ORIGINAL ARTICLE

Nutritional and Nutraceutical Properties of Millets: A Review

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ABSTRACT

Millets are one of the underutilized groups of cereal grains. In spite of the presence of high nutritional and nutraceuticals components, these are still considered as food of poor people. Millets are considered as rich source of energy, carbohydrate, and protein and are comparable to other cereals but have more fat, calcium, iron, dietary fiber, and Vitamin E (tocopherols and tocotrienols) content. These are found to be rich sources of phytochemicals such as phenolic acids, flavonoids, catechins, phytic acid, and phytosterols. Researchers have reported that the presence of dietary fiber and phenolic compounds help in the prevention of many diseases such as diabetes, cardiovascular diseases, and cataractogenesis. These phytochemicals are reported to have antioxidant and antimicrobial properties also.

Key words: Antioxidants, diabetes, millets, nutraceuticals, nutrition, polyphenols

INTRODUCTION

Millets are small-seeded grasses that are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture. They account for <1% of global cereal production and 3% of coarse cereal production. African countries account for 59% of the global area under millets and 55% of global production. Asian countries are the second most important block of millet producers, accounting for 38% of the global area and 42% of the global production. As per the FAOSTAT, global millet production for the year 2016 was 30.35 million tonnes. Indian millet production is ~10 million tons and in that small millet production is 467 thousand tons. Millets are consumed primarily as food in most of the developing countries. It is highly nutritious, high energy food, and in recent years, an important component of processed foods.

Major millets are sorghum and pearl millet. Among the millets, small millet comprises finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), proso millet or white millet (*Panicum miliaceum*), barnyard millet (*Echinochloa* spp.), kodo millet (*Paspalum scrobiculatum*), and little millet (*Panicum sumatrense*).

NUTRITIONAL COMPOSITION

Millets are rich in valuable nutrients such as carbohydrates, proteins, dietary fiber, minerals, and vitamins. Protein content is very much comparable to other cereals, but carbohydrates are present in lower amounts. Fat content of common millet, foxtail millet, and barnyard millet is very high and is one of the reasons of reduction in storage stability. Millets are rich in ash content showing a higher amount of inorganic matter. Finger millet is known as the richest source of calcium [Table 1].

Carbohydrates

The millet carbohydrate in the milled grains consists of free sugars (2–3%), non-starchy polysaccharides (15–20%), and starch (60–75%). Among the free sugars, glucose, fructose, and sucrose are prominent. The non-starchy polysaccharides,

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which are regarded as dietary fibers comprises of cellulose, hemicellulose, and pectinacious material. Flatulence causing oligosaccharides such as arabinose and stachyose are absent. Negligible amounts of β-glucans and lignin-like materials are present. Out of total dietary fiber, 90% is insoluble dietary fiber contributed by aleurone layer and cell wall matter of the kernel. Millet starch contains amylose and amylopectin in ratio 25:75 as contained in other cereals also. Millets are known as high amylose grains and some waxy varieties are also cultivated in China. Starch granules are compacted in the cellular matrix and a major portion of endosperm is of vitreous nature.[1] The nutrient composition is shown in Table 2.

Studies by Subramanian and Jambunathan,[2] Subramanian and Jambunathan,[3] Murty *et al*.,[4] Wankhede *et al*.,[5] and Becker and Lorenz[6] have revealed that total sugars (g/100 g) in pearl millet (2.16–2.78) are higher followed by finger millet (0.59–0.69) and foxtail millet (0.46).[2-6] Raffinose and stachyose are also higher in pearl millet. Sucrose is major sugar (g/100 g) in finger millet (0.20–0.24), foxtail millet (0.15), and proso millet (0.66).

Proteins

Millets have been reported to have albumins, globulins, cross-linked prolamin, glutelin-like, glutelin, etc., type of protein fractions. Millets are richer in prolamin and glutelin fractions followed by albumin + globulin fractions. Prolamin in pearl millet range from 22.8 to 31.7(%), finger millet have 24.6–36.2 (%), and foxtail have 47.6–63.4 (%) of the total protein fraction. Glutelin is higher in case of finger millet 12.4–28.2 (% of total protein) then foxtail (6.7% of total protein). Albumin + globulin fraction ranges from 11.6 to 29.6 % in these millets.[7,8] Essential amino acid composition of millets is given in Table 3. Of all millets, pearl millet has highest average protein (6.9–12%) whereas fonio and finger millet tend to have lowest protein values (5.1–10.4, 4.9–11.3%), respectively. Lysine content of finger millet is 5.5 g/100 g of protein. Teff (2.0–4.0/10 0g protein) and kodo millet (3.0–3.5/100 g proteins) are high in lysine. Proso and Japanese millets have the poorest essential amino acid composition.[9] True digestibility of millet proteins varies from 95 to 99.3 lowest for foxtail and barnyard millets while highest for common millet.[10] Biological value and net protein utilization of pearl millet protein (BV = 58.8–65.6 and NPU = 55.7–62.9) is higher than in minor millets (BV = 48.4–56.5 and NPU = 46.3–54.5), whereas digestible energy of minor millets (95.6–96.1) is higher than pearl millet (85.3–89.9).[10,11]

Table 1: Phenolic content and reducing capacity of millets

Millet	Phenolic content (%)	Reducing capacity (%)
Finger millet	7.2±0.57	5.7±1.15
Foxtail millet	2.5±0.56	4.8±1.15
Proso millet	3.4±0.58	2.6±0.20
Khodo millet	10.3±1.15	4±1.73

Source: Rao *et al*., (2011)

Lipids

The fat content of the millets ranges from 1% to 5%, lowest in finger and kodo millet (1%) and highest in pearl, foxtail, and proso millets (5%). The fat is distributed in bran as well as in the endosperm. The fat generally consists of more than 60% unsaturated fatty acids including linolenic acid.[1] Common millet contains 1.8–3.9% lipids. The embryo contains about 24% of the total grain fat. The fatty acid profile showed the total amount of saturated fatty acids present is 17.9–21.6% while unsaturated fatty acids content is 78–82%.

