

**Review Article**

# Millet Grain Processing, Utilization and Its Role in Health Promotion: A Review

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**Abstract:** The enormously increasing population is raising needs for solving the problem of food scarcity. Researchers and nutritionists are working hard to find the cheaper and larger sources of nutrients to deal with this scarcity. Pearl millet, a staple crop is economically feasible for poorer section of the world's population and works are going on for the improvement in the bio-accessibility of the minerals for increasing its utilization. Researches are proving pearl millet comparably better in nutritional quality with high protein content, energy, minerals like iron and zinc, vitamins, dietary fibre, less glycemic index and phytochemicals like antioxidants. New advanced techniques applied for post-harvest technology and value addition are giving out more products of wide acceptance in rural as well as urban areas. In relation with the nutritional quality, convenience of food uptake and other sensory properties, many food processing technologies have been developed. These techniques are widely used now-a-days and are milling, decortication, soaking, germination/malting, fermentation etc. These processes increase the nutritional value and are very effective in dealing with undernourishment problem and other food and health management practices. A large scale implementation of these technologies or commercialized use will increase the ease of adopting their products at wide scale. This type of commercialization will not only deal with the undernourishment problem but also will earn great profits for all the persons in chain from producer like farmers to the consumers but will require policy-support and campaign for health, ecological sustainability and nutritional benefits of the crop. So this review focusses on pearl millet's high nutritional aspects, the post-harvest techniques potent for its improvement at large scale and the related health benefits to support the need at rural as well as urban level.

**Keywords:** Millets, Nutritive Value, Composition, Processing, Health Benefits

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## 1. Introduction

Today's scenario is facing environmental as well as global issues like variation in climatic conditions, scarcity of water, increment in the birth rates i.e. snowballing population and other social plus economic impact and these are expected to have negative effects on agriculture and food security over the world. These issues are encouraging techno and nutrition experts to research for other possible potential food sources capable to deal the increased hunger and security of food. Cereal grains being the utmost important food source for the world today is significant in the human diet worldwide. The productivity and the production area of cereals are increasing day by day. Recent findings are evident that productivity of

cereals has doubled in the past fifty years. Millet presently comprises approximately 11.4% of the total area employed for cereals and 4.1% of the total cereals output (FAOSTAT 2007). They are capable to grow in harsh climatic conditions like less rainfalls, no fertilizers availability or any other facilities so are frequently recommended for farmers dealing with difficult circumstances. Moreover, millets constitute principal energy source, proteins, minerals and vitamins for poor society in the regions with harsh conditions. So these grains are dragging more attention from developing and underdeveloped countries in utilization terms as food and in developed countries for their great potential in production of biofilms and bioethanol (Li *et al.*, 2008). Additionally, they also have nutraceutical properties and provide health benefits like cancer prevention,

tumor incidence reduction, cardiovascular disease, low blood pressure, cholesterol problem, fat absorption rate, heart disease, gastric problems, and also gastro-intestinal bulk supply (Truswell 2002; Gupta *et al.*, 2012). They are crops with small seeds with wide varieties like pearl millet, kodo millet, finger millet, foxtail millet, proso millet, barnyard millet and little millet (Bouis 2000; Kaur *et al.*, 2012). Out of all varieties of millet, pearl millet occupies cultivated area of greater than 29 million hectare but is restrictedly distributed geographically within Africa and Asia with area of 15 million and 11 million respectively as being the largest producer.

India, the largest producer of pearl millet covers an area of 9.8 million of hectares over the world. Pearl millet known under coarse grain cereals is called as the poor man's crop and has yet been neglected by commercialization, investment of research, development and food system commerce point of view. Under the concerns of adverse environmental changes and their hazardous effects on nutritional and food security and the urgent need to increase the food production compared to resource investment for rising population, millets accompanied with other not well utilized crops are believed to have great potential to deal with the reason on wide scale in both urban and rural areas belonging to both developed and developing countries. There are beliefs about the nutritional and health benefiting values of pearl millet in large areas of rural section and also variety of products from it can be advantageous and should be produced. Limited works have been done on processing and technology applied for food products to extract high nutrition and health related aspects of pearl millet. Results on lab scale are proving good future prospects even in commercial possibilities. So this study takes under consideration the various techniques which can be applied to improve the nutritional status of pearl millet and its utilization in diet due to its beneficial aspects in sense of dealing with health and diseases.

### 1.1. Trends of Production and Yield

Pearl millet is mostly grown in the tropical semi-arid and arid areas of Africa and Asia where temperature of soil can rise to a stage of posing adverse effects on germinating seeds and their survival causing poor cropping conditions and less green growth. Pearl millet seedlings are capable to grow even at high soil temperatures of 62°C (Peacock *et al.*, 1993). It's a crop of summers and its harvesting area is increasing in areas of Rajasthan, Gujrat, Maharastra, Uttar Pradesh and Tamil Nadu (Hollington, 1998). Other advantageous characteristics of millet are they have short duration of growing seasons, highly resistant to diseases and pests and gives good productivity in drought endemic areas as compared to other cereals (Devi *et al.*, 2011). Diverse trends in areas of production and levels of yields have defined three periods. They are post independent growth from 1947 to 1965, public supported from 1966 to 1985 and the growth driven by private sector from 1986 to present time. Post-independence growth period gave evidence of high increase in millet production but the public-supported one showed stagnant growth and again in the latter period the growth increased. This data is in the support of government of India stats 2008.

