# 2.0 Review of literature

In India, out of the total population, 8% accounting nearly 168 million people are tribal farmers. Out of these, a reasonable population lives in the hilly areas of north-western regions of Tamil Nadu (Anonymous, 2002). The tribal farmers in those areas practice traditional crop cultivation methods and realize very little output. Hence, the life style of those farmers contributed by their crop components in their farming and per capita income has not met with any improvement over the past several decades. Although several agro techniques possibly capable of improving their net income as well as their standard of living are available, the ignorance of the farmers due to their remoteness has been a major negative factor(Geetha and Bhaskaran, 2013).

Over three billion people are currently malnourished globally, due to inconsistent supply of foods with essential nutrients to meet daily needs (Welch, 2005). The potential benefits of cereals as nutritionally- balanced diet, help in eliminating deficiency disorders (Zuzana *et al.,* 2009). Cereals play an important role in composite food preparation due to their cheapest sources of food energy contributing a high percentage of calories (>56%) and proteins (50%) in Indian diets (Mahajan and Chattopadhyay, 2000). All current dietary guidelines have cereal foods as largest component of recommended daily intake (NHMRC, 2003), as they are good source of vitamins and a number of minerals, notably iron, zinc, magnesium and potassium. Earlier reviewers also report that consumption of grains exerts cardioprotective influence (Kushi *et al.,* 1999).

Beside this, these crops also contain biologically active compounds including Tannins, Phenols, Anthocyanins and Flavonoids which has been linked with potential antioxidant activities. The literature relevant to the present study entitled **"A Comprehensive Study on Changes in the Selected Biochemical Composition and Antioxidant Levels of Five Millets on Soaking and Germination"** is reviewed in this chapter under the following headings:

**2.1. Millets**

**2.1.1. Pearl millet**

**2.1.2. Finger millet**

**2.1.3. Little millet**

2.1.4. Foxtail millet

2.1.5. Kodo millet

2.2 Pharmaceutical Properties of millets

2.3. Millet based Products

## 2.1. Millets

In modern lifestyle, consumption of rapidly processed fast food leads to various diseases (Kearney, 2010). Human epidemiological studies brought out that almost 90 % of diseases occur due to intake of food with high calorific value. Earlier studies showed that intake of fatty food leads to chronic metabolic diseases like diabetes, cardiovascular diseases and ageing (Everitt *et al.,* 2006). Hence, disease prevention through dietary modulation plays a vital role in the present world of fast food. In this scenario, cereals are preferred as foremost choice for low calorie diet. Recently, preparations of low calorie food from cereals have become the major focus of health Care industries in which either traditionally processed (germinated & fermented) or non processed (non-germinated and non-fermented) cereals are used.

**Plate 2.1. Different types of Millets**


**A.** Little millet; **B.** Kodo millet ; **C.** Foxtail millet; **D.** Finger millet; **E.** Pearl millet

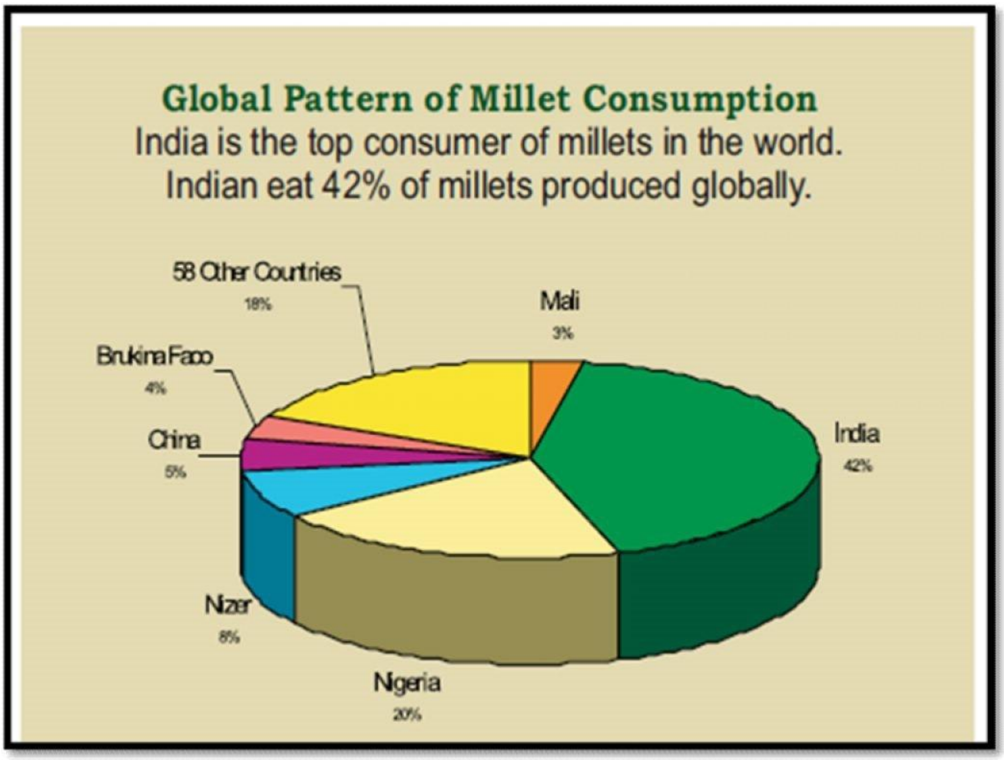
**Table 2.1. GLOSSARY- NAMES OF MILLETS IN DIFFERENT LANGUAGES**

| ENGLIH | HINDI | TAMIL | KANNADA | TELUGU | MALAYALAM |
|---|---|---|---|---|---|
| Finger millet | Nachani /mundua | Kezhvaragu | Ragi | Ragula | Panji pullu |
| Kodo millet | Koden/ Kodra | Varagu | Harka | Arikelu | Koovaragu |
| Foxtail millet | Kangni/ Rala | Thinai | Navane | Korra | Thina |
| Little millet | Kutki | Saamai | Saame | Sama | Chama |
| Pearl millet | Bajra | Kambu | Sajje | Sajjalu | Kambam |

The millets include five genera of the *Panaceae* family (*Panicum, Setaria, Echinochloa, Pennesetum and Eleusine*). The most important cultivated species are: Proso millet *(Panicum miliaceum)*, Foxtail millet *(Setaria italica)*, Japanese barnyard millet *(Echinochloa frumentacea)*, Finger millet *(Eleusine coracana)* and Koda millet *(Paspalum scrobiculatum)* are the important millets cultivated largely in the Asian and African countries. Fonio (*Digitaria exilis*) and Tef (*Eragrostic tef*) are specific to Nigeria and Ethiopia respectively. Most of the millets are grown in different regions of the world from east to west (FAO, 2012).

