinary excretion of P and urea N.
Soluble fiber from oats has been recognized as beneficial in decreasing blood cholesterol levels. Although barley contains high amounts of soluble fiber, it is not consumed as extensively as oats. Eighteen moderately hypercholesterolemia men (28-62y) consumed a controlled equilibration diet (Step 1, 30% fat, 55% carbohydrate, 15% protein, <300mg cholesterol) for 2 weeks followed by the diet with about 20% of energy replaced with brown rice/whole wheat, (1/2) barley and (1/2) brown rice/whole wheat or barley (<0.4g, 3g and 6g added soluble fiber/2800 kcal, respectively) for 5 weeks in a Latin-square design. This study concluded that the soluble fibre, through consumption of barley, in a healthy diet can reduce cardiovascular risk factors (Behall et al., 2004).

Kay et al., (2004) investigated whether the consumption of barley would reduce cardiovascular disease risk factors comparably with that of other sources of soluble fiber. The addition of barley to a healthy diet may be effective in lowering total and LDL cholesterol in both men and women. These results indicate that the dietary changes especially greater consumption of whole grains including barley, higher β-glucan intake, and lower fat intake can reduce the risk factors associated with CVD.

Vladmir et al., (1999) tested the effects of laxation and serum lipid metabolism of a novel source of wheat fibre and protein produced by the amylolytic digestion of starch from wheat. They concluded that the product of amylolytic digestion of starch from wheat flakes, which is high in wheat fibre and protein, has a fecal bulking effect similar to that of wheat bran and may have a beneficial effect on serum lipids.

According to Jacobs et al., (1999) whole grain cereals are clearly much the same as ‘high fibre’ cereals. Two reports by the Harvard epidemiology and nutrition group appeared in 1999 from the US Nurses cohort study. One is about dietary fibre, the other about whole-grain consumption in relation to CHD. In the paper by Wolk et al., (1999) they found a significant inverse association between total dietary fibre intake and risk of CHD. This was due to a significant inverse relation with cereal fibre, but not with vegetable or fruit fiber. Women in the highest quintile of cereal fibre intake had a 34% lower risk of CHD events, compared with those in the lowest quintile. The FDA of the US now permits a health claim (U.S. Food and Drug Administration, 1998) for whole grain foods (as defined) ‘Diets rich in whole grain...
foods and other plant foods and low in total fat, saturated fat and cholesterol may reduce the risk of heart disease and some cancers’. For the purpose of health claim whole grain foods contain 51% or more whole grain ingredients by weight per reference amount with dietary fibre 2.3 g/50 g or 1.7g per 35 g and the food low in fat.

The authors discussed the new evidence-based dietary recommendations founded on an inclusive food strategy and to address the challenges that are posed by integrating a growing list of heart healthy foods into the diet without increasing energy intake beyond that required to achieve a healthy body weight. The American Heart Association recommends a variety of foods to target four major goals: achieve a healthy overall diet, achieve a healthy weight, promote desirable lipid levels, and promote desirable blood pressure. Specific foods recommended include fruits and vegetables, grain products (including whole grains), fish, lean meat and poultry, fat-free or low-fat dairy products, and legumes. In addition, the new National Cholesterol Education Program Adult Treatment Panel III recommends reductions in saturated fat and cholesterol and therapeutic dietary options for enhancing LDL-cholesterol lowering, with inclusion of plant stanol/sterols (2 g/day) and increased viscous (soluble) fiber (10-25g/day). Parallel to the evolution of new dietary recommendations is the expanding list of specific foods that have cardio protective effects. Additional foods in this list are nuts, soy, legumes, alcohol, tea, and garlic (Kris et al., 2002).

Two diets, the Low-Fat diet and the Low-Fat Plus diet, designed to be identical in total fat, saturated fat, protein, carbohydrate, and cholesterol content, consistent with former American Heart Association Step I guidelines. The Low-Fat diet was relatively typical of a low-fat U.S. diet. The Low-Fat Plus diet incorporated considerably more vegetables, legumes, and whole grains, consistent with the 2000 American Heart Association revised guidelines. Previous national dietary guidelines, primarily, emphasized avoiding saturated fat and cholesterol; as a result, the guidelines probably underestimated the potential LDL cholesterol-lowering effect of diet. In this study, the emphasis on including nutrient-dense plant-based foods, consistent with recently revised national guidelines, increased the total and LDL cholesterol-lowering effect of a low-fat diet (Gardner et al., 2005).
Cookies enriched with psyllium or oat bran lower plasma LDL Cholesterol in normal and hypercholesterolemic men from Northern Mexico. These results indicate that psyllium and oat bran are efficacious in lowering plasma LDL cholesterol in both normal and hypercholesterolemia individuals from this population (Ana et al., 1998).