Another quality of pearl millet is it has high drought dealing capacity as its efficiency of using water is very high in comparison to maize and sorghum. In some comparative study, it became evident that when irrigation was frequent, efficiency of using water is hardly same in sorghum, pearl millet and maize but with the decrease in the frequency of irrigation sorghum won the dry matter producing efficiency race (Singh and Singh 1995). When the conditions became more adverse and stress full like only one irrigation pearl millet showed highest water utilizing capacity (Table 1). This proved the water scarcity dealing capacity of the pearl millet. Huge variability in the capability of drought dealing has been noticed, by the identification studies of closely related quantitative trait molecular marker at loci having relation with tolerance of drought.

Pearl millet has more tolerance compared to sorghum and is known as the second most tolerant to salinity after barley. Along with this much great genetic variations for full plant response has been noticed in pearl millet by some researchers (Krishnamurthy *et al.*, 2007; Ashraf M. 1994). According to updated researches of ICRISAT (International Crop Research Institution for Semi-Arid Tropics) in association with ICBA (International Centre for Bio-saline Agriculture), National Agriculture Research System and International Centre for Agriculture Research in Dry Areas (ICARDA) in Asian continent has proved tolerance to high salinity of pearl millet. Lack of capability of maize to tolerate stress conditions make it uneconomical to grow it in such areas but the effective role of millet in dealing both fodder and food needs has proved it of great importance in cultivation count. Hybrids of pearl millet mature in 80-85 days in summers with irrigation accompanied with application of 60-80 kg per hectare of nitrogen giving an output of 4000-5000 kg per hectare of yield.

**Table 1.** Water use efficiency (WUE) of sorghum, pearl millet, and maize at different frequencies of irrigation: S0 = 7 irrigations, S1 = 4 irrigations; S2 = 3 irrigations; S3 = 2 irrigations.

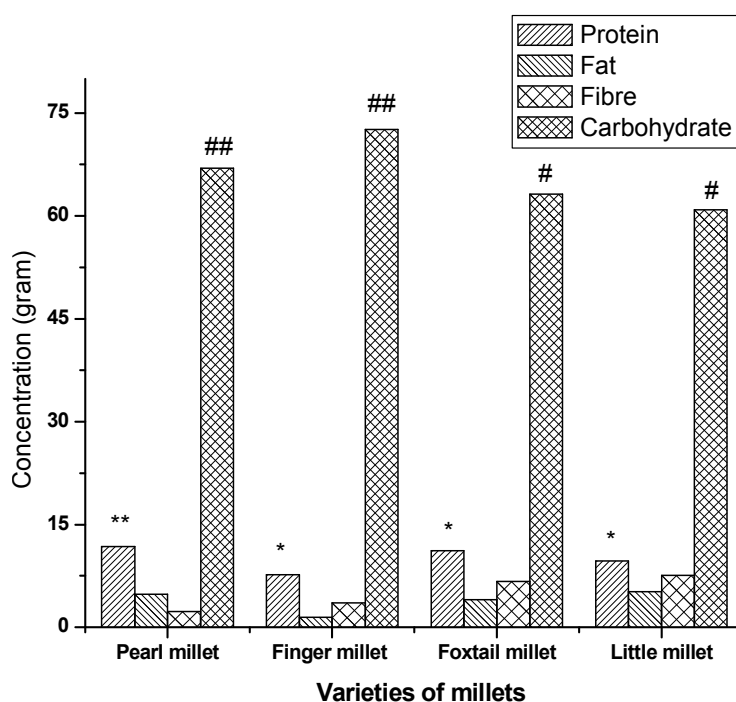
Crops	Dry matter (g/ha/mm water) at irrigation level			
	S0	S1	S2	S3
Sorghum	15400	16400	18500	14000
Pearl millet	14600	13800	16300	17900
Maize	15000	12800	13700	11000

Source: Singh and Singh (1995)

### 1.2. Pearl Millet's Nutritional Parameters

Nutritional levels of food are of utmost importance according to human health prospects because nutritionally sufficient food will provide proper development and increment in genetic potential in man. Also for the solution of the large scale problem of insecurity of food and malnutrition, dietary quality is of major concern (Singh and Raghuvanshi, 2012). Millets along with cultivation advantages are researched to be grains of high nutritive value than that of major popular cereals, rice and wheat (Parameswaran and Sadasivam, 1994). Research says that millet crop proteins have high amounts of amino acids in comparison to other cereals but has less lysine and threonine content whereas methionine is relatively in higher amounts. They are also rich

micronutrients and phytochemical sources (Mal *et al.*, 2010; Singh *et al.*, 2012). The nutritional parameters of pearl millet are given in table below (Table 2a and 2b).



**Fig. 1.** Composition of macronutrients in millets per 100 g of edible portion. Protein concentration in pearl millet is significantly higher (\*\*) than others (\*). Carbohydrate content of pearl millet is also high among the above varieties except than that of finger millet. Fibre content is high (##) in finger millet and pearl millet as compared to other millet crops (#).