Lipids extracted from millets when calculated on seed dry weight basis found to be 7.2%. This fraction consisted of neutral lipids, phospholipids, and glycolipids amounted as 85%, 12%, and 3%, respectively. 85% of the total neutral

Table 2: Nutrient composition of millets (per 100 g edible portion, Dry weight basis)

Source	Carbohydrates (g)	Crude Protein (g)	Fat (g)	Crude fiber (g)	Ash (g)	Energy (kcal)
Pearl millet	60.0–76.0	12.0 –14.0	4.8 –5.7	2 –2.5	2.0–2.2	363–412
Finger millet	60.0–80.0	7.0–10.0	1.3–1.8	3.6–4.2	2.6–3.0	328–336
Foxtail millet	59.0–70.0	11.2–15.0	4.0–7.0	4.5–7.0	2.0–3.5	330–350
Kodo millet	66.0–72.0	8.0–10.0	1.4–3.6	5.0–9.0	4.0–5.0	309–353
Little millet	60.0–75.0	10.0–15.0	5.0–6.0	4.0–8.0	2.5–5.0	329–341
Barnyard millet	55.0–65.0	6.0–13.0	2.0–4.0	9.5–14.0	4.0–4.5	300–310
Proso millet	55.0–70.0	10.0–13.0	1–3.5	2.0–9.0	2.0–4.0	330–340
Teff	70.0–73.0	10.0–11.0	2.0–4.0	1.0–2.0	2.8–3.1	330–340
Fonio*	75.0–82.0	7.0–9.0	0.5–2.0	2.0–3.5	1.0–4.0	360–370

*Wet weight basis. Sources: McWatters *et al.* (2003), Gebremariam *et al.* (2014), Sadik *et al.* (2012), Gopalan *et al.* (1989), Saldivar, (2003), Ravindran (1991), Hulse *et al.* (1980), and National Research Council (US), Board on Science and Technology for International Development (Eds.)(1996)

Table 3: Mineral composition of millets (mg/100 g)

Minerals	Pearl	Finger	Foxtail	Little	Proso	Kodo
K	440–442	408–570	250–400	129–370	250–320	144–170
Na	10.0–12.0	7.0–11.0	4.6–10	6–8.1	8.2–10	4.6–10
Mg	130–137	110–137	100-130	120–133	117–153	130–166
Ca	10.0–46.0	240–410	10.0–30.0	12.0–30.0	20–23	10.0–31.0
P	350-379	240–320	270–310	251–260	230–281	215–310
Mn	1.15–1.8	5–5.5	2.19–26	1.0–20.0	0.6–1.81	1.10–2.9
Zn	2.95–3.1	2–2.3	2.14–9	3.5–11	1.4–2.4	0.7–1.5
Cu	0.62–1.06	0.4–4	1–3.0	1.0–4.0	0.83–5.8	1.6–5.8
Fe	7.49–8.0	3.9–7.5	3.26–19	13–20	4.0–5.2	0.7–3.6

Sources: Varriano-Marston and Hoseney, (1980), Serna-Saldivar *et al*., (1991), Hulse *et al*.,(1980), Serna-Saldivar and Rooney, (1995), Pore, and Magar, (1979), Lorenz *et al*., (1976), Chung, (1991), Barbeau, and Hilu, (1993), Chavan, (1989), and Chavan, *et al*. (1989)

lipids were found to be triacylglycerols and rest contains a small fraction of mono- and diacylglycerols, free fatty acids, and sterols. Campesterol and stigmasterol were found to occur in same proportion in both free and esterified form. Lysophosphatidylcholine (42%) was the major phospholipid present in millet seeds. Smaller amounts of lysophosphatidylethanolamine (21%), phosphatidylcholine (24%) and traces of phosphatidic acid, phosphatidylglycerol, phosphatidylinositol, and phosphatidylserine were also present. The major glycolipids were sterol glycoside, esterified sterol glycoside, cerebrosides (ceramide monohexosides), monogalactosyldiacylglycerol, and digalactosyldiacylglycerol.[12]

Vitamins

The millets are rich sources of Vitamin E and B-complex vitamins (except Vitamin B 12). Total niacin content present is 10.88 mg. However, only 13% of the total niacin present was cold-water extractable. Matured grains of millets have shown low levels of Vitamin C. The tocopherol content of millets is less than that found in soybean and corn oil. The α-tocopherol content in millet seeds is very low and the tocopherols are mostly present as γ-isomer. Vitamin activity of α-tocopherol is very high as compared to other tocopherols. Vitamin E activity of γ-tocopherol is <10% that of α-tocopherol.[13] The unrefined fat is extracted using the kernel of common millet and was found to contain Vitamin A equivalent (8.3–10.5 mg) and Vitamin E (87–96 mg) per 100 g. When refining is carried out, it was found that vitamin A has lost its activity and losses in Vitamin E were also significant. In little millet, total niacin is quite higher compared to other cereal grains.

Minerals

Mineral content of millets is quite comparable to other cereals such as sorghum, but the content of calcium and manganese was found to be very high [Table 3]. High-yielding varieties and some high protein (8–12.1%) varieties of finger millet were found to contain calcium 294–390 mg/100 g.[14] Joseph *et al*., 1959 conducted studies on replacement of rice-based diet to finger millet, in the diet of 9–10-year-old girls showed that it improved calcium retention along with maintaining positive nitrogen balance. Thus, finger millet could be used in place of rice to overcome the calcium deficiency.[15]

The iron content of little millet and barnyard millet was very high 9–12%, whereas kodo millet and common millet were rich in copper content. The total mineral matter or ash content was higher in common, little, foxtail, kodo, and barnyard millets than most commonly consumed cereal grains including sorghum. The above-stated millets have highly fibrous hull and dehulling is a usual practice before consumption. However, dehulling was found to lower the content of mineral matter significantly, and this loss is variable and dependent on millet species. Dassenko observed significant losses of calcium, magnesium, and sodium but not of iron and potassium on milling pearl millet to flour with an extraction rate of 67%.[16] Millets are a rich source of phosphorus which is an important mineral for energy production. It is an essential component of ATP – the energy currency of the cell. It also forms a part of the nervous system and cell membranes. A well-cooked cup of millet gives 26.4% daily need for magnesium and 24% daily need for phosphorus. Magnesium from millets helps in relaxing blood vessels and maintains the blood pressure, enhances nutrient delivery by improving the blood flow and thus further protects the cardiovascular system. Millet is such a grain that should be listed as heart-healthy choices because of its importance as a good source of magnesium. Magnesium increases insulin sensitivity and lowers triglycerides. It also acts as a cofactor for more than 300 enzymes.

Bioavailability of Nutrients from Millets

Despite the potential of having a huge number of beneficial nutrients, there are some hindrances in its availability.

