Review of Literature
CHAPTER 2

REVIEW OF LITERATURE

The research works related to the present study on “Development of millet mixes, acceptability of millet mix based recipes, their iron bioavailability and popularisation” by various researchers were reviewed extensively and are given under the following headings.

2.1 Present Indian national food scenario and production of millets in India.

2.2 Types and varieties of millets.

2.3 Millets and their uses.

2.4 Nutritional value of millets and their health benefits.

2.5 Antinutritional factor - Phytate in millets and its effect on nutrients bioavailability.

2.6 Iron Bioavailability – A cause of iron deficiency anemia.

2.1 Present Indian national food scenario and production of millets in India

Major advances have occurred in food production during last four decades, due to large scale of adoption of green revolution technology. Between 1966 and 2000, the population of densely populated low income countries grew by 90 percent, but food production more than doubled. Development of high yielding varieties of rice, wheat and maize led to the dramatic achievements in world food production during the last 35 years. Adoption of green revolution technology was facilitated by

- Development of irrigation facilities.
- Availability of inorganic fertilizers and pesticides.
- Benign government policies.
It many Asian countries, the growth in cereal production have outstripped the rise in population, leading to substantial increases in food grain consumption and per capita energy intake. During 1965-90, the daily energy supply in relation to requirement improved from 89 percent to 94 percent in India (United Nations Development Program, 1994). It is important that agriculture should help developing countries not only to produce enough food for the growing population, but should also lead to the generation of more income and opportunities for skilled employment (Swaminathan, 1999).

Food security implies access by all people at all times to sufficient quantities of food to lead an active and healthy life. The world food summit, used the following definition, in its action plan: “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious foods to meet their dietary needs and food preferences, for an active and healthy life. In the developing world, hunger and poverty are the most terrible problems that remain unsolved despite of multifold increase in the production of food grains, since there is excessive load on traditional agriculture products; there is an urgent need of identifying the alternate food source (Sankhala and Vyas, 2006).

In recent years millets are recognized as important substitute for major meals crops to cope up with worldwide food shortage (Shanmugapriya and Sujatha, 2006). The name “millet” is applied to numerous small seeded grasses which originated in Asia and Africa. Millets are one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes. Millets are small-seeded grasses that are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture. Millets are also unique due to their short growing season. They can develop from planted seeds to mature, ready to harvest plants in as little as 65 days. When properly stored, whole millets will keep for two or more years.
Millets are highly nutritious, non-glutinous and like buckwheat and guinoa, is not an acid forming food, so is soothing and easy to digest. In fact, it is considered to be one of the least allergenic and most digestible grains available and it is warming grain so will help to heat the body in cold or rainy season and climates. Millet Network of India, (MINI, 2009) has urged the central Government to include millets into the National Food Security Act and has requested the centre to put millets into the public distribution system (PDS) in phases so as to create a huge market for millet farmers acting more as an incentive. Millets are of great local value in semiarid areas, poor or rocky soils and in areas of low or inconsistent rainfall, because of its strong and deep rooting system and efficient use of available moisture, some millets can survive in areas with as little as 300 mm or less seasonal rainfall. Mostly the millets are therefore, grown as subsistence crops, although in some countries or areas, the millet is the staple food of the whole population and remains an important cash crop for small farmers (David et al., 2005).