The compositional proportion of macronutrients i.e. the amount of protein, fat, fibre and carbohydrates in different varieties of millets are shown above (Figure 1). The significantly high protein level of pearl millet compared to others proves its good nutritional status. The carbohydrate

content in pearl millet is less than that of finger millet but is higher than others so it is also a high energy source with respect to others and also more fat content than finger millet makes pearl millet a highest energy providing one out of all, which is given in detail in further section.

**Table 2a.** Major Nutrient composition of millet as compared to other cereals (per 100 g edible portion).

Constituent	Pearl millet	Wheat	Rice	Sorghum	Maize
Protein (mg)	11600, 11800, 11000**	11800	6800	10400	4700
Crude fiber (mg)	2300*, 2200**	1200	200	1600	1900
Fat (mg)	5000, 4800*, 5000**	1500	500	1900	900
Carbohydrates (mg)	67000*, 69000**	71200	78200	72600	24600

\* Hulse. Laing and Pearson. 1980: United States National Research Council/National Academy of Sciences. 1982. USDA/HNIS. 1984.

\*\*Source: Cultivated plants, primarily as food sources – *Sorghum and Millets* - Irén Léder, Nutritive value of Indian Foods, NIN, 2003

**Table 2b.** Micro Nutrients of cereals compared to pearl millet per 100 g of edible proportion.

Constituent	Pearl millet	Wheat	Rice	Sorghum	Maize
Minerals (g)	0.0023	0.0015	0.0006	0.0016	0.0008
Phosphorous (g)	0.296	0.306	0.160	0.222	0.121
Calcium (g)	0.042, 0.042*, 0.025**	0.041	0.010	0.025	0.009
Zinc (g)	0.0031,	0.0027	0.0014	0.0016	-
Iron (g)	0.008, 0.011*, 0.003**	0.0053	0.0007	0.0041	0.0011
Magnesium (g)	0.137, 0.106#	0.138	0.090	0.171	0.040
Sodium (g)	0.0109	0.0171	-	0.0073	0.0517
Riboflavin (g)	0.00025, 0.00021*, 0.00015**	0.00017	0.00006	0.00013	0.00017
Vitamin A (µg)	132	64 0	0	47	32
Folic acid (µg)	0.0455	0.0366	0.008	0.020	-
Niacin (g)	0.0023, 0.0028*, 0.0032#, 0.0020**	0.0055	0.0019	0.0031	0.0006

\* Hulse. Laing and Pearson. 1980: United States National Research Council/National Academy of Sciences. 1982. USDA/HNIS. 1984.

# Source: <http://www.wholehealthmd.com/refshelf/Foods view/1,1523,72,00.html>

\*\*Source: Cultivated plants, primarily as food sources – *Sorghum and Millets* - Irén Léder, Nutritive value of Indian Foods, NIN, 2003.

### 1.3. Energy Provided

Pearl millet is great in providing energy approximately 361 kcal of energy per 100 g is estimated which in comparison to other cereals like rice (345 kilo calorie per 100 gm), wheat (346 kilocalorie per 100 g), maize (125 kcal per 100 g) is more. All values are according to Indian food's nutritional value (NIN, 2003). Also among different varieties of millets, pearl millet possesses highest energy which is evident by the figure shown below (Fig. 2). After pearl millet there is foxtail millet which stands on the second position with energy supply of 351 kcal and then follows finger millet (336 kcal) and then little millet with 329 kcal per 100 g of millet.

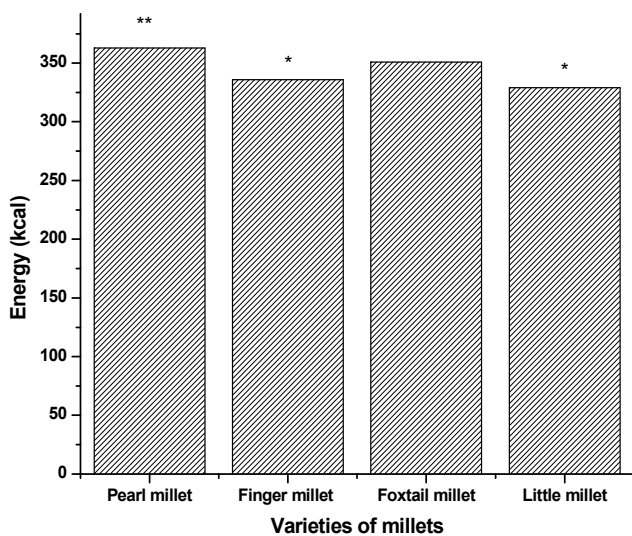


Fig. 2. Net energy yield from varieties of pearl millets per 100 g of edible proportion. Net energy yield in pearl millet is higher (\*\*) than others (\*).

## 2. Macronutrients

### 2.1. Carbohydrate

Content of carbohydrates in pearl millet amounts to 67.5 g/100g, this value is lesser than that of wheat, sorghum and rice but is more than that of maize as per NIN 2003. Carbohydrates are mainly stored in the form of starch in millets, and consist of amylose, a polymer with straight chain and amylopectin, polymer with branched chain (Malleshi and Klopfenstein, 1998; Odusola, 2013). 56%-65% kernel is comprised of starch which has 20%-25% amylose and range of sugar which is free in the grain is 2.6% - 2.8%. Sucrose is the main component of sugar in foxtail, pros, finger as well as pearl millet (Shivaraj and Pattabiraman, 1981). The physical and chemical properties of starch are responsible for providing texture to the food prepared from these grains and in water medium the behaviour of starch depends upon concentration and temperature (Whistler and Paschall, 1967).