Millets play very specific role in human nutrition because of their multiple qualities. They have high content of calcium and are suitable for diabetic patients due to low glycemic index. Millet is gluten-free and safe to eat for those who suffer from Celiac disease or for those who experience gluten sensitivity. It is a healthy alternative to gluten containing grains such as wheat. Millet is most recognized nutritionally for being a good source of the minerals namely, magnesium, manganese and phosphorus. In addition to their nutritive value, several potential health benefits such as preventing cancer and cardiovascular diseases, reducing tumor incidence, lowering blood pressure, risk of heart disease, cholesterol and rate of fat absorption, delaying gastric emptying, and supplying gastrointestinal bulk have been reported for millet (Truswell, 2002; Gupta and others, 2012). Hence, present study was undertaken to evaluate the biochemical parameters like protein, carbohydrates, free sugars and antioxidant activity from Dry, Soaked and Germinated seeds of selected five minor millets

**Fig. 2.1. Millet production rate of the world**




(Truswell, 2002; Gupta and others, 2012)

**2.1.1. Pearl millet** (*Pennisetum glaucum*)

Pearl Millet (*Pennisetum glaucum*), also known as Bajra, is a cereal crop grown in tropical semi-arid regions of the world primarily in Africa and Asia (Vanisha *et al.,* 2011). Pearl millet is a nutritious cereal grown on about 10 million hectares in India, is one of the largest producers of this crop in the world. It ranks third after wheat (*Triticum aestivum*) and rice (*Oryza sativa*) in its production (GOI, 2008). Pearl millet (*Pennisetum typhoideum*), also classified as *P. glaucum, P. americanum, or P. spicatum*, and is locally known as bajra in India (Taylor, 2004). Its advantage over other cereals is that it can be grown in marginal agricultural areas where annual rainfall is variable, unpredictable and very low (200–500 mm) and where daily temperature reaches 30°C. In its traditional growing areas, pearl millet is the basic staple for households in the poorest countries and among the poorest people. It is also one of the most drought resistant crops among cereals and millet. And it has been recommended for several therapeutic purposes, as it has been found to inhibit tumor development, control blood pressure and plasma low density lipoprotein cholesterol levels and possesses anti-allergenic characteristics. Due to its high fiber content pearl millet is also recommended for the treatment of severe constipation, stomach ulcers, and weight loss (ICRISAT and FAO 1996).

**Fig. 2.2.** ***Pennisetum glaucum***

**Table 2.2. Nutrition Aspects of Pearl millet**

| Serving Size | The serving size, in terms of the number of volume or mass/ 100g |
|---|---|
| Calories | 328kcal |
| Iron (grams) | 2.8 |
| Mineral (grams) | 2.3 |
| Iron(grams) | 16.9 |
| Calcium (grams) | 38 |
| Protein (grams) | 10.6 |
| Fiber (grams) | 1.3 |

**BOTANICAL CLASSIFICATION (Hulsi *et al.*, 1980)**

**Vernacular Name:**

| | | |
|---|---|---|
| **English** | **:** | **Spiked Millet/Pearl Millet** |
| Bengali | : | Bajra |
| Gujarati | : | Bajri |
| Hindi | : | Bajra |
| Kannada | : | Sajje |
| Marathi | : | Bajri |
| Oriya | : | Bajra |
| Punjabi | : | Bajra |
| Tamil | : | Cumbu |
| Telugu | : | Sajja |

**Scientific Name:**

| | | |
|---|---|---|
| Kingdom | : | Plantae |
| Order | : | Poales |
| Family | : | Poaceae |
| Sub family | : | Panicoideae |
| Genus | : | Pennisetum |
| Species | : | *P.glaucum* |

**Table 2.3. Possible health benefits of pearl millet on various diet related diseases/disorders and deficiency**

| DISEASE/PROBLEMS | POSSIBLE BENEFITS | POSITIVE FACTOR IN PEARL MILLET |
|---|---|---|
| **Anemia** | May Help in increasing the Hb | High iron content (8mg/100g)<br>High Zinc content (3.1mg/100g) |
| **Constipation** | May help in dealing with constipation | Highfiber (1.2g/100g) |
| **Cancer** | Anti-cancer property | Inhibit tumor development Antioxidant property, high flavonoids |
| **Diabetes** | Help in dealing with diabetes | Has Low glycemic index |
| **Celiac** | | Gluten free |
| **Diarrhea** | Anti – allergic<br>Probiotic treatment | Lactic acid bacteria |
| **NCDs** | Inhibits DNA scission, LDL cholesterol, liposome oxidation and proliferation of HT-29 adenocarcinoma cells. | Flavonoids, phenolic, Omega 3 fatty acids |

(Nambiar *et al.*, 2011)

Nutritionally pearl millet is comparable and even superior to major cereals with respect of energy value, proteins, fat and minerals (Jain *et al.,* 1997). It makes an important contribution to human diet due to high levels of calcium, iron, zinc, lipids and high quality proteins. Besides, it is also a rich source of dietary fiber and micro nutrients. The **Table 2.3,** are represents the health benefits of pearl millet (Malik *et al.,* 2002).

Germination or malting of cereal grains may result in some biochemical modifications and improved nutritional quality that can be used in various traditional recipes. Germination also appreciably improved the *in vitro* protein (14% to 26%) and starch (86% to 112%) digestibility in pearl millet (Archana and Kawatra, 2001). The improvement in protein digestibility after germination, soaking, debranning, and dry heating can be attributed to the reduction of antinutrients such as phytic acid, tannins, and polyphenols, which are known to interact with proteins to form complexes (Hassan and others 2006). Effect of germination and fermentation of pearl millet on proximate, chemical, and sensory properties of instant *fura* (a Nigerian cereal food) was examined. It was found that germination appeared to be a promising food processing method for improving the nutrient and energy densities of *fura* and, when combined with fermentation, reduced phytic acid significantly ($P < 0.05$) (Inyang and Zakari, 2008). It has also been indicated that a pearl millet-based, germinated, autoclaved, and fermented food blend maintained adequate cell viability as compared to a nongerminated food blend. Germination and probiotic fermentation caused significant improvement in the contents of thiamine, niacin, total lysine, protein fractions, sugars, soluble dietary fiber, and *in vitro* availability of Ca, Fe, and Zn of food blends (Arora *et al.,* 2011). Increased mineral availability during germination may be due to increased phytase activity, which resulted in decreased content of phytate in sprouts. Antinutrients like polyphenols and saponins are also known to hinder the availability of minerals, which are catabolized during germination leading to improvement in mineral availability (Grewal and Jood, 2006).

Hulse *et al*. (1980) reported that Pearl millet grain contains 11.8% protein, 2.3% crude fibre, 67% carbohydrates, 2.2% ash, 42 mg of calcium, 11 mg of iron, 0.38 mg of thiamin, 0.21 mg of riboflavin and 2.8 mg of niacin. Hence, it has greater oil content (4 – 9%) than all other cereal crops (Desikachar, 1975). Though the nutritive value is huge it has long been considered to be a crop of secondary importance due to lack of technical knowledge of processing methods, lack of awareness among people about nutritive value and is coined as poor men crop, the non-availability of processed products similar to rice or wheat are the main reasons for less popularity of pearl millet among rice and wheat eaters. Phytic acid content in pearl millet represents more than 70% of the total phosphorus of the grain (Abdel Rahaman *et al*., 2007). A value of 990 mg/100 g phytic acid was reported by Khetarpaul and Chauhan (1991), while Kumar and Chauhan, (2006) gave a value of 825.7 mg/100 g. Abdel Rahaman *et al*. (2007) reported that millet contains some antinutrients (phytate and polyphenols) that affect nutrient absorption by the human body. The food industry has become increasingly interested in novel food processing technologies which promise to preserve and improve the quality of food without the use of heat or chemical additives while still retaining the food quality such as refrigeration and irradiation (Mohamed *et al.*, 2010).

Taylor *et al.* (2010) reported that protein, ash, total carbohydrate and crude fiber contents of pearl Millets ranges of (14.8%), (1.64%), (4.86%), (59.8%) and 12.19%) respectively. However, phytic acid content of unmalted pearl millet grain ranged from 2.91% to 3.30% (Badau *et al.,* 2005).