Bioavailability of nutrient present in millets is low due to the presence of antinutritional factors. Some of these are phytates and tannins. High fiber content of millets is also responsible for its lower bioavailability. Phytates and tannins affect the bioavailability of minerals. Rao *et al*., 1983 studied the absorption pattern of iron in humans from millets and compared with that of rice and wheat.[17] They found that absorption from millets was lower than from rice and wheat. *In vitro* studies on commonly cultivated or highly pigmented finger millets showed poor bioavailability of iron due to their tannin content. Iron content can be enhanced as ionizable iron either by grain germination or removal/reduction of tannin by extraction with solvent. White grain varieties of finger millet with no-tannin showed that iron availability is higher in terms of ionizable iron content.[18] Thus, the advantage of the presence of micronutrients in millet in higher content is nullified by lower bioavailability. There is a need to find different methods of cooking to examine micronutrients bioavailability including minerals and B vitamins through *in vivo* studies. Effects of physiological status such as pregnancy, lactation, age, and nutritional status on bioavailability should also be investigated. Vitamins and minerals are absorbed based on body's demand.

Fibre

Kamath and Belavady found that total dietary fiber in pearl millet (20.8%) and finger millet (18.6%) was higher than that in sorghum (14.2%), wheat (17.2%), and rice (8.3%).[19] Emiola and De La Rosa found that in pearl millet water-soluble non-starch polysaccharides accounted for 0.66% of grain weight and water-insoluble non-starch polysaccharide for 3.88%.[20] Muralikrishna *et al*. found that hemicelluloses A in little, kodo and barnyard millets was a non-cellulosic beta-glucan and hemicelluloses B was composed of hexose, pentose, and uronic acid.[21] Wankhede *et al*. reported that in finger and foxtail millet, the pentosans content was 6.6 and 5.5%, respectively.[5]

Health benefits of dietary fiber are correlated with a reduction in blood cholesterol, sugar, and good bowl movement. With fibers, millets are rich in health-promoting fraction of phytochemicals such as polyphenols, phytosterols, phytoestrogens, lignin's, and phytocyanins. These chemicals protect against age-related degenerative diseases (for example, cardiovascular diseases [CVD], diabetes, cancer, etc.) as they function as antioxidants, detoxifying agents, immune modulators, etc.[22]

NUTRACEUTICALS

The term nutraceuticals (like pharmaceuticals) is used for such bioactive compounds from food sources which are having a protective effect against degenerative diseases in its isolated form.

Phenolic Compounds

Phenolic compounds encompass a wide variety of compounds characterized by the presence of an aromatic ring consisting of one or more hydroxyl groups and a variety of substitutes. Main phenolic compounds are generally categorized as phenolic acids, flavonoids, and lignans. These compounds mainly exist as glycosides linked to various sugar moieties or as other complexes linked to organic acids, amines, lipids, carbohydrates, and other phenols. Chethan and Malleshi (2007) reported considerable differences, with respect to the polyphenol contents of the finger millet varieties with brown varieties having 1.2–2.3g% and white 0.3–0.5g%.[23] They are important source of antioxidants and work in multiple ways to prevent disease associated with oxidative stress, such as cancer and CVD and are well-known antioxidants compounds.

Studies had reported that bound polyphenols (1% HCl extractable) were highest in kodo millet (81.64±0.15), followed by foxtail (11.59 ± 0.23), little millet (9.64±0.28), pearl millet (9.14 ±0.17), finger millet (3.83 ± 0.18), and proso millet (2.21±0.01).[24] Bound phenolic content in rice samples was less than that of millet samples, thus indicating it as a better source of nutraceutical concentrate. Bound phenolic compounds have antioxidant, antiobesity, antidiabetic, antimutagenic, anticarcinogenic, antimicrobial, and antiviral properties with a potential to inhibit the growth of variety of organisms as well as HIV and influenza virus. It also prevents lipid oxidation radical-mediated DNA cleavage (reference. If the study is specific to disease only it can be claimed). From this, it can be concluded that 1% acidic-methanol extract of different millets is a potential source of health beneficial polyphenols.

The potential of phenolic compounds to work as antioxidants arises from their inherent ability to donate hydrogen atoms to electron-deficient free radicals through hydroxyl groups on benzene rings and in turn form a resonance-stabilized and less reactive phenoxyl radical. Polyphenols show inhibition of the activity of digestive enzymes such as amylase, glucosidase, pepsin, trypsin, and lipases.[25] Pietta reported that polyphenolic compounds such as flavonoids, phenolic acids, and proanthocyanidins are of great interest for the radical scavenging activity and are expected to be effective in the prevention of many diseases and morbid states.[26] Phenolic compounds in the diet may provide health benefits associated with reduced risk of chronic diseases.[27]

The synergy between phenolics may play a role in mediating amylase inhibition, and therefore, have the potential to contribute the management of type 2 diabetes mellitus, which shows high blood glucose levels.[28,29] Being the inhibitors of amylase and glucosidase (similar to acarbose, miglitol, and voglibose), polyphenols result in the decrease in post-prandial hyperglycemia.[30]

Phenolic Acids

Phenolic acids are aromatic compounds with one benzene ring and a carboxylic acid function. Many of the phenolic acids are either derivatives of benzoic acid (C6-C1 structure), and they can be subdivided into two major groups, hydroxybenzoic acid and hydroxycinnamic acid derivatives. Hydroxybenzoic acid derivatives include hydroxybenzoic, protocatechuic, vanillic, syringic, and gallic acids. These components are commonly present in the bound form and are typically components of complex structures such as lignins and hydrolyzable tannins.

Hydroxycinnamic acid derivatives include p-coumaric, caffeic, ferulic, and sinapic acids. They are mainly present in the bound form, linked to cell wall structural components such as cellulose, lignin, and proteins through ester bonds. The common phenolic acids found in finger millet grains include ferulic acid, vanillic acid, caffeic acid, syringic acid, and p-coumaric acid.[31]

Ferulic acid [Figure 1b] (trans-4-hydroxy-3-methoxycinnamic acid) is one of the most common phenolic acids found in finger millet grains.[32,33] It is abundant in the aleurone, pericarp, and embryo cell walls of various grains but occurs only in trace amounts within the starchy endosperm.[34,35]

Flavonoids

Flavonoids are a class of plant secondary metabolites with a general structure of 15-carbon skeleton. It consists of two phenyl rings and one heterocyclic ring. Flavonoids are plant pigments that are synthesized from phenylalanine[36] and have a basic C6-C3-C6 structure. These comprise a large group of polyphenolic compounds that are characterized by a benzo-y-pyrone structure such as anthocyanin pigments, flavonols, flavanols, and isoflavones, which are ubiquitous in vegetables and fruits. They occur mostly as glycoside except for the flavanols which tend to polymerize to condensed tannins. The tannins could be classified either as condensed or hydrolyzable. Most condensed tannins are polymers of flavan-3-ols (catechins) or flavan 3, 4 diols (leucoanthocyanidins) while most hydrolyzable tannins are glucose or polyhydric alcohol esterified with gallic acid (gallotanins) or hexahydrodiphenic acid (ellagitannins).