Although millet occupies about five percent of the world’s cereal area, it accounts for only 1.5 percent of the world’s cereal production (FAO, 2002). In most parts of the world, millet is grown as a subsistence crop for local consumption. Millet is also cultivated for grazing, green fodder or silage. Livestock are an important component of most millet production systems, and millet crop residues contribute significantly to fodder supplies. In developing countries, millet cropping systems tend to be extensive with limited application of improved technologies, except in some of the more commercialized farming regions in India. According to DHAN foundation (2012) as on 2008-09 the production of Pearl millet {Tamil Nadu (0.84), India (88.87)} and Finger millet {Tamil Nadu (1.70) India (20.40)} are high but the Barnyard millet {Tamil Nadu (0.03), India (1.65)} production (2001-06) is very low.
The first national comprehensive scheme in India for millets development is the “Initiative for Nutritional Security through Intensive Millets Promotion” (INSIMP), introduced in 2011 under the “National Agriculture Development Programme” (NADP) or “Rashtriya Krishi Vikas Yojana” (RKVY). INSIMP purports to be an integrated scheme by combining different policy components like demonstration, inputs, seed, post-harvest technology, awareness raising, capacity building and research. It extends to all states and union territories and targets all millets (sorghum, pearl millet, finger millet and other five small millets). This programme supports millet cultivation in districts where it is low i.e. (10,000 ha for sorghum and pearl millet, 5,000 ha for finger millet and 2,000 ha for other five small millets). In 2011-12 annual budgets, Rs 300 crore has been allocated for this scheme’s implementation (INSIMP, 2011).

2.2 Types and varieties of millets

There are two kinds of millets;

MAJOR MILLETS

Pearl Millet (Pennisetum glaucum)
Finger Millet (Eleusine Coracana)
Foxtail Millet (Setaria italica)
Proso Millet (Panicum miliaceum)

MINOR MILLETS

Barnyard Millet (Echinochloa spp)
Kodo Millet (Paspalum scrobiculatum)
Little Millet (Panicum miliare)
MAJOR MILLETS

i. **Pearl Millet:** Pearl millet *cambu* is recognized as being the most widely grown of all the millet types. Its origins go back to tropical Africa in prehistoric times, and it was later introduced to India. Because of its high adaptability to any growing conditions, it can be grown in areas where cereal crops such as wheat or maize, simply couldn't survive. Pearl millet is the basic staple food in the poorest countries and used by the poorest people. For human consumption it can be used in a variety of ways including both leavened and unleavened breads, in porridges, and can also be boiled or steamed. It is also used as an ingredient in alcoholic drinks. Apart from grain, its stems are used as building materials and as a fuel.

ii. **Finger Millet:** Finger Millet also called as *ragi* in Tamil, is generally grown in higher rainfall regions. It is high in calcium (more than 0.3%) but is low in protein cereals. Ragi germinates well and is particularly suited to malting. As an adjunct, finger millet malt is used as a sweetener to improve the nutritional density and flavour of weaning porridge. In India, it was used for *chapatti’s* and for a very wide range of snack foods and sweetmeats. It is often mixed at approximately 5% with maize to improve nutritional quality.

iii. **Foxtail Millet:** It is an annual grass and is adapted to temperate regions, although found in the tropics. For a cereal, foxtail millet called “*thinai*” in Tamil is average in protein, fat and mineral content. In Andhra Pradesh, most commonly used as a “rice” (boiled whole). It is also used as stiff porridge (*Saragati*) and also as *chappathi*.

iv. **Proso Millet:** It is an annual grass and is visually very similar to foxtail millet. It is slightly richer in protein and fat than foxtail. Proso millet flour can be used a substitute for rice flour in snack foods.
MINOR MILLETS

i. **Barnyard Millet:** Barnyard or Japanese millet *kuthraivolly* is a domesticated relative of barnyard grass and there exists several varieties. It is the fastest growing of all the millets and produces a crop in six weeks. In Australia, Japan and other Asian countries the crop is grown for grain. In India, Japan and China it is often used as a substitute for rice when the paddy crop fails. In the U.S.A. it is grown primarily for forage, and can produce up to eight harvests a year. It is comparable to proso millet in protein and fat content, but the actual quality of the protein, like that of little millet have the poorest amino acid values of all the millets. It is very high in fibre.

ii. **Little Millet:** There are two races, nana and robusta. The grain is very similar to that of proso millet, but very little has been published in the international literature on composition and uses.

iii. **Kodo Millet:** It is used as a commercial crop, called as *varagu* or kobo and is grown only in India. It is relatively high in fiber and ash (5%).