### 2.1.2. Finger millet (*Eleusine coracana*)

Finger-millet, *Eleusine coracana* (Linn.) is also known as Ragi and is cultivated throughout Eastern and Southern Africa, and in parts of Central Africa, as far west as Nigeria. In Asia, it is widespread in India, Nepal and the Himalayan region, across parts of China and into Taiwan. The plant is an annual growing, with the length of 45-125 cm. For complete maturation it takes about 2.5 to 6 months. It represents a staple food for a large segment of the population and also serves as a good source of carbohydrate, protein, dietary fiber, amino acids and phytochemicals. It is nutritionally rich in minerals such as calcium, magnesium, phosphorous and manganese which are essential for the normal growth of body tissue and energy metabolism (Kang *et al.*, 2008). Its phytochemicals play a vital role as hypoglycemic agent to control blood glucose level in diabetic patients and to reduce the cancer risk further, finger millet koozh serves as an ideal low calorie diet for all age groups especially growing infants and pregnant women. Finger millet koozh is one of the popular traditional foods made in South India. It is an excellent hydrating drink and is favorable for easy digestion and health maintenance. It is commonly consumed by rural population for breakfast and lunch. But, the detailed information on the effect of different processing methods on the nutritional value of finger millet based food is scarce. Due to its significant nutritive value, processed finger millet-based food preparations should be analyzed for their microbiological, enzymological and biochemical properties for their certification as quality food for consumers (Suhasini *et al.,* 1994).

Amylases are of great significance especially in the food, brewing and detergent industry. An attempt has been made to study the characteristics of amylases produced during germination of finger millet (*Eleusine coracana Gaertn. L.*). Amylase is an enzyme which breaks down starch (the reserve carbohydrate in plants) and glycogen (the reserve carbohydrate in animals) into reducing fermentable sugars, mainly maltose, and reducing non fermentable or slowly fermentable dextrins. Amylases are produced by a variety of living organisms, ranging from microbes to plants and humans. In plants, amylases are synthesized during the germination of seeds rich in starch and convert insoluble starch to soluble sugars (Pande *et al.,* 2015).

**Table: 2.4. Properties of finger millets** (Maqsood *et al.,* 2007)

| Property | Reference |
|---|---|
| Cholesterol lowering | Hegde *et al.*, (2005). |
| Anti-ulcerative | Tovey (1994) |
| Free radical scavenging | Varsha *et al.*, (2009). |
| Anti-cataractogenesis | Chethan *et al.*, 2008b |
| Blood glucose lowering property | Hegde *et al.*, 2005 |
| Wound healing property | Rajasekaran *et al.*, 2004; |
| Lower glycemic index values for millet diets | Kumar and Chauhan, 2006 |

**Fig.2.3.** ***Eleusine coracana***

**Table 2.5. Nutrition Aspects of finger millet**

| Serving Size | The serving size, in terms of the number of volume or mass/100g |
|---|---|
| Calories | 336kcal |
| Iron (grams) | 3.9 |
| Calcium(mg) | 344mg |
| Fat (grams) | 1.3 |
| Carbohydrate (grams) | 72 |
| Protein (grams) | 7.3 |
| Fiber (grams) | 1.3 |

**BOTANICAL CLASSIFICATION (Hulsi *et al.*, 1980)**

| **Vernacular Name:** | | | **Scientific Name:** | |
|---|---|---|---|---|
| **English** | **:** | **Finger Millet** | Kingdom | : Plantae |
| Bengali | : | Marwa | Order | : Poales |
| Gujarati | : | Nagli, Bavto | Family | : Poaceae |
| Hindi | : | Ragi, Mandika,Marwah | Sub family | : Panicoideae |
| Kannada | : | Ragi | Genus | : Eleusine |
| Marathi | : | Nagli, Nachni | Species | : *E.coracona* |
| Oriya | : | Mandia | | |
| Punjabi | : | Mandhuka, Mandhal | | |
| Tamil | : | Keppai, Ragi, Kelvaragu | | |
| Telugu | : | Ragichodi | | |

Purification and properties of a carboxyl esterase from germinated finger millet (*Eleusine coracana* Gaertn). Carboxylic esterase is a group of enzymes which catalyze the hydrolysis of various types of carboxylic esters. They are a class of enzymes with wide substrate specificity, usually for a short chain acid and an alcohol with only one hydroxyl group. They are widespread in nature and are present in animals, plants and microorganisms. The widespread occurrence of these enzymes has prompted many biochemists to purify and study (Inyang and Zakari, 2008). Evaluation of antimicrobial and anticancer properties of finger millet (*Eleusine coracana*) and pearl millet (*Pennisetum glaucum*) extracts. Antimicrobial properties were studied using Kirby Bauer well diffusion technique and the polyphenols of millet showed antimicrobial activity on *Escherichia coli, Staphylococcus aureus, Proteus mirabilis, Pseudomonas aeruginosa, Serratia marcescens, Klebsiella pneumoniae, Shigella dysenteriae, Enterococcus* sp. and *Salmonella sp.* Millets could be used as a natural source of antimicrobials and antioxidants, especially for minimizing the risk of diseases arising from oxidative deterioration and also cytotoxic effects (Singh *et al*., 2015).

Functional and Phytochemical properties of Finger millet (*Eleusine coracana* L.) for health. Finger millet (*Eleusine coracana*), one of the minor cereals, is known for several health benefits and some of the health benefits are attributed to its polyphenol and dietary fiber contents. It is an important staple food in India for people of low income groups. Nutritionally, its importance is well recognized because of its high content of calcium (0.38%), dietary fiber (18%) and phenolic compounds (0.3–3%).They are also recognized for their health beneficial effects, such as anti-diabetic, antitumerogenic, atherosclerogenic effects, and antioxidant and antimicrobial properties (Mathanghi and Sudha, 2012).

### 2.1.3. Little millet (*Panicum sumatrense*)

Little millet (*Panicum sumatrense*), also known as small millet, is grown widely in India, Pakistan, Sri Lanka and Western Myanmar. The plant grows to a height of 30-90 cm and has oblong panicle that is almost 14-40 cm in length. Little millets are rich in B-vitamins and have high nutritional value especially the presence of phosphorus and. As little millets contain no gluten, they are appropriate food for those with celiac disease or other forms of allergies/intolerance of wheat. Small millets are nutrient-rich food sources traditionally grown and consumed by subsistence farmers in Asia and Africa (Adewale *et al.*, 2006). Nutrient enrichment of little millet (*Panicummiliare*) flakes with garden cress seeds. Little millet (*Panicummiliare*) is one of the nutritious minor millet. The nutrient composition was analysed by total carbohydrates, total dietary fiber, protein, moisture, total minerals and fat content (Kotagi *et al.*, 2013).