Flavonoids such as catechin, quercetin, anthocyanin, tannin, etc., are health beneficial components. They are important for human health because of their pharmacological activities as radical scavengers.[37] The antioxidant potential of flavonoids depends on the number and arrangement of the hydroxyl groups across the structure and the presence of electron donating and electron withdrawing groups. Studies conducted by Miller *et al*., 2000 show that whole grains have almost equivalent antioxidant activity (AA) to fruits and vegetables (per serving basis).[38] Reports are there on the presence of flavones only out of all the flavonoids. Finger millet leaves are found to contain eight types of flavones: Vitexin, isovitexin, saponarin, violanthin, orientin, isoorientin, lucenin-1, and tricin.[39] Reichert detected glucosylvitexin, glucosylorientin, and vitexin in pearl millet in the ratio of 29:11:4; these were found to be the cause for the yellow–green discoloration occurring at basic pH in millet flour.[40] Japanese barnyard millet was reported to have luteolin and tricin.[41] Apigenin and luteolin was reported in fonio in the concentration of 150 mg/kg and 350 mg/kg, respectively.[42] Out of this concentration, 10% of apigenin and 80% of luteolin were found to be present in free form while rest of other percentages of those compounds was bound as O-glycosylflavones.

Finger millet is the sole millet reported to have condensed tannins. Brown finger millets contain tannins 0.12–3.47% catechin equivalents in comparison with white finger millets (0.04–0.06% catechin equivalents.[43] Reports on structural characterization of millet proanthocyanidins are lacking.

Phytic Acid

Phytic acid is chemically known as myoinositol 1,2,3,4,5,6 hexakis-dihydrogen phosphate [Figure 1d]. Its concentration in foods ranges from 0.1 to 6.0%.[44,45] Reddy *et al*., 1982

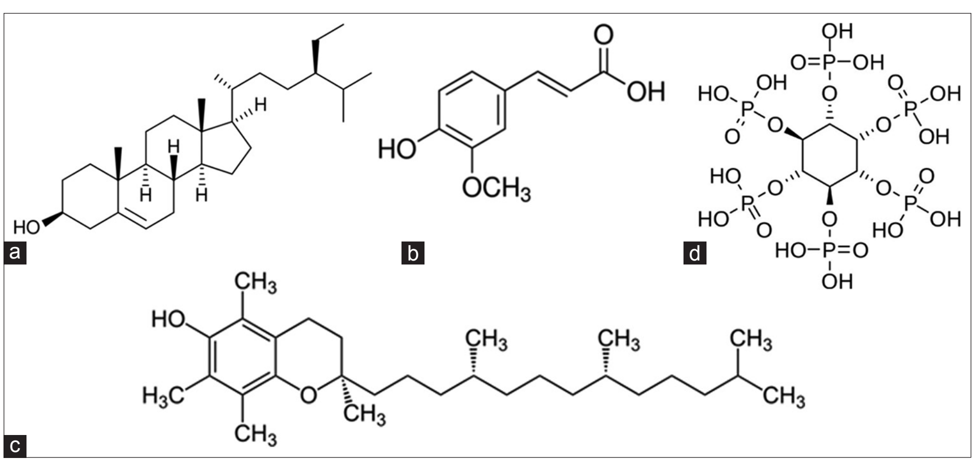

Figure 1: Structure of molecules (a) Phytosterols (b) Ferulic acid (c) Alpha-tocopherol (d) Phytic acid

found that it is present in bran region of the cereal grains or in cotyledon of oilseeds or legumes inside the protein bodies.[44] Lorenz reported the phytate content of common millet varieties range between 170 and 470 mg/100 g whole grain and also shown 27–53% reduction in phytate content on dehulling.[46] Dehulling causes phytic phosphorus content to decrease by 12% in common millet, 39% in little millet, 25% in kodo millet, and 23% in barnyard millet.

Carotenoid and Tocopherols

Food sources are rich sources of pigments and carotenoids are one of them. There are more than 600 of them have been identified. Carotenoids are well known for their provitamin-A activity. However, carotenoids are among those important compounds which protect against various diseases because they act as antioxidants. Carotenoids structurally consist of isoprenoid units with a long polyene chain containing 3 to 15 conjugated double bonds. The position of double bonds determines their absorption spectrum. Carotene is cyclized product where cyclization exists at one or both ends, while xanthophylls are formed on addition of oxygen. Some modifications based on isomerization, chain elongation, or degradation also occur.

Recent report by Asharani *et al*. have shown that values for total carotenoids content in edible millet flour varied from 78 to 366 µg/100 g with an average of 199, 78, 173, and 366 µg/100 g in finger, little, foxtail, and proso millets, respectively.[47] The carotenoid values obtained for millets were are comparable with the carotenoid content of wheat (150–200 µg/100 g) and sorghum (180–230 µg/100 g) but significantly less than maize (1800–5500 µg/100 g) and their varieties (2400- 3200 µg/100g).[48]

Vitamin E is a fat-soluble component widely found in nature consists of a family of eight different molecules. These molecules differ each other structurally but have a chromanol ring and 12-carbon aliphatic side chain in common. This side chain contains two methyl groups in the middle as well as at the end. The family constitutes of 4 saturated tocopherols and 4 tocotrienols with three double bonds. Both tocopherols and tocotrienols have four different variants, namely, alpha, beta, gamma, and delta. These variations are due to the number of methyl groups present in the chain. Vitamin E analyzed by HPLC indicated a higher proportion of γ- and α-tocopherols [Figure 1c] and lower levels of tocotrienols in the millets. Total tocopherol content in finger (3.6–4.0 mg/100 g) and proso (3.6–4.0 mg/100 g) millet varieties were higher than foxtail and little millet varieties (~1.3 mg/100 g). Vitamin E acts as antioxidant, anti-inflammatory, decrease superoxide production in mitochondria, and anti-atherosclerotic compound.