### 2.3 Millets and their uses

In the backdrop of the unprecedented drought and looming climatic change crisis, millet farming system offer food security apart from fodder, health and nutrition security. Millets are drought resistance crops and can withstand higher heat regimes. Further, they can survive under less rainfall regime than many other crops such as rice or sugar cane. It is learnt that minor millets such as sorghum, pearl millet, finger millet, foxtail millet, etc can grow without irrigation, and are nutritious than rice ([Manay and Shadaksharaswamy, 2007](#)).

Proso-millet based convenience mix for infants and children was developed by **Srivastava et al. (2001)** by malting and popping techniques. The convenience mix (100g) provided 14.32 g protein, 82.48 mg calcium, 4.20 mg iron, 8.84 mg ascorbic acid and 63.90 mg b-carotene per 50 g of the mix. Sweet and salt gruels,
halwa, burfi and biscuits based on the convenience mix were reported to be organoleptically acceptable.

Barnyard and finger millet based khichadi and laddu prepared along with legumes and fenugreek seeds by Arora and Srivastava (2002) were highly acceptable. Carbohydrate content in finger millet based khichadi and laddu provided 56.47 and 81.71 per cent of total energy, whereas the Barnyard millet based khichadi and laddu provided 51.59 and 79.40 per cent of total energy, respectively.

Veena et al. (2004) explored the substitution of Barnyard millet (25 - 100 percent) in five cereal based traditional foods viz., rice, roti, dosa, idli and chakli, that were prepared by different cooking methods like boiling, pan-baking, fermentation, shallow and deep fat frying. It was reported that the substitution improved the nutrients per serving in terms of dietary fibre and minerals but reduced the calorific value. Hence it was suggested that Barnyard millet could be used in most common cereal based traditional foods.

Begum et al. (2003) carried out experiments on nutritional enhancement of common convenience foods such as papads by substituting conventional grains with nutritious millets. Acceptable papads were formulated using Finger millet (60%), sago (20%), black gram (20%) and spices. Calcium content was observed to be exceptionally higher in papads with Finger millet (156 mg/100 g) as compared to traditional papads (82 mg/100 g). According to Premavalli et al. (2003) in ragi based sweetened convenience mixes addition of beaten rice improved the colour but increased the rate of lipid oxidation, while incorporation of coconut powder lowered the lipid oxidation. Sweetened and spiced mixes scored 7.7 and 6 on ten for overall acceptability.

Finger millet based pasta products with good cooking quality, storage stability, acceptability and higher nutritive values developed by Devaraju et al. (2003). Composite finger millet flour (50%), refined wheat flour (40%), defatted soy/whey
protein concentrate (10%), and hot water (75°C) were used for pasta making and it contained 14-18 g, 365-372 k cal, 102-148 mg and 3-5 mg of protein, energy, calcium and iron respectively.

**Shanti et al. (2005)** studied on the effect of incorporation of Finger millet in pasta products. Refined wheat flour, whole wheat flour and soya flour were blended with finger millet in different proportions, with wheat and refined wheat flour as the main ingredient. Sensory evaluation revealed that incorporation of finger millet up to 30 percent and soya flour up to 10 percent was acceptable.

**Hima Bindu and Sumathi (2003)** prepared common Indian traditional products namely muruku, dosa, chapathi, laddu and payasam by incorporating Foxtail millet. All the products were acceptable. Hence they suggested that nutritious Foxtail millet could be exploited for the nutritional benefits and value added nutritive health foods. Barnyard and Kodo millet based chappathi, dosa, noodles and rusk were developed by **Poongodi et al. (2003)**. The acceptable levels of incorporation of millet flour was reported to be 20% for noodles and 30 per cent for rusk, chapathi and dosai.

Thus, the literature reveals that the millets offer wide range of opportunities for utilization in diversified products along with better nutritional qualities.