**Fig. 2.4.** ***Panicum sumatrense***

**Table 2.6. Nutrition Aspects of Little Millet**

| Serving Size | The serving size, in terms of the number of volume or mass/100g |
|---|---|
| Calories | 207 |
| Minerals(grams) | 1.5 |
| Carbohydrate (grams) | 169 |
| Protein (grams) | 7.7 |
| Fiber (grams) | 7.6 |
| Iron(grams) | 9.3 |

**BOTANICAL CLASSIFICATION (Hulsi *et al.*, 1980)**

| **Vernacular Name:** | | | **Scientific Name:** | | |
|---|---|---|---|---|---|
| **English** | **:** | **Little Millet** | Kingdom | : | Plantae |
| Bengali | : | Sama | Order | : | Poales |
| Gujarati | : | Gajro; Kuri | Family | : | Poaceae |
| Hindi | : | Kutki, Shavan | Sub family | : | Panicoideae |
| Kannada | : | Same, Save | Genus | : | Panicum |
| Marathi | : | Sava, Halvi, vari | Species | : | *P.sumatrense* |
| Oriya | : | Suan | | | |
| Punjabi | : | Swank | | | |
| Tamil | : | Samai | | | |
| Telugu | : | Samalu | | | |

Evaluation of Little Millet (*Panicum sumatrense)* Land Races for Cooking and Nutritional Composition. Little millet is one of the oldest crops domesticated in India and is important minor millet grown in dry lands. However, its utilization is restricted to only certain cultural occasions in certain parts of the country. In Karnataka Little millet is grown in different regions, in view of this a study was conducted to document the physic-chemical properties and also to know if there are variations in nutritional and physical parameters in the little millet grain grown in different regions. The grains had a protein content of 7 per cent, fat 4.26 per cent, carbohydrates around 78 per cent, energy 370 Kcal and ash around 5 per cent. Little millet grains took 13- 16 minutes to cook and the volume of the grains increased by two and half folds. Little millet grains had different hull colors, however, the other physical, cooking and nutritional characters did not vary among the grains when classified based on hull color. Also, variations in physical, cooking and nutritional qualities were not evident in the grains cultivated in different zones (Kamatar *et al*., 2013).

Proximate and phytochemical analysis of seed coat from *P. sumantranse* (Little Millet). Little millet (*P. sumantranse*) has health benefits, and as well as economic importance. The rural farmers at Javadhu hills near Vellore district were exploited by the retailers in processing of little millets. We took this problem, in removing the seed coat from this seed in economic way using enzyme based technology. In this process, we concentrated in proximate and phytochemical analysis of the seed coat for better understanding of its chemical properties, prior to enzymatic treatment. 100 gms of seed coat is removed from the seed through mechanical treatment and we carried the proximate analysis, i.e. reducing sugar content, total carbohydrate, elemental analysis, moisture content, total fat, total protein, total fiber content and Total ash (Dangeti *et al.*,2013).

Versatile little millet therapeutic mix for Diabetic and Non diabetics Studies indicated that millets such as little, foxtail and barnyard exhibit hypoglycemic effect due to presence of higher proportion of complex carbohydrate, resistant starch, slow rising sugars and water-soluble gum β-glucans. The study was conducted to develop little millet composite mix and test glyco-lipemic responses among 6 non diabetic and 9 type 2 diabetics with four week feeding intervention. The phytochemical constituent presence of protein, fat, total dietary fiber and glycemic index (GI). The reduction in plasma glucose of experimental diabetic and non - diabetic group after consumption of little millet. The reduction in plasma triglycerides and increase in HDL-cholesterol the triglycerides reduced only non-diabetic (Itagi *et al.*, 2013).

### 2.1.4. Foxtail millet (*Setaria italica*)

Foxtail millet (*Setaria italic*a) is one of the most important food crops of the semiarid tropics, originated from China, and is now planted all over the world (Amadou *et al.,* 2011). It is also known as Italian, Hungarian, German and Siberian millet. Foxtail Millet plays a very important role in the agriculture and food of many developing countries because of its ability to grow under adverse heat and limited rainfall conditions. It was reported that foxtail millet has many nutritious and medical functions. Foxtail millet have sulphur- containing aminoacids like tryptophan, threonine, isoleucine, leucine, lysine, methionine, phenyl alanine, valine, arginine and histidine (Gurupavithra *et al.*, 2013) and carbohydrade, dietry fiber, minerals such as copper and iron. It helps to keep our body strong and immune power and also control the blood sugar and cholesterol.

Study on biochemical and nutritive value of popped foxtail millet. Foxtail millet (*Setaria italica*) is one type of minor millet are popped by mechanical process and used for the production of different snack foods. The present in physical characters like moisture, acidity, porosity, rapid viscosity, popped, unpopped, volume, length, breadth and chemical characters like fat, carbohydrate, crude fiber, amylose, protein, starch and free fatty acid were analyzed from the popped foxtail millet (Gurupavithra *et al.*, 2013).

**Fig. 2.5.** ***Setaria italica***

**Table 2.7. Nutrition Aspects of Foxtail Millet**

| Serving Size | The serving size, in terms of the number of volume or mass/100g |
|---|---|
| Calories | 336kcal |
| Iron (grams) | 3.9 |
| Calcium(mg) | 344mg |
| Fat (grams) | 1.3 |
| Carbohydrate (grams) | 72 |
| Protein (grams) | 7.3 |
| Fiber (grams) | 1.3 |

**BOTANICAL CLASSIFICATION (Hulsi *et al.*, 1980)**

**Vernacular Name:**

**English : Italian Millet/Foxtail Millet**

Bengali : Kaon

Gujarati : Kang

Hindi : Kakum

Kannada : Navane

Marathi : Kang, Rala

Oriya : Kanghu, Kangam,Kora

Punjabi : Kangni

Tamil : Tenai

Telugu : Korra

**Scientific Name:**

Kingdom : Plantae

Order : Poales

Family : Poaceae

Sub family : Panicoideae

Genus : Setaria

Species : *S.italica*

Nutrient and antioxidant analysis of raw and processed minor millets Foxtail and proso millet were subjected to different processing methods; samples were dried and powdered into fine flours, respectively. Standard methods were used to evaluate the flours for moisture, ash, protein, fibre, iron, phosphorus, calcium, magnesium and zinc. The phytochemical content was determined qualitatively (Mohankumar and Vaishnavi, 2012).

Extraction and characterization and nutritional properties of two varieties (white and yellow) of defatted foxtail millet flour (*Setaria italica*) grown in china. The study, characterized by amino acid analysis, different scanning calorimetry (DSC) and Sodium dodecyl sulphate polyacralymide gel electrophoresis (SDS-PAGE). The protein content for the white increased after defatting though not significant different and yellow decreased the protein content compared to white varieties. Fat content decreased white and increased the yellow varieties. Prolamin yellow and glutelin white were varies the protein fraction are present (kamara *et al.,* 2009).

### 2.1.5. Kodo millet (*Paspalum scrobiculatum*)

Kodo millet (*Paspalum scrobiculatum*) is grown primarily in India. The grains can be light red to dark grey in color. In India this is grown in pockets in Andhra Pradesh, Tamil Nadu, Orissa, Bihar, Madya Pradesh, Maharashtra and Gujarat. Since both the leaves and stalks are violet in color, the fields possess a characteristic violet look. It is extremely drought and salt resistant and this is grown in saline soils also. The grain is very coarse with a horny seed coat which is removed before cooking. The grain contains a diverse range of high-quality protein and has high anti-oxidant activity (anti-cancer) even when compared to other millets (Hegde *et al*., 2005). Kodo millet is rich in fiber and hence may be useful for diabetics (Chandrasekara and Chandra, 2002). It is also reasonably low in fat with high fiber content. Due to high antioxidant content, it is beneficial in protecting against oxidative stress and maintaining glucose levels in type-2 diabetes (Taylor, 2004).

Antidiabetic principles, Phospholipids and Fixed Oil of Kodo Millet (*Paspalum scrobiculatum Linn*.): Kodo millet (*Paspalum scrobiculatum Linn*.), is an extremely drought and salt resistant wild millet attributed with a number of medicinal properties such as antidiabetic, tranquilising, hypolipidaemic, anti-rheumatic and wound-healing attributed to the grains. Though this grains are reported to contain 74% carbohydrates, 11.5% protein, 1.3% fat and 10.4% fiber (Leder, 2004).