Hermansen (2003) consumption of new soy products containing high, fixed levels of isoflavones, cotyledon soy fiber, and soy phospholipids (Abaco and Abalon) significantly reduced the LDL: HDL ratio by 27%. The new soy-based supplements may, therefore, play a valuable role in reducing cardiovascular risk.

Mesomya et al., (2006) evaluated cereals and nata de coco supplementation on the lipid status in 22 subjects with hyperlipidemia. Subjects consisted of eleven men and eleven women aged 32-75 years. The study consisted of four weeks of control and 20 weeks of supplementation period. The subjects were given 15 g of the supplement twice daily for 20 weeks. The daily 30 g supplement consisted of unpolished rice, hulled mung bean, sweet corn, and nata de coco and provided 122.6 kcal, 5.5 g of protein, 0.5 g of fat, 24.1 g of carbohydrate and 2.7 g of dietary fiber. After 20 weeks, the subjects were divided into two groups, according to their dietary compliance, group A: > 90% compliance, and group B:< 90% compliance with the assigned supplement intake. There were 15 subjects in group A, and 7 in group B. Results showed that in group A the mean TG levels at weeks 4, 8, and 16 were significantly different (P<0.05), but no significant differences were observed in TC, LDL-c and HDL-c except that TC level at week 16 was significantly lower than that at week 0 (P<0.05). Thus, the results appeared to indicate that health food from unpolished rice, hulled mung bean, sweet corn and nata de coco may reduce the serum TG and TC in hyperlipidemic patients.

Lia and Andersson (1994) studied the glycaemic response and gastric emptying rate of oat bran and semolina porridge meals in diabetic subjects. Blood glucose and serum insulin response to three common type of porridge meals (oat bran, rolled oats and semolina) were investigated in a group of non-insulin dependent diabetics (NIDDM). In addition, the study examined whether the gastric emptying (GE) rate differs between meals with porridge made of oat bran and of semolina and whether there is a relation between the GE rate and the post prandial blood glucose.
and insulin response. The results showed that there was no difference in glycaemic or insulinaemic response to the three different porridge test meals in the NIDDM subjects. Neither did the GE rate differ between oat bran and semolina test meals. Even if the amount of viscous fiber was much higher in the oat bran meal than in the semolina meal, many other factors also influence the degree of glycaemia and insulinaemia. The large particle size and intact structure of the wheat grain in the semolina porridge might have been sufficient to reduce gelatinization and rate of starch digestion. Hence oat and semolina porridge was useful in dietary treatment of diabetes.

Thilakavathy and Muthuselvi (2010) studied development and evaluation of millet incorporated chappathi on glycemic response in type II diabetics. Variations were made by incorporating 30g of fenugreek leaves in 100 g of wheat flour and millet flours such as bajra, thenai, varagu and white oats and chappathies were prepared. These chappathis were given to the selected type II diabetics to determine the glycemic index. The findings showed that inclusion of millet and fenugreek leaves incorporated chappathies in the daily diet do not cause a rapid rise in blood glucose levels and would prove to be an effective management of type II diabetes.

2.5 STORAGE STUDIES ON CEREAL, PSEUDO-CEREAL AND ITS PRODUCTS

Sharp and Timme (1986) studied effects of storage time, storage temperature, and packing method on shelf life of brown rice. Brown rice was stored either in heatsealed, two-ply laminated polyethylene bags, in sealed polyethylene bags sealed in metal cans, or in perforated bags in a metal can sealed under vacuum at 3, 22, or 38°C. Samples were evaluated each month for nine months for development of off-odors and off-flavors by sensory evaluation. Tests were also conducted to evaluate changes in conjugated diene hydroperoxide and free fatty acid levels. Storage of brown rice at 3°C resulted in lower levels of free fatty acids and less change in odor and flavor than at the higher temperatures. No advantage was found in placing the sealed polyethylene bag in a metal can or vacuum sealing the metal can compared
to sealing in polyethylene bags. The combination of 3°C storage temperature and a sealed polyethylene bag provided the best shelf life for brown rice.

Airtight storage of brown rice with a low moisture content was tested and evaluated by Genkawa et al., (2007) as an alternative to refrigerated storage. Brown rice samples (500 g each) at 16.2%, 14.4%, 12.8%, and 11.0% moisture contents (m.c.w.b.) were stored in plastic bottles for 6 months at 15 and 25 °C. Germination rate, fat acidity, and microbial growth were measured every month during the storage term to evaluate the effect of decreasing moisture content on storability of rice. The germination rate of brown rice with 16.2% m.c.w.b. at 25 °C declined from 97% to 27%, but for rice with less than 12.8% m.c.w.b. at 25 °C germination was above 90%. In addition, no significant difference was observed in the fat acidity of brown rice with 11.0% and 16.2% m.c.w.b. at 25 and 15 °C, respectively. Moulds were observed on the rice with more than 14.4% m.c.w.b. at 25 °C, but no mould was observed on rice with less than 12.8% m.c.w.b. From these results it is suggested that low-moisture-content storage could be as effective as low-temperature storage.