### 2.2. Protein and Associated Quality

Pearl millet has 9% to 13% of protein content in general but variation of 6% to 21% has been observed (SernaSaldivar,

McDonough and Rooney, 1991). This content of protein is nearest to the concentration in wheat but is more than rice, maize and sorghum according to NIN 2003. It also has improved balance of amino acids compared to sorghum. In comparison to maize, pearl millet has 8% to 60% high levels of crude proteins and 40% more rich in lysine and methionine. Pearl millet lysine level is 21% more than corn and 36% more than sorghum (Irén Léder, 2004). Quality of protein is having strong relation with patterns of distribution of fractions of proteins. Detailed information about protein fraction can be given as: out of total nitrogen, 22-35% of prolamin and prolamin like, 22-28% albumin and globulin and 28-32% glutelin and glutelin like. It lacks gluten and is an exception that retains alkaline property after cooking also which is profitable for those having allergy from wheat.

### 2.3. Lipid

Pearl millet has rich content of fats (5 mg per 100 g according to NIN 2003) in comparison to other food grains. Out of all fatty acid present unsaturated are 75%. Linolenic acid and Omega-3 accounts for 4% of total content of fatty acid present in pearl millet (Chowdhury and Punia 1997, Rooney, 1978). This gives it a higher amount of fatty acids having n-3 as compared to other cereals. Researchers like Orban and Adeola in 1994 evidently said that fat digesting capacity is much more in pearl millet as compared to corn. Varriano-Marston and Lai in 1980 reported pearl millet have large sized germs which lead to rapid fatty acid development in meal of pearl millet and this occurs due to lipase action causing bitterness and leading to an unacceptable meal after the milling action.

### 2.4. Micronutrients

#### *Vitamins and Minerals*

Pearl millet has various micronutrients which are essentially required by our body. Total content of minerals is 2.3 mg per 100 g which is more in quantity in comparison to other cereals consumed commonly. It is a rich source of potassium, B-vitamin, phosphorous, copper, magnesium, zinc, iron, manganese (NIN, 2003). Matured and dried kernels do not have vitamin C but vitamin B is present in sufficient amount in aleurone layer and the germs. Decortication used for removing hull results in reduced levels of niacin, riboflavin and thiamine to an extent of 50% in flour. In cereals, niacin is present in both bound and free form and is mainly synthesized by using tryptophan (Sandberg, 2002). Quantity of niacin is enough even in hulled form of millet. This is the reason that pellagra-the deficiency disease is rarely found in high millet consuming areas. Pearl millet accompanying grains of other types have oxalic acid which by forming a complex, which is insoluble, with calcium results in reduction of bioavailability of this mineral (Pawar and Machewad, 2006). The concentration of calcium in pearl millet is very less and if oxalate is present then the condition will become worse.

### 2.5. Dietary Fibre

Dietary fibre is a term which describes polysaccharides from plant source which are indigestible and they include hemicellulose, cellulose, oligosaccharides, pectins, gums and other lignified components. In 1980, Kamath accompanied with Belavady by using analysis protocols of Hudson, Southgate and Englyst, found that the total fibre of 20.4% is present in pearl millet and 18.6% of fibre is in finger millet which is higher than sorghum fibre content of 14.2%, wheat fibre content of 17.2% and rice fibre content of 8.3% (ElSheikh *et al.*, 2000).

### 2.6. Inhibitory and Toxic Factors

All the legumes and the cereals are having high mineral content but due to some anti-nutritional components like polyphenols and phytate their bio-availability decreases (Valencia *et al.*, 1999). Minerals are also found in large quantity in pearl millet but the nutritional level depends on the chemical composition and the amount of anti-nutritional components such as polyphenols, tannin, trypsin and phytic acid which are not desired as they reduce mineral bioavailability (ElSheikh *et al.*, 2011). Phytate, the leading phosphorous storage form is most abundantly found in legumes and cereals (Reddy *et al.*, 1989). They form chelating compounds with Ca, Mg, Zn and Fe thus making them less biologically available (Sandberg, 2002). Due to lack of absorbance of phytate and limited hydrolysing ability of body they give hazardous effect on mineral bio availability (Pawar and Machewad, 2006).

Another such compound is tannins which are grouped as non-nitrogenous phenolic compounds and can be classified as condensed and hydrolysable tannins (Muthulisi, 2007). These tannins impair nitrogen retention and nutritional digestibility as well as cause reduction in intake of feed (Muthulisi, 2007). Pattabiraman and Shivaraj in 1981 reported an inhibitor's presence which is a bifunctional single protein responsible for inhibition of amylase as well as trypsin at different respective sites. Chandrashekara *et al.* in 1982 concluded that there are considerable amount of differences in inhibitors of proteases in millets and also reported that finger millet has greater antitryptic activity as compared to antichymotryptic.

### 2.7. Technologies of Grain Processing and Their Effect on Nutritional Quality in Millet Grains

There are some leading technologies used in food product manufacturing and these are related to enhancement of sensory property, nutritional characteristic and also the convenience of uptake. Various food processing methods frequently used in house hold and other common preparation methods are also effective in enhancing the availability of nutrients in body usually in diets based on plants. These various methods are mechanical processing, germination or malting, thermal processing, soaking and fermentation. The mentioned processes mainly increase physiological and chemical accessibility in body of micronutrients and also

decrease antinutrients like phytates or enhance the components responsible for increasing bioavailability (Hotz and Gibson, 2007).