**Fig. 2.6.** ***Paspalum scrobiculatum***

**Table 2.8. Nutrition Aspects of Kodo Millet**

| | |
|---|---|
| Serving Size | The serving size, in terms of the number of volume or mass |
| Calories | 309 |
| Fat (grams) | 9 |
| Iron (grams) | 0.5 |
| Calcium (milligrams) | 27 |
| Minerals(grams) | 2.6 |
| Carbohydrate (grams) | 108 |
| Protein (grams) | 8.3 |
| Fiber (grams) | 8 |

**BOTANICAL CLASSIFICATION (Hulsi *et al.*, 1980)**

**Vernacular Name:**

**English : Kodo Millet**

Bengali : Kodo

Gujarati : Kodra

Hindi : Kodon

Kannada : Harka

Marathi : Kodra

Oriya : Kodua

Punjabi : Kodra

Tamil : Varagu

Telugu : Arikelu, Arika

**Scientific Name:**

Kingdom : Plantae

Order : Poales

Family : Poaceae

Sub family : Panicoideae

Tribe : Paniceae

Genus : Paspalum

Species : *P. scrobiculatum*

Aqueous and ethanolic extracts of this grain produced a dose-dependent fall in fasting blood glucose (FBG) and a significant increase in serum insulin level. This indicates that *P. scrobiculatum* possesses significant antidiabetic activity. A study on inhibition of collagen glycation and cross linking *in vitro* by methanolic extracts lead to the concluded that Kodo millet can be used in the treatment of skin wounds (Hegde *et al.,* 2005).

## 2.2. Pharmaceutical Properties of millets

Pearls millets contain number of medically important activity such as anemia, constipation, cancer, diabetes and allergies, antimicrobial properities, antioxidant properties, glycemic response wound healing process, anti-lithiatic effect and inhibition of aldose reductase.

### 2.2.1. Anemia

Pearl millet contains high amount of Iron (8mg/100g) and Zinc (3.1mg/100g), (NIN, 2003) which may help to increase the Hb levels. However the presence of several non-nutrients such as phytates and polyphenols may decrease the bioavailability of iron. Use of household processing technologies such as popping, germination, fermentation as described above may lead to reduction of these non-nutrients and further leads to increase in bioavailability of iron and zinc (Sharma and Kapoor, 1996)

### 2.2.2. Constipation

The high fiber content (1.2g/100g) of pearl millet can be extensively used to prepare healthy foods for people who needs high fiber diet, especially it is helpful in obesity and dealing with problem of constipation (NIN, 2003).

### 2.2.3. Cancer

Pearl millet contains high level of antioxidants namely the phenolic compounds and may have anticancer property. Sripriya *et al.* (1996) reported the phenolic content of 51.4 and 43.1 mg/100gDW of pearl millet and sorghum respectively. Sharma and Kapoor, (1996) have reported the phenols in pearl millet grains as 608.1mg/ 100g and that in pearl millet flour as 761mg/ 100g. Phenolic compound especially flavonoids, have been found to inhibit tumor development. These compounds are concentrated in the pericarp and testa. Since traditionally, the entire pearl millet grain is milled, products made out of the flour would provide the health benefits of the flavonoids and phenols (Huang and Ferraro, 1992).

### 2.2.4. Diabetes

Pearl millet has a very high amylase activity, about 10 times that of wheat. Maltose and D-ribose are the predominant sugars in the flour, while fructose and glucose levels are low (Oshodi *et al.,* 1999). Diet is considered to be the cornerstone in the management of diabetes mellitus and more so in the case of noninsulin-dependent diabetes mellitus (NIDDM) in which the primary derangement is of carbohydrate metabolism, with secondary abnormalities of lipid and protein metabolism. Dietary management of diabetes involves the reduction of postprandial hyperglycaemia and good glycaemic control. The concept of glycaemic index (GI) emerged as a physiological basis for ranking carbohydrate foods according to the blood glucose response they produce on ingestion, and was introduced by Jenkins *et al.* (1981). Mani *et al.* (1993) have reported that pearl millet (*Penniseteum typhoideum*), has the lowest GI (55) as compared to Varagu (*Plaspalum scorbiculatum*) alone and in combination with whole and dehusked greengram (*Phaseolus aureus Roxb*), Jowar (*Sorghum vulgare*) and Ragi (*Eleusine coracana*). Foods with a low glycemic index are useful to manage maturity onset diabetes, by improving metabolic control of blood pressure and plasma low density lipoprotein cholesterol levels due to less pronounced insulin response. Several pearl millet based novel food products can be developed and traditional recipes need to be promoted for the diabetic patients (Asp, 1996).

### 2.2.5. Allergies

Pearl millet is a gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with wheat allergies. Pearl millet grains are all very high in calories—precisely the reason they do wonders for growing children and pregnant women (www.icrisat.org).

### 2.2.6. Antimicrobial properties

Plant phenolics have been implicated for minimising the intensity of several diseases and also to inhibit the *in vitro* growth of an assortment of fungal genera. It was also indicated that finger millet grain phenolics including tannins may be involved in resistance of the grain to fungal attack (Seetharam and Ravikumar, 1994). Phenolic compounds, particularly tannins in the outer layers of the grain serve as a physical barrier to the fungal invasion. The acidic methanol extracts from the seed coat showed high antibacterial and antifungal activity compared to whole flour extract due to high polyphenols content in seed coat. It was reported that the fungal load (total fungal load and infection levels) of the unmalted millet grain and its malt, were negatively correlated ($p<0.05$) with total phenolics and phenolic type (condensed tannins, anthocyanins and flavan-4-ols). Oxidation of microbial membranes and cell components by the free radicals formed, irreversible complexation with nucleophilic amino acids leading to inactivation of enzymes are major biochemical benefits of polyphenols towards the antifungal activity. Besides, loss of their functionality and also the interaction of phenolic compounds, especially tannins with biopolymers such as proteins and polysaccharides and complexing with metal ions making them unavailable to micro-organisms are some of the mechanisms involved in the inhibitory effect of phenolic compounds on microorganisms. The extremely good storage property of finger millet and its processed foods could be attributed to its polyphenol content (Siwela *et al.,* 2010).

### 2.2.7. Antioxidant properties

Antioxidant compounds are gaining importance due to their main roles as lipid stabilizers and as suppressors of excessive oxidation that causes cancer and ageing. Their stable radical intermediates prevent the oxidation of various food ingredients, particularly fatty acids and oils. Henolic acids and their derivatives, flavonoids and tannins present in millet seed coat are of multifunctional and can act as reducing agents (free radical terminators), metal chelators, and singlet oxygen quenchers (Sripriya *et al.,* 1996). The potency of phenolic compounds to act as antioxidants arise from their ability to donate hydrogen atoms via hydroxyl groups on benzene rings to electron- deficient free radicals and in turn form a resonancestabilized and less reactive phenoxyl radical. Studies were carried out on the natural antioxidants in edible flours of small millets. Total antioxidant capacity of finger, little, and proso millets were found to be higher and their total carotenoids content varied from 78–366 mg/100 g in the millet varieties. Total tocopherol content in finger and proso millet varieties were higher (3.6–4.0 mg/100 g) than in foxtail and little millet varieties (~1.3 mg/100 g). HPLC analysis of carotenoids for the presence of β-carotene showed its absence in the millets, and vitamin E indicated a higher proportion of γ-and α-tocopherols; however, it showed lower levels of tocotrienols in the millets. Edible flours of small millets are good source of endogenous antioxidants6. The antioxidant activity of millet phenols and their health benefits have also been reported. For instance, in Japanese barnyard millet, the antioxidant activity of luteolin was nearly equal to that of quercetin; however, the activity of tricin was lower than luteolin. Finger millet is a potent source of antioxidants and has potent radical-scavenging activity that is higher than that of wheat, rice, and other millets; these results corresponded to their phenolic content. The brown or red variety of finger millet, which is commonly available, had higher activity (94%) than the white variety (4%) using the DPPH method5. Kodo millet quenched DPPH by nearly 70% higher than other millets (15–53%); white millet varieties had lower activity (Hegde and Chandra, 2005).