### 2.4 Nutritional value of millets and their health benefits

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., 2013**). On an average millet contain 10% protein, 25% fat and 73% carbohydrate. Millets are rich in B-Vitamins (especially niacin and B₆), calcium, iron, potassium, magnesium and zinc. They are generally low in lysine (amino acid) and must be used along with foods that are rich in lysine to balance the protein diet (**D’ Souza et al., 1987, Lonnerdal 2000**).
Millets in general contain 4.5 to 6.3 per cent of crude fibre (Gopalan et al., 2013). Barnyard millet was reported to contain crude fibre in the range of 5.35 to 7.90 per cent in nine different varieties (Veena et al., 2005). The crude fibre content reported in Kodo millet was 6.3 per cent followed by Little (5.73%) and Proso millet with 5.51 per cent (Malleshi and Desikachar, 1985 and Kulkarni et al., 1992). Thus, minor millets are good store houses of nutrients with varietal differences evident within the species.

The potential health benefits of dietary fibre have been demonstrated almost four decades ago by Burkitt et al. (1972). It was reported that dietary fibre reduces intestinal transit time, provides fecal bulk and in turn prevents constipation. Thus, it helps in providing protection against duodenal ulcers and colorectal cancers (Nyman and Asp, 1982). Millets have been reported to be the rich sources of dietary fibre (Wisker et al., 1985).

A study done by Pawar and Pawan (1997), on the malting characteristics and biochemical changes of millets; showed that the steeping of grains in water for 8 to 16 h and germination at 30º C upto 72h significantly decreased the dry matter, starch, protein, crude fibre while the soluble protein, free amino acid, reducing sugars, invitro protein digestibility and invitro availability of iron significantly increased.

Processing treatments namely grinding, soaking, debranning, dry heat treatment and germination altered the nutritional quality of pearl millets. Debranning and soaking reduced the crude protein, true protein and non-protein nitrogen. Autoclaving increased the non protein content, thus reducing the true protein and fat content was reduced on debranning and starch was reduced on giving various treatments. Total soluble sugars and reducing sugars increased on germination and autoclaving. Whereas non reducing sugars decreased after processing (Sharma and Kapoor, 1997). A study done by Kumar, Chauhan and
Nutritionally pearl millet is regarded as a good feed grain. In different pearl millet genotypes the starch content of the grain varied from 62.8 to 70.5 percent, soluble sugar from 1.2 to 2.6 percent and amylose from 21.9 to 28.8 percent. When compared to maize by weight however, pearl millet can be 8%-60% higher in crude protein, 40% richer in the amino acids Lysine and methionine, has good levels of Cystine, and is 30% richer in threonine. It is regarded as having the highest scores of all the millets when comparing essential amino acids. The essential amino acid profile shows more lysine, threonine, methionine and cystine in pearl millet protein than in proteins of sorghum and other millets. Its tryptophan content is also higher. The grain is also gluten-free. The total fat content of pearl millet is higher than all of the other millets. It is quite high in polyunsaturated fats, and linolenic acid comprises approx 4% of the fatty acids present (FAO, 1995).

Finger millet is lower in protein than other millets and poor when compared to other cereals. Tannin content of many varieties is also high which affects the absorption of the available protein. It has an extremely high calcium and manganese content, but other minerals and trace elements are comparable to that of sorghum. The availability of iron in the seed is drastically lowered by its high tannin content. Fibre content is high. Finger millet, like foxtail and Kodo millet, contain less fat in the kernel than other millets (FAO, 1995). Malted finger millet flour thus extensively used for the preparation of baby foods. Low cost nutritious sweets prepared from finger millet malt are suitable not only for weaning children, but also for all the age groups in the entire family (Kumari and Srivastava, 2000).

Studies on several varieties of Barnyard millet revealed the total mineral content ranging between 1.5 to 4.0 per cent (Veena et al., 2005). Among the
different millets, Kodo millet had the highest proportion of total minerals (4.9%) and lowest was recorded in Foxtail millet (1.4%). The other millets viz., Proso and Little millet were reported to contain fat of about 3.5 and 4.1 per cent respectively with varietal differences (Malleshi and Desikachar, 1985; Sahu, 1987; Monteiro et al., 1988; Kulkarni et al., 1992; Hadimani and Malleshi, 1993 and Veena et al., 2005).