Phytosterols

Phytosterols are desmethyl sterols, which share a common ring structure with cholesterol. These are essential structural and functional components of plant cells. As their structure [Figure 1a] is very much similar to cholesterol, they show significant lowering in the serum cholesterol levels by altering the rate of uptake of both dietary and endogenously produced cholesterol. Phytosterol esters have the potential to reduce blood serum LDL cholesterol levels up to 14% but no effect on HDL levels.[49]

Daily consumption of phytosterols reduces the risk of heart diseases up to 40% that depends on age and some other factors. However, the presence of sterols reduces absorption of alpha and beta-carotene and also of Vitamin E.[50] Etherification, emulsification, and solubilization mechanisms adversely affect their bioavailability. Sterol content of finger millet was reported to be 0.149% on seed weight basis,[51] whereas other millets contain only trace amount. Phytosterol content of sorghum and corn was reported to be 0.5 mg/g and 0.9 mg/g.[52]

Arabinoxylans

Arabinoxylans is a class of hemicelluloses which are found as components of plant cell wall both primary and secondary cell wall. These contain a chain of 1,4-linked xylose with 2,3-linked arabinose residues.[53,54] These components as non-digestible are regarded as dietary fibers. Dietary fiber provides bulk to the diet and has a positive effect on cholesterol regulation. Xylooligosaccharide content in finger millet bran was estimated at level of 15.60%, wheat bran at 40%, and corn bran 9.33%.[55]

These arabinoxylans undergo enzymatic hydrolysis to yield arabinoxylan-oligosaccharides (AXOS), which consists of arabinoxylooligosaccharides and xylooligosaccharides (XOS). This reaction occurs during the processing of cereals, or in the making of bread and beer, and in the colon by fermenting bacteria. These compounds (AXOS and XOS) shown to have a prebiotic effect in the colon of humans and animals through selective stimulation of beneficial intestinal microbiota.[56] Studies have shown positive effect of dietary fibers on chronic diseases such as type II diabetes,[57,58] CVD,[59,60] and gastrointestinal cancer[61] on the basis of large-scale prospective studies.[62]

MILLETS AND HEALTH EFFECTS

Epidemiological studies conducted on the diets rich in plant foods, especially those including whole grains protect us from non-communicable diseases as they are rich in health-promoting nutrients and phytochemicals. Millets which are rich in its hidden treasure of highly potent health-promoting phytochemicals are regarded as functional foods.

Diabetes

Epidemiological studies have shown a lower incidence of diabetes in millet consuming populations.[63] Kumari and

Sumathi (2002) studied the effect of consuming finger millet on hyperglycemia in non-insulin-dependent diabetes mellitus (NIDDM). It was found that glycemic index of finger millet was lower than that of rice and wheat. The reason of lower glycemic response may be due to the presence of polyphenols in whole finger millet flour. These are known to reduce the starch digestibility and absorption. Finger millet polyphenols (FMP) were extracted in acidified methanol and then investigated for their ability to inhibit the activities of porcine pancreatic α-amylase and rat intestinal α-glucosidase. This shows that these phenolics have huge potential for managing hyperglycemia.[64] Tadera *et al.* reported that the starch digestive enzymes were inhibited by naringenin, kaempferol, luteolin, apigenin, (+)-catechin/(–)-epicatechin, daidzein, and epigallocatechin gallate which are present in millets. The potential for inhibition of these enzymes is dependent on the presence of number of hydroxyl groups in flavonoids.[65] Kinetic studies on interaction between seed coat phenolics and enzymes of starch digestion showed non-competitive inhibition of the two key enzymes α-glucosidase and pancreatic amylase.[32]

Cataractogenesis Inhibition

Western countries are facing problems of retinopathy and cataract as a major cause of blindness worldwide. Diabetes is one major and quite a significant risk factor in retinopathy and cataract. The prevalence of blindness in India is 15/1000 while cataract alone accounts for 80% of this blindness. In diabetes-induced cataract, there occurs an accumulation of sorbitol. This accumulation is mediated by the action of a key enzyme aldose reductase (AR). Binding of glucose to protein molecule a form of non- enzymatic glycation that is induced during diabetes is regarded as the key factor for aldose reductase-mediated sugar-induced cataract. Chethan *et al.* evaluated FMP for AR inhibiting activity to show their antidiabetic and antioxidant potential. Phenolic constituent in FMP such as gallic, protocatechuic, p- hydroxybenzoic, p-coumaric, vanillic, syringic, ferulic, trans-cinnamic acids, and the quercetin inhibited cataract eye lens effectively.[32] Structural and functional analysis of phenolics revealed that the presence of -hydroxyl group at the 4th position was important for the aldose reductase inhibitory property. Furthermore, the presence of O-methyl group neighboring to –OH group in phenolics denatured the aldose reductase activity.

Wound Healing and Nerve Growth Factor (NGF) Production

Rajasekaran *et al*. reported the role of finger millet feeding on skin antioxidant status, NGF production, and wound healing parameters in healing impaired early diabetic rats. Hyperglycemic rats received 50 g finger millet per 100 g of diet.[66] Full-thickness excision skin wounds made after 2 weeks prior feeding of finger millet diet. The rate of wound contraction and the levels of collagen, hexosamine, and uronic acid in the granulation tissue were determined. The lipid peroxide concentration and skin antioxidant status were also monitored during the study. In hyperglycemic rats fed with finger millet diet, the healing process was hastened with an increased rate of wound concentration. Interestingly, the index of oxidative stress, thiobarbituric acid reactive substances (TBARS) was elevated in the wound tissues of all the groups, when compared to normal (unwounded) skin tissues. However, in diabetic rats, the TBARS levels of both normal and wounded skin tissues were significantly elevated as compared with control and diabetic fed with FM. Impaired production of NGF, determined by ELISA, in diabetic rats was improved upon FM feeding and further confirmed by immunocytochemical observations reflecting the increased expression of NGF in hyperglycemic rats supplemented with FM-enriched diet. Histological and electron microscopical evaluation revealed the epithelialization, increased synthesis of collagen, activation of fibroblasts, and mast cells in FM fed animals. Thus, increased levels of oxidative stress markers accompanied by decreased levels of antioxidants play a vital role in delaying wound healing in diabetic rats. Reports show finger millet feeding to the diabetic animals, for 4 weeks, controlled not only the glucose levels but also improved the antioxidant status, which hastened the dermal wound healing process. They are reported to improve aortic fragility and elasticity by attenuating elevation of blood pressure and they increase vasorelaxation.[67]