**2.2.8. Glycemic response**

Recent reports indicate that hyperglycemia could induce non-enzymatic glycosylation of various proteins, results in the development of chronic complications in diabetes. Therefore, control of postprandial blood glucose surge is critical for treatment of diabetes and for reducing chronic vascular complications which can be controlled by intake of high complex carbohydrate and high fiber diet. Research has shown that the carbohydrates present in finger millet are slowly digested and assimilated than those present in other cereals. Regular consumption of finger millet is known to reduce the risk of diabetes mellitus and gastrointestinal tract disorders and these properties were attributed to its high polyphenols and dietary fiber contents (Chethan *et al.,* 2008b). The beneficial effect of phenolics is due to partial inhibition of amylase and α-glucosidase during enzymatic hydrolysis of complex carbohydrates and delay the absorption of glucose, which ultimately controls the postprandial blood glucose levels. Beneficial effect of dietary fiber is usually attributed either to slower gastric emptying or formation of un-absorbable complexes with available carbohydrates in the gut lumen and these two properties might result in delayed absorption of carbohydrates and in the reduction of absolute quantity absorbed. Another study provided evidence for hypoglycaemic, hypocholesterolaemic, nephroprotective and anti cataractogenic properties of finger millet, the 'healthgrain'. Feeding a diet containing 20% millet seed coat matter (SCM) to streptozotocin induced diabetic rats for 6 weeks exhibited lesser degree of fasting hyperglycemia and partial reversal of abnormalities in serum albumin, urea and creatinine compared to diabetic control. Hypercholesterolaemia, hypertriacylglycerolaemia, nephropathy and neuropathy associated with diabetes were notably reversed in diabetic group fed with the diet containing millet seed coat matter (Shobana *et al.,* 2009).

### 2.2.9. Wound healing process

The process of wound healing is determined by inflammation, a vital and protective response offered by the injured cells at the wound site that actually starts the process of tissue repair. The perfect wound healing process is interrupted in diseased conditions like diabetes and age associated biochemical phenomenon due to increased level of reactive oxygen species (ROS). The diabetic conditions had a deleterious influence on the wound healing process through abnormal physiological response. Free oxygen radicals damage the cells in the zone of stasis, which lead to necrosis and conversion of superficial wound into a deeper wound. Antioxidants significantly prevent tissue damage and stimulate the wound healing process. Antioxidant effects of finger millet on the dermal wound healing process in diabetes induced rats with oxidative stress-mediated modulation of inflammation were studied (Rajasekaran *et al.,* 2004). They reported that the role of finger millet feeding on skin antioxidant status, nerve growth factor (NGF) production and wound healing parameters in healing the impaired early diabetic rats. Hyperglycemic rats received food containing 50 g/100 g finger millet (FM) and the non-diabetic controls and diabetic controls received balanced nutritive diet. Full-thickness excision skin wounds were made after 2 weeks prior to feeding of finger millet diet. They studied the intensity of wound, levels of collagen, hexosamine and uronic acid in the granulation tissue, skin antioxidant status and lipid peroxide concentration. The healing process was hastened with an increased rate of wound contraction in hyperglycemic rats fed with finger millet diet and skin antioxidant levels of glutathione (GSH), ascorbic acid and $\alpha$- tocopherol in alloxan-induced diabetic rat was lower as compared to non-diabetics. Altered activities of superoxide dismutase (SOD) and catalase (CAT) were also recorded in diabetic rats. The thiobarbituric acid reactive substances (TBARS) levels of both normal and wounded skin tissues were significantly elevated ($P<0.001$) when compared with control (nondiabetic) and diabetics fed with Finger millet (Rajasekaran *et al.,* 2004).

### 2.2.10. Anti-lithiatic Effect

The effect of aqueous and alcohol extracts of *Eleusine coracana* on calcium oxalate nephrolithiasis has been studied in male albino rats were studied (Chethan *et al.,* 2008). Ethylene glycol feeding resulted in hyperoxaluria as well as increased renal excretion of calcium and phosphate. Supplementation with aqueous and alcohol extracts of grains significantly reduced the elevated urinary oxalate, showing a regulatory action on endogenous oxalate synthesis. The increased deposition of stone forming constituents in the kidneys of calculogenic rats was significantly lowered using extracts. Prophylactic and therapeutic treatment with extracts of grains of finger millet had an inhibitory effect on crystal growth, with improved kidney function & cytoprotective effect (Bahuguna *et al.,* 2009).

### 2.2.11. Inhibition of aldose reductase

Mode of inhibition of aldose reductase from cataracted eye lenses by finger millet polyphenols was studied. Diabetes induced cataract is characterized by an accumulation of sorbitol, which is mediated by the action of a key enzyme aldose reductase (AR). The non-enzymatic glycation (binding of glucose to protein molecule) induced during diabetes appear to be the key factor for AR mediated sugar induced cataract. AR enzyme is crucial in cataractogenesis via a polyol pathway. Crude phenolic extracts from finger millet exhibited the strong inhibitory effects on AR activity and showed an IC50 of 60.12 μg/ml. Mode of inhibition of polyphenols on aldose reductase could be by preventing either the enzymatic conversion of glyceraldehyde toglycerol and glucose to sorbitol, thereby replenishing the depletion of NADPH levels. Phenolic constituents in finger millet phenolics such as gallic, protocatechuic, phydroxy benzoic, p-coumaric, vanillic, syringic, ferulic, trans-cinnamic acids and the quercetin was found to inhibit cataract effectively. Structure and function analysis revealed that phenolics with hydroxy groupat 4th position is important for aldose reductase inhibitory property. Furthermore, the presence of neighboring O-methyl group in phenolics denatured the AR activity. Quercetin is the most potent AR inhibitory component among the finger millet polyphenolic constituents with IC50 at 25.23±2.2 μg/ml. The activity was correlated with antioxidant potency with the correlation coefficient ($r=0.99$, $p\leq0.1$) between antioxidant and AR inhibitory effect of phenolic constituents suggesting that the proton abstracting ability isresponsible for

AR inhibitory effect. Quercetin exhibits non competitive inhibition on AR enzyme and it may render reversible inhibition by successfully blocking the polyol pathway leading to cataracto- genesis. The strong hydrogen abstracting ability of quercetin may replace the proton donation from AR-Histidine-110/ Tyrosine-48, which is a key step in the NADPH regenerating potential substantiating the effective AR blockade activity. AR inhibitions potentially resulted in no or only trace accumulation of sorbitol, which is beneficial to overcome the osmotic pressure that may also affect eye lens (Rajasekaran *et al.,* 2004) ..

**2.3. Millet based Products**

Most of the millets produced in India are used as staple food and less in ready-to-use and convenient food products due to non-availability of proper milling technology. The major constraints for widespread utilization of millet are its coarse fibrous seed coat, coloured pigments, astringent flavour and poor keepingquality of the processed products (Desikachar, 1975). Pearling, debranning and chemical treatments of millets overcome some of these constraints; improve nutritional quality and consumer acceptability (Akingbala, 1991). Although millets are nutritionally superior to cereals, yet their utilization is not wide spread. One possible way of extending their utilization could be by blending them with wheat flour after suitable processing (Singh *et al.,* 2005). On addition of millet flour there would be changes in physico-chemical, nutritional and functional characteristics.