Resistant starch (defined as any starch that escapes digestion in small intestine) was also reported to exhibit a wide range of health benefits such as lowering caloric density and low glycemic response (Jenkins et al., 1982 and Ring et al., 1988). It was also reported to lower digestibility and act as a fecal bulking agent (Ranhotra et al., 1991). Minor millets, with their low carbohydrate content, low digestibility and water soluble gum content (β-glucan) have been attributed to improve glucose metabolism. These grains release sugar slowly in the blood and also diminish the glucose absorption (Chen et al., 1984 and Anderson et al., 1991). The dietary fibre and resistant starch of minor millets have been attributed to exhibit hypoglycemic and hypolipidemic effects (Mani et al., 1993, Slavin and Dwyer, 1994, Krishna Kumari and Thayumanavan, 1997 and Pathak and Srivastava, 1998).

Further the antioxidative properties of minor millets against hyperglycemia and oxidative stress have also been studied, which is mainly determined by their higher reserves of phytochemicals like phenolics, tannins, phytates, micro minerals etc. (Hegde et al., 2004). In addition, these grains have been demonstrated to exhibit beneficial effects on cholesterol levels, which is again attributed to their high dietary fibre and phytochemical content. It is reported that cardiovascular diseases, duodenal ulcers and hyperglycemia occur rarely in regular millet eaters (Menon, 2004). For all these superior properties of minor millets, they can be designated as “nutritious millets”. 

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2.5 Antinutritional factor - Phytate in millets and its effect on nutrients bioavailability

Phytic acid (also known as Inositol hexakisphosphate) and phytate are widespread in plant seed grains (also including cereals), roots and tubers (Lasztity and Lasztity, 1990 and Graf, 1986). Phytic acid is generally regarded as the primary storage form both phosphate and inositol in seeds. Literature suggests that phytic acid occurs primarily as potassium, magnesium and calcium salts (Cheryan et al., 1980). In this anionic form, phytate can form complexes with proteins and minerals leading to decreased availability of these nutrients in the digestive tract (Cheryan et al., 1980). Thus phytate is regarded as an antinutrient.

Although millets are rich in nutrients, they are also rich in phytic acid. Phytic acid has been implicated in binding certain minerals particularly divalent irons, thus making these non absorbable. (D’souza et al., 1987 and Nadeem et al., 2010), Ravindran and co workers (1994) had found that phytic acid has a strong binding capacity, hence readily forms complexes with multivalent cations and proteins. These phytate – mineral complexes are generally insoluble at physiological pH and hence render the mineral biologically unavailable to monogastrics. Phytates bind Zinc, iron, calcium and Magnesium. It forms insoluble complexes with iron and thus makes iron unavailable phytates present in cereals contribute significantly to poor absorption of iron from cereal based diets (Gopalan et al., 2013). Phytate reduces the bio availability of minerals and cause growth inhibition. Zinc and iron deficiencies were reported as a consequence of high phytate intake (Lonnerdal, 2000).

Independent studies done by Erdman (1979), Maga (1982), Reddy et al. (1982), established that antinutrients present generally reduce the bioavailability of minerals. In ragi, phytic acid, tannin and trypsin inhibitors are the main antinutritional factors normally present. Several reviews have been published stating the presence of anti-nutritional compounds like phytic acid
which reduce bio-availability of minerals, thereby reducing the nutrition quality. Ravindran (1991) had identified that foxtail millet has a higher phytate than finger millet.

Archana et al. (1998) reported that blanching of pearl millet resulted in significant reduction in polyphenol (28%) and phytic acid (38%). Destruction of polyphenols (38 to 48%) and phytic acid (46 to 50%) was significantly higher in grains subjected to malting than blanching. The overall results suggested that malting with 72 h of germination was most effective in reducing the antinutrient level of pearl millet grains.

Lestienee et al. 2005, proved that when using millet grains, dehulling and milling before soaking facilitated the reduction of phytates and phytases in the aqueous medium and hence phytate degradation. The highest decreases for millet were obtained after soaking of flour for 8 h (Phy / Fe: 0.1- 7.7 and Phy / Zn: 20.3 – 15.1). The steeping of grains in water for 8 to 16 h and germination at 30º C upto 72 h significantly decreased phytate and polyphenols (Pawar and Pawan, 1997). Increased protein digestibility on soaking may be due to leaching of phytic acid and polyphenols in water (Sharma and Kapoor, 1997). Improved iron availability in germinated grains can be partly attributed to a reduction in phytate content due to enzymatic breakdown of phytate (Gopalan et al., 2013).