#### (a) Decortication or Dehulling

In 1979, Scheuring and Rooney defined decortication which is also called as dehulling or pearling, as a technique of removing pericarp from grains of cereals. It improves texture, colour and cooking quality of respective grains. The most in demand decortication is when only the pericarp is removed of pearl millet which have large amount of polyphenols but the germ which contain most of the nutrition is retained in the endosperm (Dykes and Rooney, 2007). Some coarse grains and millet are subjected to dehulling and other treatments and then consumed to increase edible and sensory quality (Liu *et al.*, 2012). These decorticated forms of millet are cooked as rice to get an edible soft texture in 5 minutes which is difficult without dehulling. Dough and pasting properties and other functional characteristics indicates the versatility for diverse use as food (Shobana *et al.*, 2007). This decortication is done to an extent so that only 12-30% of outer surface of grains is removed. Excess decortication leads to loss of fat, ash and fibre. In monocots, phytic acid is found in grain's outer layer and to some extent inside the germ. So the decortication process highly causes the reduction of phytates (Dlamini *et al.*, 2007). More efficient technology of dehulling is required so that only the phytic acid containing germ is removed and no excess loss of grain may occur. For the production of low fat meal approximately 40% grain should be decorticated giving out a flour yield of 60%. Along with it this leads to protein loss, insoluble fibre, ash, fat, lysine and also some more amino acids (Serna-Saldivar *et al.*, 1994). Over all that this process removes the amylase inhibitors, phytic acid and polyphenols with an increase in starch digestibility, protein content, and availability of minerals (ElShazali *et al.*, 2011; Malleshi and Klopfenstein, 1998).

#### (b) Milling

Maximum number of millets which are frequently produced in our country are considerably staple food and so less readily used and are not convenient for making food products due to lack of milling technology. The major utilization of millet crop is due to the reason of fibrous coarse seed coat, astringent flavour, coloured pigment, and poor processed product keeping quality (Archana and Kawatra 2001). Hammer or roller mills are usually used for grain milling but the flour from hammer mill contains large size of particles and not so uniform so not convenient for preparation of stiff and thin porridge having rough texture and also for the preparation of steamed and baked smooth textured food.

Milling effects are studied by many researchers with the concerns to milling fraction and nutritional contents. One study suggested that milling changes the chemical composition at gross level in pearl millet. Additionally, during chapatti making heat treatment and milling lowers phytic acid and polyphenols and also improves starch and protein digestibility significantly (Chowdhury and Punia, 1997). One more advantage with this process is, it reduces microbial population on grain.

### (c) Malting

Limited germination under moist controlled conditions of cereals is malting. In concern with pearl millet the procedure consists of soaking and then germination for varying period. Then after these steps the grains are subjected to drying in oven then by the use of abrasives vegetative growth is removed (Beta *et al.*, 1995). This technique enhances the starch and protein content digestibility of pearl millet and even improvement of crop is much more when germinated as compared to balancing (Archana and Kawatra, 2001). Digestibility of proteins is improved by the above mentioned steps of malting and also contributes for the reduction of anti-nutrients like tannins, phytic acids and polyphenols those are capable of having interaction with the protein by forming complexes (Hassan *et al.*, 2006). This malting process decreases soluble proportion of oxalates in pearl millet from 0.502-0.068% and also increases proportion of calcium which is soluble from 2.4-14.1 mg per 100 g of grain (Saleh, 2013). This process of malting enhances the contents of nutrients and food digestibility and this can prove itself a good one to derive minerals like iron etc. from grains (Platel *et al.*, 2010). Malting can also be used in combination of processes to make the grains malt rich which will provide us with opportunity to prepare healthy, nutritious products like infant diet, food blends and complementary products of food.

### (d) Fermentation

Fermentation is in wide use due to its concerns with food preservation. It possesses potential to preserve a large variety of food products and give varying flavours along with improved nutritional property. These fermented foods are taken up by a large population over the world due their above mentioned importance (Mugocha *et al.*, 2000; Gotcheva *et al.*, 2001). While fermentation proceeds, enzymes present in grains and media accounts for soluble sugar and starch degradation. Nutritional quality of fermented cereals is higher due to increased bioavailability of nutrients (Elyas, 2002). As the fermentation time increases, correlation between increase in mineral bio availability and non-nutritional components reduction like that of tannins and phytic acid improves. In 1987, Dhankher and Chauhan reported that pearl millet fermentation of 9 hrs decreases the phytic acid from 27 to 30% and polyphenols from 10 to 12%. These grains before their germination occurs and fermentation process occurs are steeped. Increased germination time and the fermentation time lead to increasing amylase production and also increases soluble sugar content. On the basis of literature, one can lead to a conclusion that enzyme based hydrolysis and fermentation are quite promising for obtaining highly nutritious food when used singly or in combinations.