AA

As being rich in antioxidants, fiber and complex carbohydrates millets have beneficial effects against cancer, cardiovascular disease, and aging. These diseases are caused due to the generation of harmful oxygen species such as free radicals and peroxides which damage the cells. Millets are reported to protect us from oxidative stress. Studies have been conducted on phenolic acids extracted from milled fractions of finger millet for the evaluation of their antioxidant and antimicrobial properties.[68] Milled fractions (whole grain, flour, and seed coat) were found to be rich in polyphenols in acidic methanol extracts. Major phenolic acids identified are daidzein, gallic, coumaric, syringic, and vanillic acids. Daidzein content was found to be highest. Seed coat extracts have shown reducing power significantly ($P < 0.05$) higher than the whole flour extract. Carotene–Linoleic acid assay was carried to determine AA of seed coat extract and whole flour extract, and it was found that in case of seed coat AA is 86%, whereas later has AA only up to 27%. Asharani *et al*., 2010 reported the total antioxidant capacity of edible flours of millets such as finger (15.3 + 3.5 mM TE/g), little (4.7 + 1.8 mM TE/g), foxtail (5.0 + 0.09 mM TE/g), and proso millets (5.1 + 1.0 mM TE/g). Chandrasekara and Shahidi also reported that soluble as well as bound fractions of kodo, finger, proso, and other millets grains are rich in phenolic compounds with antioxidant, metal chelating, and reducing power.[24] Rao *et al*. also reported the phenolic content and reducing power of small millets with higher activity for finger and kodo millet from whole grain extracts [Table 1].[22] Table 1 shows that kodo has highest phenolic content and foxtail has lowest, whereas reducing capacity is highest for finger millet followed by foxtail.

Ferulic acid exists in bounded form is major phenolic acid in millets. It is commonly known to exist as an ester linked mainly to arabinoxylans and hence influences their physicochemical properties.[69] Ferulic acid is supposed to have a number of health benefits from decrease in total cholesterol level, increase in Vitamin-E bioavailability, and increase in the vitality of sperms and to act as protective agent against UV radiation-induced skin damage. Ferulic acid exhibited very strong antioxidant, free radical scavenging, and anti-inflammatory activity[70] and shows effects against cancer and tumor.[71]

The chemical reaction between the aldehyde group of reducing sugars and the amino group of proteins termed non-enzymatic glycosylation, a major factor responsible for the complications of diabetes and aging. Proteins like collagen have a long half-life and slow turnover are at an increased risk of undergoing glycation *in vivo*. Earlier reports have shown the role of oxygen in cross-linking and chemical modification of collagen by glucose. Free radicals play a vital role in the non-enzymatic glycosylation and crosslinking of collagen. Antioxidative conditions and free radical scavengers inhibit these reactions.[33]

Celiac disease millets are non-glutinous so they are being used by the people suffering from celiac disease and gluten allergy. It can be replaced in place of wheat in diet. When consumed, they do not form acid in the digestive tract and hence easy to digest. They are also non-allergenic.[63]

Other health beneficial effects: Millets because of its high amount of fiber and antioxidants have shown lowering of serum lipid profile along with the lowering of blood sugar. Studies showed that increased consumption of proso millet and its products are associated with reduced risk of chronic diseases, such as elevated serum cholesterol.[72] Shobana *et al*. reported hypoglycemic, hypocholesterolemic, nephroprotective, and anticataractogenic properties by feeding a diet containing 20% millet seed coat matter to streptozotocin-induced diabetic rats.[73] Liver studies have shown that proso millet can be considered as preventive food in liver injury like hepatic encephalopathy upon chronic liver failure and liver injury.[72]

Hence, it can be inferred that millets have potential to protect against age-onset degenerative diseases. This area needs to be explored as these diseases are engulfing Indian population. India is the largest producer of millets so we should try to capture the world market by supplying appropriate validated functional foods.

CONCLUSION

Millets are important crops in semiarid and tropical regions of the world due to their resistance to pests and diseases, short-growing season, and productivity under heat and drought conditions when major cereals cannot be relied upon to provide sustainable yields. Of the total millet produced in the world about 90% is utilized in the developing countries and about two-thirds of millets produced are consumed as food. They are consumed traditionally as health and vitality foods by the poor segment of the population. Nutritive potential of millets in terms of protein, carbohydrates, and energy values are comparable to the popular cereals such as rice, wheat, and barley. Most of the health benefits associated with the millets are generally due to the presence of phytochemicals such as polyphenols, tocopherols, phytosterols, and dietary fiber and also due to the abundant presence of some of the minerals, vitamins, and trace elements. Many healthful effects are attributed to millets and some of these effects have more scientific support. The strongest evidence for health effects of millets comes from animal studies and evidence from human studies (epidemiology and experimental) is still limited. Some epidemiological studies have shown that regular consumption of millet grains and their products is associated with reduced risk of developing chronic diseases such as diabetes, cardiovascular disease, cancers, and all-cause mortality. Therefore, dietary modification by increasing the consumption of a wide variety of fruits, vegetables, and millet grains daily is a practical strategy for consumers to optimize their health and reduce the risk of chronic diseases. Although millet foods are considered among the healthiest food choices that are available, their consumption remains well below in developed countries where diet-related chronic diseases are alarming. It is necessary to increase production and lower cost by introducing revolutionary improvements in production techniques. There is also a lack in the processing techniques, machinery, and standardization of products. People still consider millets as poor man's food. Many processed products need to be optimized to give proper benefits to the consumer. Millets have a potential for the preparation of healthy foods. Because of their health benefits, these grains do need a great promotion to reach heights of the major cereals in terms of their utilization.

REFERENCES

1. Ushakumari SR, Malleshi NG. In: Krishnegowda K, Seetharam A. Small Millets: Nutritional and Technological Advantages. Food uses of Small Millets and Avenues for Further Processing and Value addition. UAS, Bangalore: All India Coordinated Small Millets Improvement Project ICAR; 2007.
2. Subramanian V, Jambunathan R. Traditional methods of processing sorghum (*Sorghum bicolor* L. Moench) and pearl millet (*Pennisetum americanum* L.) grains in India. Rep Int