Recent studies on single foods have shown that milling of cereals greatly affects their iron bioavailability. Iron in milled polished rice, for instance, is about four times better absorbed than is iron in unmilled rice (Rasmussen, Hallberg, Walker, 1973). Similarly, the bioavailability of wheat iron in bread baked with flour of different extraction varies in proportion to the bran content (Rasmussen, 1974). The bread making process with yeast fermentation is beneficial for reducing the levels of phytate content with the subsequent increase in magnesium and phosphorus bioavailability (Haros et al., 2001). Cereal processing takes two basic forms, mechanical (e.g., milling) and thermal (e.g., baking), which increase the
bioavailability of the nutrients in the grain and customer satisfaction (Eastman et al., 2001). The above studies indicate that unrefined cereals contain more phytate than refined ones.

2.6 Iron Bioavailability – A cause of iron deficiency anemia

Low bioavailability of iron is one of the factors that limits dietary adequacy. (Tait et al., 2005) Iron and phytate content and density were negatively correlated to iron availability. In vitro solubility of iron from these meals decreased from 7.9 to 1.52 percent as phytate content increased from 0.3/1.3g/d. Further, diets with rice (low in iron and phytate) as staple had better availability compared to diets with Bajra (high in iron, phytate) as staple. (NIN, ICMR 2005-06). Thus adequate iron availability can be achieved principally by minimizing the inhibitors (phytates, tannins) and enhancing the promoters (ascorbic acid / meat / fish).

Poor bioavailability of consumed iron in relation to the need (Gillespie, 1998) has been reported as the major cause of iron deficiency in a population whose diet is predominantly cereal-based and of poor quality (Rao, Vijaysarathy and Prabhavathi 1983 and Taylor et al., 1995).

Diets consumed in many developing countries are cereal-based and thus high in phytic acid, a potent inhibitor of iron absorption (Hallberg et al., 1987, Hurell et al., 1992 and Davidsson et al., 1994) and low in major promoters of iron absorption such as ascorbic acid and animal tissue (Layrisse et al., 1984, Hallberg et al., 1989 and Taylor et al., 1986). One can increase absorption of iron by adding vitamin-C containing food and by avoiding inhibitors like phytates and tannin (present in tea) (De Maeyer et al., 1989 and Kapil, Atlee and Gupte, 1998).

Iron deficiency is the most common and widespread nutritional disorder in the world, and is a public health problem. Iron deficiency anemia results in 25 million DALYS (Disability Adjusted Life Years) lost. Anemia is defined as a low blood hemoglobin concentration. It is estimated that over two billion people
are anemic, around 0.8 million deaths (1.5 percent of the total) can be attributed to iron deficiency each year (WHO 1996 and 2001).

More than half the pregnant women and young children are anemic in Southeast Asia, West pacific and Africa (WHO, 1998). However in 2003, Florentino stated that in India, anemia affects an estimated 50 percent of the population. In women anemia may become the underlying cause of maternal mortality and perinatal mortality. India contributes to about 80 percent of the maternal deaths due to anemia in South Asia.

The Indian Council of Medical Research estimated the prevalence of anemia among pregnant women to be 88 percent (Koen et al., 1992). The Indian subcontinent alone contains nearly half the world’s anemic women (Gillespie, 1998). A national family health survey in India (1998-1999) reported a high prevalence of anemia (72 percent) in children aged 6—35 months (NFHS – 2, 2000). Although the prevalence of anemia is slightly lower among school-age children and non pregnant women, it is still high enough to deserve intervention strategies.