In developed countries many convenience products including extruded products are popularly consumed. Extruded products include spaghetti, macaroni, vermicelli and noodles, pasta, etc. The products are made using refined durum wheat flours or semolina as their main ingredient. Many research workers have attempted to produce composite millet flours by replacing conventional cereal flours to some extent in making the traditional foods, ready-to-use or RTE food products or in the production of pasta. Multi-grain flour by combining wheat and finger millet in the ratio of 7:3 is one of the simple semi-finished products suitable for making chapatti (roti). Kamaraddi and Shanthakumar (2003) incorporated the small millet flours to commercial wheat flour and studied the effect of incorporation of refined millet flours on chemical, rheological and baking characteristics. It was found that substitution of wheat flour with millet flours was possible from 10 to 20% level. Barnyard millet and proso millet can be added 20 and 15%

respectively. Puffing or popping of cereals is an old traditional practice of cooking grains to be used as snack or breakfast cereal either plain or with some spices/salt/sweeteners. Starch is the main carbohydrate in human nutrition and offers a range of desired technological properties.

The nutritional quality of starch strongly depends on starch structure and on its processing (Lehmann and Robin, 2007). Puffing or popping process brings about such structural changes in starch or starch-protein matrix of the millet grain or preconditioned pasta that leads to expansion of the grain or pasta pieces and produce a puffed product with high crisp and other textural attributes. The high temperature short time (HTST) treatment exploits the thermo-physical properties of starch and prepares expanded grains or flakes. During this process the Millard reaction takes place in which the sugars present in the aleurone layer react with amino acids of the millet and gives a pleasant and highly desired aroma to the puffed product. In also reduces anti-nutrients like phytates, tannins, etc., increase bio-availability of minerals, give pleasing texture to the product, and enhances protein and carbohydrate digestibility (Nirmala *et al.*, 2000).

### 2.3.1. Noodles and Other Products

Noodles are the pasta products also known as convenience foods prepared through cold extrusion system which become hard and brittle after drying. The cooking of these noodles is very convenient and requires few minutes. Noodles of different combinations are prepared such as noodles exclusively made of finger millet, finger millet and wheat in the ratio of 1:1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1. Pasta can be prepared with finger millet, refined wheat and soy flour/whey protein concentrate composite flour formulated (50, 40 and 10%) (Devaraju *et al.,* 2006) or proso millet and wheat flour blend with appreciable shelf life (Sudhadevi *et al.*, 2013). Pasta was extracted in dolly pasta machine.

Noodles are one of the most preferred food items among all age groups having longer shelf life and good commercial importance. Barnyard millet has relatively low carbohydrate content (58.56%) having slow digestibility of 25.88% (Veena, 2003). This health benefit of millet was exploited by preparing value added low glycaemic index noodles from barnyard millet flour by incorporating sago flour, pulse flour and bengal gram leaf powder at different levels to develop plain, pulse and vegetable noodles respectively (Surekha *et al.*, 2013). Punia *et al.* (2003) prepared ladoo *(*sweet balls*)* and shankarpara (from dough and formed into flakes) from kanagini or foxtail millet (*Setaria italica*) by substituting maida with 50% kangini flour and observed that kangini ladoo had protein 13.13%, ash 4.92% and iron and zinc13.83 and 2.35 mg/100 g respectively. It was also found that both the products prepared were acceptable and appearance, texture, and taste of the product were in the category of 'liked very much'.

Srivastava *et al.* (2003) prepared popped grains from barnyard, foxtail and little millet using common salt as heating medium in an open iron pan containing sample and salt in the ratio 1:20 at 240-260°C for 15- 25 s. Two types of ladoos (sweet balls of 5 cm dia) first one using individual popped millet grains and jiggery and second type by using millets, roasted groundnut and coconut powder were prepared. The sensory scores on nine point hedonic scales for first and second type ladoo were 5.0-6.9 and 7.2-8.1 respectively. Products based on foxtail millet had higher values of protein and calcium than those based on barnyard millet. Incorporation of groundnut and coconut in the formulation increased the contents twice in protein (7.27-8.39 g/100 g), energy, calcium and iron compared to those containing only millets and jiggery in the first type of ladoo.

**2.3.2. Baked Products**

Bakery products are popular all over the world and the production has risen by many folds due to their low cost, varied taste and textured profiles with attractive package and longer shelf-life to suit easy marketing (Patel and Rao, 1996). The use of millets in bakery products will not only be superior in terms of fibre content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products (Verma and Patel, 2013). These are mostly prepared from the wheat flour but efforts are being made to replace few portion of it with millets in order to provide an alternative and reduce over dependence on wheat and make gluten free bread. Finger millet and foxtail millet flour can be incorporated in bakery items like biscuits, *nan-khatai*, chocolate, cheese, cakes, muffins, etc. Research findings have revealed that substitution of 40% wheat flour with finger millet flour in baked products like cake and biscuits is possible (Begum *et al.,* 2003; Yenagi *et al.*, 2013). The chocolate cup cake, gel cake, masala cake, carrot cake, soup sticks, rusk and muffins prepared with finger millet have good appearance, texture, flavour and overall acceptability scores. Attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fibre content by supplementing with malted finger millet flour (Desai *et al.*, 2010).

### 2.3.3. Extruded Products

A majority of world population suffers from qualitative and quantitative insufficiency of dietary protein and calories intake. In all such cases physiological maintenance and growth are impaired, and malnutrition results. In this context extrusion is a beneficial process. Extrusion cooking is a HTST cooking process, which could be used for processing of starchy as well as proteinaceous materials. The use of extrusion cooking has distinct advantages like versatility, high productivity, high product quality, increase in in-vitro protein digestibility (Dahlin and Lorenz, 1992) and production of new food without effluents. Extrusion Cooking is accomplished through the application of heat either directly by steam injection or indirectly through jacket or by dissipation of mechanical energy through shearing occurring within the blend. Extrusion process increases the iron availability of the extruded weaning foods based on pearl millet, cowpea and peanut or milk powder by 3.5 to 6.5 times higher than the corresponding roasted weaning foods (Cisse *et al.*, 1998). Millet based extruded snack foods are prepared using twin-screw extruder from kodo millet-chickpea flour blend (70:30) (Geetha *et al.*, 2012); pearl millet, finger millet and soybean flour blend (Balasubramanian *et al.*, 2012) or ragi, sorghum, soy and rice (42.03,14.95,12.97 and 30%) flour blend (Seth and Rajamanickam, 2012) with desired quality. Expansion index (2.31) and sectional expansion index (5.39) was found to be maximum for feed rate and screw speed combination of 9.5 kg/h and 250 rpm for pearl millet (81.68%), finger millet (7.02%) and decorticated soy bean (11.29%) composite flour. The barrel temperature significantly affects all the product attributes like expansion ratio, bulk density, hardness and crispiness significantly. Kodo-chickpea flour blend desirable crispy extrudates at higher screw speed of 280 rpm, lower feeder speed 20 rpm, and medium to high temperature of 123 °C. About 15% moisture content of the millet-pulse or millet-soy feed at 10 to15% blend ratio appears to be acceptable level (Singh *et al.,* 2008). Microwave cold extrudated puffed barnyard millet based ready to eat fasting foods with comparable sensory quality was developed by Dhumal *et al.* (2014). Extrusion of malted pearl millet grains can be used to prepare instant beverage powder from pearl millet and it reduces the peak viscosity of the starches significantly ($p \leq 0.05$) (Obilana *et al.*, 2014).