Assoc Cereal Chem 1980;10:115-8.
3. Subramanian V, Jambunathan R, Suryaprakash S. Sugars of pearl millet [*Pennisetum americanum* (L.) Leeke] grains. J Food Sci 1981;46:1614-5.
4. Murty DS, Singh U, Suryaprakash S, Nicodemus DS. Soluble sugars in five endosperm types of sorghum. Cereal Chem 1985;62:150-2.
5. Wankhede DB, Shehnaj A, Rao MR. Carbohydrate composition of finger millet (*Eleusine coracana*) and foxtail millet (*Seturia italica*). Qual Plant Plant Foods Hum Nutr 1979;28:293-303.
6. Becker R, Lorenz K. Saccharides in proso and foxtail millets. J Food Sci 1978;43:1412-4.
7. FAO. Amino Acid Content of Foods. Rome: FAO, Nutritional Studies; 1970. p. 24.
8. Indira R, Naik MS. Nutrient composition and protein quality of some minor millets. Indian J Agric Sci 1971;41:795-7.
9. Hulse JH, Laing EM, Pearson OE. Sorghum and the Millets: Their Composition and Nutritive Value. London: Academic Press; 1980.
10. Geervani P, Eggum BO. Nutrient composition and protein quality of minor millets. Plant Foods Hum Nutr 1989;39:201-8.
11. Singh P, Singh U, Eggum BO, Kumar KA, Andrews DJ. Nutritional evaluation of high protein genotypes of pearl millet (*Pennisetum americanum* (L.) Leeke). J Sci Food Agric 1987;38:41-8.
12. Osagie AU, Kates M. Lipid composition of millet (*Pennisetum americanum*) seeds. Lipids 1984;19:958-65.
13. Bieri JG, Evarts RP. Vitamin E activity of γ-tocopherol in the rat, chick and hamster. J Nutr 1974;104:850-7.
14. Babu BV, Ramana T, Radhakrishnan TM. Chemical composition and protein content in hybrid varieties of finger millet. Indian J Agric Sci 1987;57:520-2.
15. Joseph K, Kurien PP, Swaminathan M, Subrahmanyan V. The metabolism of nitrogen, calcium and phosphorus in undernourished children. V. The effect of partial or complete replacement of rice in poor vegetarian diets by ragi (*Eleusine coracana*) on the metabolism on nitrogen, calcium and phosphorus. Br J Nutr 1959;13:213-8.
16. Dassenko S. Effect of Milling, Fermentation and Cooking on Nutritive Value of Pearl Millet (*Pennisetum americanum* (L.) Leeke). Thèse de doctorat. Manhattan, Kansas: Etats-Unis Kansas State University; 1980.
17. Narasinga Rao BS, Vijayasarathy C, Prabhavathi T. Iron absorption from habitual diets of Indians studied by the extrinsic tag technique. Indian J Med Res 1983;77:648-57.
18. Rao PU, Deosthale YG. *In vitro* availability of iron and zinc in white and coloured ragi (*Eleusine coracana*): Role of tannin and phytate. Plant Foods Hum Nutr 1988;38:35-41.
19. Kamath MV, Belavady B. Unavailable carbohydrates of commonly consumed Indian foods. J Sci Food Agric 1980;31:192-202.
20. Emiola LO, de la Rosa LC. Characterization of pearl millet non starchy polysaccharides. J Food Sci 1981;46:781-5.
21. Muralikrishna G, Paramahans SV, Tharanathan RN. Carbohydrate makeup of minor millets. Starch 1982;34:397-401.
22. Rao BR, Nagasampige MH, Ravikiran M. Evaluation of nutraceutical properties of selected small millets. J Pharm Bioallied Sci 2011;3:277-9.
23. Chethan S, Malleshi NG. Finger millet polyphenols: Optimization of extraction and the effect of pH on their stability. Food Chem 2007;105:862-70.
24. Chandrasekara A, Shahidi F. Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. J Agric Food Chem 2010;58:6706-14.
25. Rohn S, Rawel HM, Kroll J. Inhibitory effects of plant phenols on the activity of selected enzymes. J Agric Food Chem 2002;50:3566-71.
26. Pietta PG. Flavonoids as antioxidants. J Nat Prod 2000;63:1035-42.
27. Liu RH. Whole grain phytochemicals and health. J Cereal Sci 2007;46:207-19.
28. Saito N, Sakai H, Suzuki S, Sekihara H, Yajima Y. Effect of an alpha-glucosidase inhibitor (voglibose), in combination with sulphonylureas, on glycaemic control in Type 2 diabetes patients. J Int Med Res 1998;26:219-32.
29. Toeller M. Alpha-glucosidase inhibitors in diabetes: Efficacy in NIDDM subjects. Eur J Clin Invest 1994;24 Suppl 3:31-5.
30. Bailey C J. New approaches to the pharmacotherapy of diabetes (In JC Pickup & G. William (Eds.). Text book of diabetes (Vol. 2, pp. 73.1–73.2).UK: Blackwell Science Ltd 2001.
31. Chethan S, Sreerama YN, Malleshi NG. Mode of inhibition of finger millet malt amylases by the millet phenolics. Food Chem. 2008;111: p. 187–191
32. Chethan S, Dharmesh SM, Malleshi NG. Inhibition of aldose reductase from cataracted eye lenses by finger millet (*Eleusine coracana*) polyphenols. Bioorg Med Chem 2008;16:10085-90.
33. Hegde PS, Chandrakasan G, Chandra TS. Inhibition of collagen glycation and cross linking *in vitro* by methanolic extracts of Finger millet (*Eleusine coracana*) and Kodo millet (*Paspalum scrobiculatum*). J Nutr Biochem 2002;13:517-21.
34. McDonough CM, Rooney LW, Earp CF. Structural Characteristics of *Eleusine coracana* (finger millet) using Scanning Electron and Fluorescence Microscopy. USA: Food Microstructure; 1986.
35. Mcdonough CM. In: Kulp K, editor. The Millets in Handbook of Cereal Science and Technology. New York: CRC Press Book; 2000.
36. Harborne JB, Turner BL, Harborne JB. Plant Chemosystematics. Vol. 4. London: Academic Press; 1984.
37. Cook NC, Samman S. Flavonoids-chemistry, metabolism, cardioprotective effects, and dietary sources. J Nutr Biochem 1996;7:66-76.
38. Miller HE, Rigelhof F, Marquart L, Prakash A, Kanter M. Antioxidant content of whole grain breakfast cereals, fruits and vegetables. J Am Coll Nutr 2000;19 sup3: 2-319S.
39. Hilu KW, De Wet JM, Seigler D, Flavonoid patterns, Horan FE, Heider MF. A study of sorghum and sorghum starches. Cereal Chem 1978;23:492-503.
40. Reichert RD. The pH-sensitive pigments in pearl millet. Cereal Chem 1979;56:291-4.
41. Watanabe M. Antioxidative phenolic compounds from Japanese barnyard millet (*Echinochloa utilis*) grains. J Agric Food Chem 1999;47:4500-5.
42. Sartelet H, Serghat S, Lobstein A, Ingenbleek Y, Anton R, Petitfrère E, *et al.* Flavonoids extracted from fonio millet (*Digitaria exilis*) reveal potent antithyroid properties. Nutrition 1996;12:100-6.
43. Ramachandra G, Virupaksha TK, Shadaksharaswamy M. Relation between tannin levels and *in vitro* protein digestibility