Deka et al., (2000) studied the effect of storage on fatty acid profiles of basmati rice (Oryza sativa L.) genotypes. Eleven basmati and one non-basmathi rice genotype were evaluated for fatty acid profiles of fresh, 4, 8 and 12 months old rice, at different storage periods. The results indicated that the total saturated fatty acids increased steadily, while the total unsaturated fatty acids showed a reverse trend.

Choi et al., (2008) investigated the changes in the physicochemical and cooking properties of brown rice after milling according to storage temperature and varieties. Brown rice samples were stored at 15°C and 35°C for 10 weeks. They reported milled brown rice stored at 15°C had higher physicochemical and cooking quality, than those at 35°C: increased head rice rates of milled rice and glossy value of cooked milled rice but lower colour b value and hardness of cooked rice.

Shanthi (1998) developed instant idli mix using two types of leavening agents (sodium bicarbonate and yeast) using IR 20 variety parboiled rice. They observed the chemical changes during storage in different types of packaging materials. The initial
values for moisture, pH, acidity, protein, lysine, methionine, thiamine and ash content of the instant idli mixes with sodium bicarbonate and yeast as leavening agent were 12 and 11.90 per cent, 4.81 and 4.84, 0.240 and 0.133 per cent, 11.36 and 13.62 per cent, 340.90 and 363.22 mg per cent, 130.68 and 136.21 mg per cent, 162.2 and 608.1 μg/100g and 3.89 and 3.70 per cent respectively.

**Shanthi et al., (2000)** studied the processing and evaluation of instant idli mixes. Instant idli mixes were prepared with chemical leavening agents (A) and yeast (B). These were packed in-PP and MPP pouches, protected with brown paper bags and stored at room temperature. The chemical composition, microbial load and the organoleptic characteristics of the instant idli mixes stored in different packaging materials were studied during storage at regular intervals upto 180 days. A decreasing trend in moisture, pH and thiamine content of instant idli mixes stored in different packaging materials were noted. The idlis prepared from the instant idli mixes had soft texture with uniform grain distribution and maintained the score values for all the organoleptic attributes throughout the storage period in the order of (A) and (B) mixes.

Different traditional materials were tested by **Avijit et al., (2012)** as for their effect on storability of brown rice. After six months of storage at ambient temperature samples stored with parad tablet and boric acid remained free flowing and maintained a healthy look during the period while others got infested with ants within 45 days. The sample protected with parad tablet had normal appearance and good taste on cooking, bifurcation of cooked grains at both ends and a watery taste were observed in grains protected with boric acid. The amount of free fatty acid (FFA) increased in control samples during storage, whereas the parad tablet protected samples showed little variation. Moreover, storage with parad tablet was also found to be effective in preventing the loss of carbohydrate, protein and lipid. The study found a suitable protectant(s) which is locally available and can extend the shelf life of brown rice which is otherwise nutritionally very rich.

**Songtip et al., (2012)** revealed that the storage duration (2, 4, 6, 8, 10 and 12 months) of paddy rice and pH (3 and 6.8) of steeping water during germination were significantly influenced the physicochemical properties of germinated brown
rice flour (GBRF). GBRF obtained at pH 3 vs. 6.8 provided the highest both reducing sugar content and free gamma-aminobutyric acid (GABA) content (99.8 vs. 54.2 mg per 100 g flour respectively) as the paddy rice was stored for 8 months. The peak viscosity of GBRF obtained at pH 3 and 6.8 exhibited the lower values than that of non-GBRF throughout the storage. From the principal component analysis, reducing sugar had a positive correlation with α-amylase activity whereas a negative correlation was found with peak viscosity. GBRF from paddy rice stored for 8 months and germinated at pH 3 possessed the highest free GABA content, 50 times of the non-GBRF, which can be further utilised in functional and healthy foods.

Pathak and Srivastava (1998) developed dhokla, upma and laddu mixes with foxtail millet in combination with fenugreek seeds and pulses. The products were found to have an excellent storage quality in terms of organoleptic quality when packed in polythene pouches and stored at ambient conditions for one month.