National Family Health Survey done in 2002 reported that a total of 84 percent pregnant and 92.2 percent lactating women were anemic with severe anemia in 9.2 and 7.3 percent respectively; while the prevalence of severe anemia in pregnant and lactating was 39.2 and 27.3 percent in Madhya Pradesh, it was 14.4 and 8.6 percent in Assam, 8.5 percent and 13.4 percent in Haryana respectively, but in Himachal Pradesh severe anemia was not observed in both pregnant (0.7 percent) and lactating women (1.0 percent). Anemia in children is still a substantial problem in India (Bentley and Griffiths, 2003) Kapur, Agarwal and Agarwal 2002) and leads to increased morbidity and mortality (Barbin, Premji and Verhoeff; 2001).

In Tamil Nadu, 97 percent of adolescent girls have any anemia. Twenty nine percent of them are mildly anemic, 50 percent are moderately anemic and 18 percent are having severe anemia. It has been found that from the survey results
that except severe anemia the percentage of girls in all other categories of anemia diminishes marginally with the increase in age from 10-14 to 15-19 years. The incidence of any anemia is higher (97 percent) among adolescent girls who are currently unmarried compared to that to their married counterparts (95 percent). In the rural areas of Coimbatore, Tamil Nadu the anemia was predominant in 293 preadolescent girls of corporation schools while 294 adolescent girls from matriculation and 292 adolescent girls from corporation schools had anemia (Rema and Vasanthamani, 2011). In the rural areas of Tamil Nadu the prevalence of anemia among the adolescent girls was 44.8 percent. While, the prevalence of severe anemia was found to be two percent; that of moderate anemia was above six percent and that of mild anemia was 36.5 percent. Mean Hb decreased as the age increased (Rajaratnam, Abel, Asokan and Jonathan, 2000).

When (iron deficiency) is sufficiently severe, the haemoglobin (Hb) concentration in the blood decreases, leading to iron deficiency anemia (IDA), which has negative health consequences, especially in children (Lozoff et al., 1991) and adolescents (Scholl et al., 1992, Allen, 2000 and Hinton et al., 2000). Adverse health effects of anemia in children include impaired psychomotor development and renal tubular function, poor cognitive performance and mental retardation (Palti et al., 1983, Lozoff et al., 1987, Walter et al., 1989, Hurtado et al., 1999 and Ozcay et al., 2003). Anemia adversely affects the cognitive performance, behaviour and growth of infants, preschool and school aged children (Binkin, Yip, 1997).

Children with iron deficiency anemia perform less well on psychomotor tests than nonanemic counterparts (Pollitt and Metallinos-Katsaras, 1990). Infants and children who become anemic through iron deficiency is at high risk of long-term, even permanent, impairment in mental & motor development and co-ordination, impaired language development, scholastic achievement, psychological and behavioural effects and decreased physical activity (Agarwal, Upadyay and
Tripathi, 1987, Lozoff, 1990, Lozoff et al., 1991, Yip, 1994 and Dubey, Sachdev and Choudhary 1994). There are studies to suggest that children with anemia or even mild iron deficiency show poor attentiveness, memory and academic performance in the areas of vocabulary, reading and knowledge. Children with iron deficiency perform less well on standardised scholastic tests and have impaired motor development. Aerobic capacity in anemic children is reduced and anaerobic metabolism makes a greater contribution to the stress of exercise, resulting in early fatigue. Work capacity, work output and endurance are impaired in iron deficiency.

A varied array of intervention such as oral iron therapy, parental Iron therapy, dietary improvement, food fortification, chemical fortification, mass fortification, targeted fortification, market-driven fortification, household and community fortification, bio-fortification of staple foods exists that are designed to prevent and correct iron deficiency anemia.

Of the different interventions listed above, dietary diversification is an easily adoptable method to meet the needs of an individual. The International Conference on Nutrition (ICN), which was organised by FAO and WHO in Rome in December 1992, laid out the measures to prevent and control iron deficiency as a part of an overall frame work to improve nutritional wellbeing. Increasing dietary diversification is the most important factor in providing a wide range of micronutrients and to achieve this in a development context requires an adequate supply access and consumption of a variety of foods (Bothwell et al., 1989) including millets.