in finger millet (*Eleusine coracana* Gaertn.). J Agric Food Chem 1977;25:1101-4.
44. Reddy NR, Sathe SK, Salunkhe DK. Phytates in legumes and cereals. Adv Food Res 1982;28:1-92.
45. Harland BF, Oberleas D. Phytate in foods. World Rev Nutr Diet 1987;52:235-59.
46. Lorenz K. Tannins and phytate content in proso millets (*Panicum miliuceum*). Cereal Chem 1983;60:424-6.
47. Asharani VT, Jayadeep A, Malleshi NG. Natural antioxidants in edible flours of selected small millets. Int J Food Prop 2010;13:41-50.
48. de Almeida Rios S, Paes MC, Cardoso WS, Borém A, Teixeira FF. Color of corn grains and carotenoid profile of importance for human health. Am J Plant Sci 2014;5:857-62.
49. Weststrate NM, Glück J. Hard-earned wisdom: Exploratory processing of difficult life experience is positively associated with wisdom: Correction to weststrate and glück (2017). Dev Psychol 2017;53:1177.
50. Granado-Lorencio F, Herrero-Barbudo C, Blanco-Navarro I, Pérez-Sacristán B, Olmedilla-Alonso B. Bioavailability of carotenoids and α-tocopherol from fruit juices in the presence of absorption modifiers: *In vitro* and *in vivo* assessment. Br J Nutr 2009;101:576-82.
51. Mahadevappa VG, Raina PL. Sterol lipids in finger millet (*Eleusine coracana*). J Am Oil Chem Soc 1978;55:647-8.
52. Singh V, Moreau RA, Hicks K. Yield and phytosterol composition of oil extracted from grain sorghum and its wet-milled fractions. Cereal Chem 2003;80:126-9.
53. McCleary BV. Dietary fibre analysis. Proc Nutr Soc 2003;62:3-9.
54. de Vries RP, van den Broeck HC, Dekkers E, Manzanares P, de Graaff LH, Visser J. Differential expression of three α-galactosidase genes and a single β-galactosidase gene from *Aspergillus niger*. Appl Environ Microbiol 1999;65:2453-60.
55. Veenashri BR, Muralikrishna G. *In vitro* anti-oxidant activity of xylo-oligosaccharides derived from cereal and millet brans–a comparative study. Food Chem 2011;126:1475-81.
56. Broekaert WF, Courtin CM, Verbeke K, Van de Wiele T, Verstraete W, Delcour JA, *et al.* Prebiotic and other health-related effects of cereal-derived arabinoxylans, arabinoxylan-oligosaccharides, and xylooligosaccharides. Crit Rev Food Sci Nutr 2011;51:178-94.
57. Montonen J, Knekt P, Järvinen R, Aromaa A, Reunanen A. Whole-grain and fiber intake and the incidence of Type 2 diabetes. Am J Clin Nutr 2003;77:622-9.
58. Schulze MB, Schulz M, Heidemann C, Schienkiewitz A, Hoffmann K, Boeing H, *et al.* Fiber and magnesium intake and incidence of type 2 diabetes: A prospective study and meta-analysis. Arch Intern Med 2007;167:956-65.
59. Mozaffarian D, Kumanyika SK, Lemaitre RN, Olson JL, Burke GL, Siscovick DS. Cereal, fruit, and vegetable fiber intake and the risk of cardiovascular disease in elderly individuals. JAMA 2003;289:1659-66.
60. Jensen MK, Koh-Banerjee P, Hu FB, Franz M, Sampson L, Grønbaek M, *et al.* Intakes of whole grains, bran, and germ and the risk of coronary heart disease in men. Am J Clin Nutr 2004;80:1492-9.
61. Schatzkin A, Mouw T, Park Y, Subar AF, Kipnis V, Hollenbeck A, *et al.* Dietary fiber and whole-grain consumption in relation to colorectal cancer in the NIH-AARP diet and health study. Am J Clin Nutr 2007;85:1353-60.
62. Poutanen K, Shepherd R, Shewry PR, Delcour JA, Björck I, van der Kamp JW. Beyond whole grain: The European healthgrain project aims at healthier cereal foods. Cereal Foods World 2008;53:32-5.
63. Saleh AS, Zhang Q, Chen J, Shen Q. Millet grains: Nutritional quality and potential health benefits. Compr Rev Food Sci Food Saf 2013;12:281-95.
64. Lakshmi Kumari P, Sumathi S. Effect of consumption of finger millet on hyperglycemia in non-insulin dependent diabetes mellitus (NIDDM) subjects. Plant Foods Hum Nutr 2002;57:205-13.
65. Tadera K, Minami Y, Takamatsu K, Matsuoka T. Inhibition of alpha-glucosidase and alpha-amylase by flavonoids. J Nutr Sci Vitaminol (Tokyo) 2006;52:149-53.
66. Rajasekaran NS, Nithya M, Rose C, Chandra TS. The effect of finger millet feeding on the early responses during the process of wound healing in diabetic rats. Biochim Biophys Acta 2004;1689:190-201.
67. Mizutani K, Ikeda K, Kawai Y, Yamori Y. Extract of wine phenolics improves aortic biomechanical properties in stroke-prone spontaneously hypertensive rats (SHRSP). J Nutr Sci Vitaminol (Tokyo) 1999;45:95-106.
68. Viswanath V, Urooj A, Malleshi NG. Evaluation of antioxidant and antimicrobial properties of finger millet polyphenols (*Eleusine coracana*). Food Chem 2009;114:340-6.
69. Ishii T. Structure and functions of feruloylated polysaccharides. Plant Sci 1997;127:111-27.
70. Castelluccio C, Paganga G, Melikian N, Bolwell GP, Pridham J, Sampson J, *et al.* Antioxidant potential of intermediates in phenylpropanoid metabolism in higher plants. FEBS Lett 1995;368:188-92.
71. Mori H, Kawabata K, Yoshimi N, Tanaka T, Murakami T, Okada T, *et al.* Chemopreventive effects of ferulic acid on oral and rice germ on large bowel carcinogenesis. Anticancer Res 1999;19:3775-8.
72. Nishizawa N, Fudamo Y. The elevation of plasma concentration of high density lipoprotein chloesterol in mice fed with protein from proso millet (*Panicum miliaceum*). Biosci Biotech Biochem 1995;59:333-5.
73. Shobana S, Harsha MR, Platel K, Srinivasan K, Malleshi NG. Amelioration of hyperglycaemia and its associated complications by finger millet (*Eleusine coracana* L.) seed coat matter in streptozotocin-induced diabetic rats. Br J Nutr 2010;104:1787-95.

How to cite this article: Himanshu K, Chauhan M, Sonawane SK, Arya SS. Nutritional and Nutraceutical Properties of Millets: A Review. Clin J Nutr Diet 2018;1(1):-10.