### 2.3.4. Fermented Products

Fermented foods like Dosa and Idli are popular and common breakfast foods and even as the evening meals in many parts of India. Millets are good source of protein but the protein quality in terms of lysine and tryptophan content is low, hence there is growing emphasis on the improvement of protein quality. Fermentation not only improves the taste but at the same time enriches the food value in terms of protein, calcium and fibre, B vitamins, in vitro protein digestibility and decreases the levels of anti-nutrients in food grain (Chavan and Kadam, 1989; Maha *et al.,* 2003; Verma and Patel, 2013). Fermentation of the ground germinated pearl millet grains gives higher protein digestibility (>90%). (Khetarpaul , 2003) fermented the pearl millet by inoculating the micro flora namely, *S. diastaticus, S. cerevisiae, L. brevis and L.* fermentation and incubated at 30o C for 72 h in single culture, mixed culture and sequential culture fermentation. The samples were oven dried and ground to fine flour and found that controlled pure culture fermentation did not change the protein and ash content of pearl millet (sprouted and flour) and increased the starch digestibility of flour significantly. High dietary calcium and phytic acid reduces bio-availability of zinc by Zn-Ca-phytate or Zn-phytate complex. Fermentation is one of the most economic and effective measure for reducing polyphenols and phytic acid significantly and improves HCL-extractability of zinc (Sripriya *et al.,* 1996b; Murali and Kapoor, 2003), iron, copper, calcium and manganese but maximum reduction is brought out by sequential fermentation.

### 2.3.5. Beverage

'Kodo ko jaanr' is the most common fermented alcoholic beverage prepared from dry seeds of finger millet in the Eastern Himalayan regions of the Darjeeling hills and Sikkim in India. *Chhang* is also a fermented finger millet beverage popular in Ladakh region in India. *Koozh* is another fermented beverage made with pearl or finger millet flour and rice, and consumed by ethnic communities in Tamil Nadu (Ilango and Antony, 2014). The traditional, naturally fermented finger millet product is called *Ambali*. Finger millet is the cereal of choice for the preparation of porridges for children and for the sick and old in India. Millet malt is also used to prepare beverages either with milk of lukewarm water with the addition of sugar since pretty old times. *Mahewu* is a non-alcoholic beverage prepared in Zimbabwe from finger millet (1/3) and sorghum (2/3) malt by traditional fermentation (Gadaga *et al*., 1999). Some liquid foods with different local names prepared from millets are consumed in India. Ragi soup is also famous and prepared by mixing the ragi flour into water (one part ragi flour and 2.5 parts water). Vidhyavathi *et al.* (2004) made a scientific effort to develop finger millet based ethnic common recipes. Two types of beverages namely *Ambli* and *malt* were prepared and found a good score for appearance, texture and flavour with overall acceptability scores from 4.0-4.5 in sensory evaluation. There was a non-significant difference between the control and experimental products in all the parameters of sensory attributes. Modern products incorporating finger millet like *ragi* health drink (baby vita) are now available in the market.

**Enzymic and Non – enzymic antioxidants**

Organisms have developed some mechanisms to protect their bodies from free radicals-induced oxidative or nitrosative stress. They produced antioxidant molecules to protect cells from damage which caused by free radicals. At a low concentration in the body, antioxidants could protect the cells and its content like proteins, lipids, carbohydrates, and DNA significantly. Plants produced some compounds such as polyphenols and flavonoid that tend to have free radical scavenging activity (Achmad *et al.,* 2014).Antioxidants interfere with the oxidative processes by scavenging free radicals, chelating free catalytic metals and by acting as electron donors. The natural antioxidant mechanisms may be insufficient in variety of conditions and hence dietary intake of antioxidant compounds is important. The therapeutic effects of several medicinal plants are usually attributed to their antioxidant phytochemicals. It has been suggested that there is an inverse relationship between dietary intake of antioxidant rich foods and incidence of human diseases. Plant based antioxidants are preferred to the synthetic ones because of their multiple mechanisms of actions and non-toxic nature. These facts have inspired widespread screening of plants for possible medicinal and antioxidant properties; the isolation and characterization of diverse phytochemicals and the utilization to antioxidants of natural origin to prevent the diseases (Padmanabhan and Jangle, 2012).

**2.1.6.1. Peroxidase**

Peroxidases is a heme containing enzymes which are able to oxidize organic and inorganic compounds using hydrogen peroxide as co-substrate. The non-specificity of peroxidase makes the enzyme suitable to the broad range of electron donorsubstrates (Srinivasahan and Durairaj, 2014).

Pyrogallol + $H_2O_2$ $\longrightarrow$ Oxidized pyrogallol + $H_2O$

**2.1.6.2. Superoxide dimutase:**

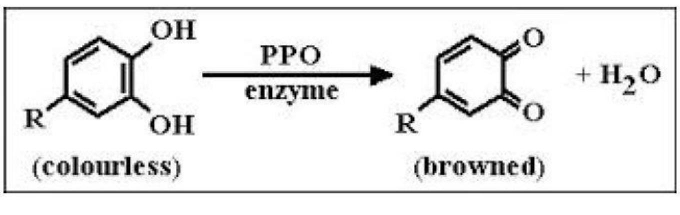
Superoxide dismutase (SOD) is an enzyme that removes the superoxide (O2-) radical, repairs cells and reduces the damage done to them by superoxide, the most common free radical in the body. SOD is found in both the dermis and the epidermis, and is key to the production of healthy fibroblasts (skin-building cells) (Chakraborty *et al.*, 2009).

Superoxide dismutase is one of the most effective intracellular enzymeand it catalyzes the conversion of superoxide anion to oxygen and hydrogen peroxide. Superoxide dismutase exist in several isoform, which differ in the nature of active metal centre and amino acid composition (Rahman, 2007).Enzyme, which is mainly present in cell cytoplasm and in mitochondria in order to maintain a low concentration of superoxide anion. It provides the primary defense against oxidative damage (Hosseinian *et al.,* 2006).

$2O_2^- + 2H^+$ -----------> $H_2O_2 + O_2$

**2.1.6.3. Polyphenol oxidase (PPO)**

Polyphenol oxidase has been found in higher plants and millets and responsible for Enzyme browning of raw fruits and vegetables. Many medicinal plants products have been reported to contain large amount of Polyphenol oxidase other than vitamin C and vitamin E. (Chakraborty *et al.*, 2009).



**Ascorbic acid**

The ascorbate ion is the predominant species at typical biological pH values. It is a mild reducing agent and antioxidant. It is oxidized with loss of one electron to form a radical cation and then with loss of a second electron to form dehydroascorbic acid. It typically reacts with oxidants of the reactive oxygen species, such as the hydroxyl radical. Such radicals are damaging to animals and plants at the molecular level due to their possible interaction with nucleic acids, proteins, and lipids. Sometimes these radicals initiate chain reactions. Ascorbate can terminate these chain radical reactions by electron transfer. Ascorbic acid is special because it can transfer a single electron, owing to the resonance-stabilized nature of its own radical ion called, semidehydroascorbate. The net reaction is:

$$RO\bullet + C_6H_7O_6^- \rightarrow RO- + C_6H_7O_6^{\bullet} \rightarrow \rightarrow ROH + C_6H_6O_6.`$$

The oxidized forms of ascorbate are relatively unreactive and do not cause cellular damage.

However, being a good electron donor, excess ascorbate in the presence of free metal ions can not only promote but also initiate free radical reactions, thus making it a potentially dangerous pro-oxidative compound in certain metabolic contexts (Srinivasahan and Durairaj, 2014).