### (e) Soaking and cooking

Grain soaking is helpful and is widely used to reduce non-nutritional components and improve mineral bioavailability. Performed studies about leaching and degradation of phytates and their activity and zinc and iron concentrations are done after applying soaking operation on flour, dehulled and whole seeds. Results obtained indicated that milling and dehulling when performed earlier to soaking

improves phytates leaching in aqueous solution also and leads to its degradation. Though flour cooking when done using the water used for soaking do not enhances degradation of phytates (Lestienne *et al.*, 2007). Reduction of minerals was observed when acid soaking period of pearl millet is increased but enhancement in HCl extractability varied to some extent. Moreover no effect of irradiation was observed on anti-nutrient phytate and tannin on 2 cultivations but when preceded by cooking significant reduction in their levels for both dehulled and whole grains flour was observed. In foxtail millet dehulling process, soaking process and then cooking decreases anti-nutrients, improve mineral bioavailability and improved digestibility of protein *in vitro* (Pawar and Machewad, 2006). Hence, soaking along with cooking can be opted as pre-treatments when optimized conditions are present for the reduction of anti-nutrients in millets to increase bioavailability of nutrients and the quality of nutrition of millet products.

## 3. Millet Based Products and Formulations

### (a) Composite Flour

Though millets have high nutrition than that of the cereals even then their utilization is not considerably flourished, their utilization can be increased by a way that directs to blend them with wheat flour (Singh *et al.*, 2005). By this blending nutritional, physical, chemical as well as functional changes can be observed. Extruded products like macroni, spaghetti, etc. prepared form porridges made of millets which are extruded and cowpea (press dried) have higher nutrition with weaning foods acceptable properties (Almeida-Dominguez *et al.*, 1993). Pearl millet blended snacks are of low cost (Balasubramanian *et al.*, 2012). Millet along with buck wheat and amaranth are used in place of maize and wheat flour for extruded snacks manufacturing. Incorporation of millet flour in wheat flour was done by Kamaraddi and Shanthakumar in 2003 and studies were conducted on rheological, chemical as well as baking properties. This type of replacement of wheat with millet in flour is 10-20% possible as this increases the ash content and also decreases the damaged protein and starch percentage. Although the colour of crust remains unchanged on the other hand crumb colour changes from white creamy to light brown. In 2005, Singh *et al* primed flours of finger millet, barnyard and foxtail with flour of wheat by the addition of 10% to 30% of millet flour and noticed that this has enhanced the fat, protein and ash concentration. One of the study prepared biscuits from pigeon pea and millet flour in different ration of constituents in the blend and observed high carbohydrates and protein concentrations. Results from sensory evaluation shows high ratings of sensory properties and blend recipe of 65/35% of millet/pigeon pea has given high scores for texture, flavour and acceptability (Eneche, 1999). To prepare noodles by incorporating finger millet for diabetics, flour of finger millet in varying proportion was blended with wheat flour. This proportion ranges from

30-50%. On sensory evaluation basis, the result of glycemic index having 30% finger millet in the above noodle preparation was lower compared to control (Shukla and Srivastava, 2011). Thus such type of millet blending apparently shows that this is the easiest technique to get enhanced nutrition and functional levels of the food product for promoting its utilization.

#### (b) Baked products

Products of bakery are becoming popular over the whole world because of their varying taste, less cost and profile textures along with packaging which is attractive and long shelf life which suit marketing (Patel and Rao, 1996). As pearl mill is gluten free, the dough which is formed is of low consistency so it is not considered as a good bakery raw material. Though after treating the pearl millet flour that is by hydrating it with water, drying and then supplementing with 0.6% of unrefined soy lectin will give better results, this will make cookies of spread property equivalent to soft cookies of wheat flour. Different varieties of cookies are being developed by complementing different malted millet flour along with blanched flour and are being found acceptable and convenient to be stored till 3 months (Singh 2003). Wheat and pearl flour blends are being used for long to make products like cakes, yeast leavened bread, cookies, muffins and biscuits (Torres *et al.*, 1993; Suhendro *et al.*, 1998). Researches approved that 40 percent wheat flour substitution with millet in bakery products is good like in biscuits and cakes (Begum *et al.*, 2003; Yenagi *et al.*, 2013). Many attempts are being done to increase the nutritional level of cakes in respect to fibre and minerals by the supplementation of finger millet malted flour (Desai *et al.*, 2010). But making of zero wheat millet or sorghum bread is still a challenge (Taylor *et al.*, 2006). Some tried for 100% pearl millet or sorghum cookies but they had tough, gritty, hard and mealy taste and texture. They lacked cracks on top and spread but lipid composition proved them inferior.

#### (c) Extruded Products

Extrusion is in increased use for the production of ready to eat products. In this process cooking of cereals is done at high temperatures for small amount of time. This leads to gelatinized starch and denaturation of protein to improve digestibility, also anti nutritional factors get inactivated (Rooney and Awika, 2004). Utilization of this technique has various advantages for example high productivity, versatility, high quality, increased *in vitro* digestibility of proteins (Dahlin and Lorenz, 1992). This process increases availability of iron in extruded foods which are based on cowpea, pearl millet and peanut powder about 3.5-6.5 times more than corresponding weaning roasted foods (Cisse *et al.*, 1998). Optimum quality extruded food snacks which are millet based are prepared by use of twin screw type extruder from the blend of kodo millet and cowpea in ratio of 70:30; finger millet, pearl millet and soyabean blend or soy, ragi, rice and sorghum blend of flour (Geetha *et al.*, 2012; Balasubramanian *et al.*, 2012; Seth and Rajamanickam, 2012). Extruded product production with millets is suitable like noodles, vermicelli etc. as millet contain unavailable carbohydrates in higher proportion which decreases the sugar release and thus responsible for lower