Kalavathi et al., (2000) investigated the effect of storage containers on the storability of Italian millet (S. italica) cv. CO 5. The seeds were precleaned, graded, dried to 8% moisture content. Half of the seeds were subjected to the following treatments: (T1) neem oil (5 ml/kg), (T2) neem cake powder (10 g/kg), (T3) bavistin (2 g/kg), (T4) Albizia amara leaf powder (10 g/kg) and (T5) thiram (2 g/kg), then packed in a 700 gauge polyethylene bag at room temperature. The other half of the seeds were stored in the following containers: (C1) cloth bag, (C2) 300 gauge polyethylene bag, (C3) Gunny bag lined with 300 gauge polyethylene bag, (C4) mud pot and (C5) 700 gauge polyethylene bag. The seed could be stored for more than 15 months in 700 gauge polyethylene bags retaining its seed quality characteristics. Among the treatments, T4 was the best for maintaining viability and vigour potential in storage. Among the chemicals used, thiram was very effective in maintaining seed vigour and viability over a 15-month period.

Foxtail and Little millet based mix suitable for diabetics, did not reveal any apparent effects of storage in sensory quality when stored for six months in two different packaging materials (Itagi, 2003). A significant increase in moisture and peroxide values of the mixes stored in aluminium box were observed than those packed in polythene bags and aluminium pouches.
Ocheme (2007) studied the effect of storage of millet flour on the quality and acceptability of millet flour porridge. Millet flours were produced from untreated millet grains, soaked millet grains, malted millet grains and an equal blend of malted millet grains and soaked millet grains. The flours were packaged in high density polyethylene and stored at ambient temperature and relative humidity (32±2°C and 65-70% RH, respectively) for 3 months. At monthly intervals, the flours were analysed for moisture content, pH and least gelation concentration while porridges made from the flours were subjected to sensory evaluation. Porridges made from the flours were acceptable up to two months and three months of storage for flours from malted millet grains and flours untreated and soaked millet grains, respectively.

Eishazali et al., (2010) examined whole and dehulled flour of millet cultivars Ashana and Dembi was stored for 30 and 60 days before and after refrigeration and/or cooking. The effects of refrigeration and/or cooking on antinutrients, protein digestibility and sensory characteristics of the whole and dehulled flour during storage. Regardless to the storage period, the results showed that tannin and phytate contents of the whole flour of both cultivars were unchanged by refrigeration. However, cooking before and after refrigeration significantly (P ≤ 0.05) decreased tannin and phytate contents. Regardless to the treatments and storage period, dehulling of the seeds significantly (P ≤ 0.05) reduced tannin and phytate contents for both cultivars. Further reduction was observed when the treated and untreated dehulled flour was cooked. The protein digestibility was significantly (P ≤ 0.05) reduced after cooking of the treated and untreated whole and dehulled flour. The sensory quality of the flour and the product reduced with the storage period. However, refrigeration greatly improved the acceptability of the flour before and after cooking. The results obtained demonstrate the benefits of refrigeration on the nutritional as well as sensory quality of millet flour.

Karuppasamy et al., (2011) studied the development and evaluation of millet based convenience mix. The mix prepared in the combination of sorghum and maize were C₁(40:60, sorghum:maize), C₂(50:50), C₃(60:40) was packed in different packaging materials (HDPE&MPP) stored in ambient conditions and analysed for proximate composition of moisture, protein, fat, reducing sugar, total sugar, crude
fiber, ash, calcium, iron and tannin content. The shelf life of cereal flour was found to be good up to 90 days at ambient conditions under packaging.

Millets are milled to remove the inedible husk or outer bran, prior to cooking. The dehulled seeds are either used as such or further milled to grits and flours for specific end uses. Simple milling process might trigger oxidative rancidity and development of off flavor during storage of both grains and flour. An investigation by Chaudhary and Kapoor (1984) revealed that the whole grain and flour of pearl millet (3 varieties) stored in gunny sacks, earthen pots, tin cans and polythene bags turned rancid on 6, 7, 8 and 10 days, respectively. Further, the meal turned inedible on days 11, 12, 13 and 14, respectively on storage. This indicated poor storage quality of whole pearl millet flour. Among the packaging materials, polythene bags were relatively good barriers and gunnysacks were the poor barriers for development of rancidity. The author attributed these differences to higher moisture content and free access to air in the gunnysacks.

Kaced et al., (1984) demonstrated that the ground pearl millet turned rancid due to increased fat acidity and peroxide value. The deterioration was more rapid in ground millet than in whole intact millet. The millet meal stored in polythene bags showed rapid increase in peroxide value and appeared to signal the start of rancidity. However, millet meal stored in cotton bags showed no peroxide accumulation.

Meera et al., (2003) proved that heat processing could arrest development of free fatty acids. Two varieties of pearl millet grains were subjected to heat treatment (98°C) for 5, 15 and 25 mins. The processed grains were either ground as such or decorticated prior to grinding. The results indicated that heat processing for 15 min was effective in arresting the development of free fatty acid content (<10%) up to four months of storage in whole and decorticated flour of both the varieties.