glycemic index. Though millets have high nutritive value but their utilization is not flourished even when many millet flours have potential to be used at industrial scale for various products formation on the basis of functional characters (Singh *et al.*, 2005). Pasta is usually made from durum wheat as it maintains firm desirable texture while cooking and have amber natural colour associated with high quality pasta. Some other ingredients like amaranth, buck wheat, lupin flour, millet have been used for increasing functional and nutritional quality of noodles and pasta (Devaraju *et al.*, 2008; Shukla and Srivastava, 2011). Snacks extruded with millet flours having rice or corn or starch tapioca in specific proportion can give desirable texture, colour, flavour and appearance (Siwawij and Trangwacharakul, 1995). So in support of all these researches, this can be concluded that pearl millet accompanied with others gives acceptable quality of extruded products.

#### (d) Fermented Products

Idli and dosa are the most widely consumed fermented foods in India. Other fermented foods are also quiet popular and consumed all over the world because of the importance as human food (Mugocha *et al.*, 2000; Gotcheva *et al.*, 2001). Fermentation modifies the chemical composition of the grains of millet and thus the food products manufactured from it. This process also contributes to the reduction in the level of anti-nutritional components and enhances the *in vitro* protein digestibility (abbreviated as IVPD). It has also been observed that pearl millet when processed and then fermented shows the same significant reduction of anti-nutritional components along with increase in IVPD (Hassan *et al.*, 2006). Pearl millet when fermented leads to chemical changes in its composition like ash content, moisture content, fat, fibre and protein and also causes marked reduction in minerals like potassium, sodium, copper, magnesium, zinc, iron etc. (Ahmed *et al.*, 2009). High protein digestibility is observed when pearl millet germinated in ground is fermented, which accounts for 90%. For the fermentation process many microorganisms are used for pearl millet in some study researchers used yeast and *lactobacilli* alone and also in combinations with the natural microbial flora at a temperature of 30°C for a duration of 48 hours after applying various treatments for processing. This study showed that yeast and *lactobacilli* when used in combination proved it an effective technique as it increases protein digestibility along with starch digestibility more efficiently than when done with pure cultures (Sharma and Kapoor, 1996). Fermentation when done naturally reduces total phytic acid and polyphenols concentration in the crop (Elyas *et al.*, 2002). Different recipes like weaning mixtures, vermicelli, cutlets and biscuits from mixed and naturally fermented pearl millet flour made a great place in consumer world. Fermentation by pure culture can be included in diet easily without any problem for the improvement in protein and mineral availability and starch digestion (Maha *et al.*, 2003). On the basis of updated literature, this can be suggested that enzyme hydrolysis and fermentation can be a profitable formula to improve the nutritive value and the reduction of anti-nutritive constituents. Though on large scale these techniques are not so frequently used but are common on

house hold levels.

(e) Flakes and pops

Cereals can be puffed or popped and can be taken as snacks with salt or sugar or spices. Studies on flaking of sorghum were done at CFTRI in Mysore and standardization of various parameters like temperature, dry heat treatment condition, wet heat, and soaking time was done (CFTRI, 1985). The soaked grains to their equilibrium content of moisture is roasted to the stage at which the starch is fully gelatinized then they are dried to the extent that only 18% of moisture remains, then conditioned, decorticated, and lastly flaked with in time by heavy duty rollers. Structural changes occur in starch or matrix of protein on flaking and puffing. Starch of millet or pasta that is preconditioned, on puffing cause expansion of grains or pieces of pasta and thus leads to a puffed high crisp product and also contribute other attributes concerned to texture. Maillard reaction occurs during puffing in which the sugar in the layer of aleurone react with millet's amino acids and communicate a desired and pleasant aroma to the products. It works for the reduction of phytates, polyphenols, tannins etc. and increases the availability of minerals to the body, gives good texture, and increases the digestibility of carbohydrates and proteins (Nirmala *et al.*, 2000). Popping ratio and volume are affected by properties like porosity, kernel size, bulk density, moisture and salt or sugar. Acceptable temperature and moisture deals importantly with the quality of cereals popped as this process produce steam and pressure inside the grains (CFTRI, 1985). The process when applied to pearl millet after conditioning with sand at 250°C temperature results in expansion in size of 2.3 to 11.3 percent and yield of 8.3 to 77.1% (Hadimani *et al.*, 1995). This process also decreases 21 to 50% phytic acid and tannins to 3 to 18% (Wadikar *et al.*, 2006). On the other hand, it increases significantly the zinc bio availability which is 18 g per 100 g in pearl millet (Krisnan *et al.*, 2012). As the moisture content is reduced significantly to 3%-5% the shelf life is increased (Verma and Patel, 2013). Advantages of this process are being mostly utilized to make mothers and infant weaning foods (Bhaskaran *et al.*, 1999). As pearl millet has rich resource of micronutrients source and phytochemicals, products of pearl millet will gain more scores than those of wheat and rice.

(f) Healthy foods

Coarse grains especially millets are rich source of nutrients

and are source food capable to prevent diseases like degenerative ones such as cancer, diabetes, cataract, Parkinson's etc. and also enhance the health by the presence of biologically active chemicals in plant food and other health promoting chemicals. Millets are the safest diet for people with celiac disease and gluten allergy due to the property of not forming acids and anti-allergic properties (Saleh *et al.*, 2013). Pearl millet contains high insoluble fibre content and can be used for the preparation of various health profiting foods. These fibres cause slow sugar release thus making it a good diet for diabetic patients. Along with all this pearl millet has low glycemic index which can in turn prove it profitable (Table 3).

**Table 3.** Pearl millet based diabetic food product's health values.

Product	Glycemic index	
	Pearl millet-based products	Control (wheat flour)
Chapati	48.0	69.4
Biscuit	58.1	72.7
Instant idli	52.1	69.8
Dhokla	38.0	68.4

Source: Mani and others (1993).

Pearl millet is an excellent antioxidant source which can scavenge the free radicals and have reducing capabilities (Muthulisi *et al.*, 2007; Odusola *et al.*, 2013). Some compounds like phenols which are popular antioxidants also show treating effects on diabetes and can be used for its cure. In 2007, Dykes and Rooney reported presence of anthocyanins in pearl millet and pigmented sorghum in the pericarp which can be removed during dehulling along with bran which can have specific value at industrial level (Dykes L, Rooney, 2007).

## 4. Additional Health Benefits of Millets

Being a economically feasible and high nutritious diet, millets also comprise other essential health benefits. Its outstanding composition makes it an effective food for the treatment of cancers, anaemia, diabetes, constipation, non-communicable diseases and allergies. Several research studies have shown that millets contain several nutrients that supports in potential health benefits and thus accepted as functional and nutraceutical food (Table 4) (Saleh *et al.*, 2013).

**Table 4.** Additional health benefits of pearl millet.

S. No.	Health Disorder	Potential Assistance	Positive Properties in Pearl millet
1	Anemia	Enhancing the level of Hb	High iron and Zinc content
2	Constipation	Reducing the problem of constipation	High fiber
3	Cancer	Anti carcinogenic property, Reduce the risk of tumor development	Antioxidant property, high flavonoids
4	Diabetes	Anti-diabetic	Low glycemic index
5	Celiac	Anti allergic	Gluten free
6	Diarrhoea	Act as Probiotic	Lactobacillus
7	Non Communicable Diseases	Inhibits DNA scission, LDL cholesterol, liposome oxidation and proliferation of HT-29 adenocarcinoma cells.	Flavonoids, Omega 3 fatty acids

Source: Vanisha *et al.* (2011)

Pearl millet contains high amount of Iron (8mg/100g) but many non-nutrient components are responsible for decreasing

the bio accessibility of iron. By the use of household processing technologies, such as germination and



fermentation we can reduce the amount of non-nutrient components and can support the cure of anaemia (Sharma and Kapoor, 1996).

The high fiber content is helpful for those people who are dealing with the problem of obesity and constipation. Pearl millet is a good source of fibre (1.2g/100g) and can be used to prepare healthy foods (NIN 2003). Millet grains are rich in antioxidants and phenolics so they can contribute to antioxidant activity important in health, aging, and metabolic syndrome (Bravo 1998). The major factor for ageing is the chemical reaction between the aldehyde group of reducing sugars and the amino group of proteins. Studies have shown that methanolic extracts from millet inhibit glycation and cross-linking of collagen. Therefore helps in the protection against ageing (Hegde et. al. 2002). Phenolic compounds have also anticancer property. These compounds are concentrated in the pericarp and testa. Flavanoid, a phenolic compound, helps to inhibit tumor development and reduce the risk of breast cancer (Huang and Ferraro 1992). Gluten intolerance, is a physiological and lifelong disorders affecting humans in many areas of the world (Catassi and Fasano 2008). Being a gluten free grain, millet is useful for those people who are suffering from celiac disease (Chandrakara and Shahidi 2011). It is the only grain that retains its alkaline properties after being cooked which is ideal for people with wheat allergies (www.icrisat.org). Some studies were carried out on humans (male & female) in order to investigate the effect of millet grains and their fractions on diabetes. Results have shown that persons who consumed millet diet were found to have considerably decreased blood glucose levels (Pradhan et. al. 2010). Various pearl millet-based food products were found to have a lower glycemic index (GI) than those based on wheat (Mani et. al., (1993)). Low glycemic index of foods are useful because it improves the metabolic control of blood pressure and low density lipo protein cholesterol levels (Asp, 1996).

## 5. Conclusion

Though the health benefits and nutrition provided by millets is equivalent to other major cereals like rice, wheat and maize but the technologies used to process can work out to improve its quality in terms of nutrition and other edible properties for house hold consumption. The present work complies scientific studies done, till date, for the improvements of processing of millets and nutritional improvements to get high quality food products. Increment and efficiency advancement in post-harvest technology and value addition technology has given opportunities to prepare and process enhanced products which are accepted by both urban and rural consumers. Even more high quality products of millet are required to enforce well-being and profit to all producers to farmers. So this topic of millets demands extensive research for improved millet food products that not only provide good health and other beneficial effect but also have good taste, extended shelf life and appealing colour and are also economically feasible for all

grades of population.

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