Plant Archives Vol. 19 No. 1, 2019 pp. 875-883 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

MILLETS : THE UNTAPPED AND UNDERUTILIZED NUTRITIOUS FUNCTIONAL FOODS

Monika Thakur* and Pratibha Tiwari

Amity Institute of Food Technology, Amity University, Uttar Pradesh-201303, India

Abstract

In today's context, indigenous agriculture sources are one of the most important sources of renewable wealth in the world. Millets are native to Ethiopia but are also grown in various parts of world such as such as USA, India and Australia. It is considered as one of the most versatility crop to harsh environmental extremes and plays an important role in food security. Due to the awareness of functional foods among masses, millets have gained an importance due to its antioxidant, antimicrobial, anti-tumerogenic, anti-tumerogenic and etc which is mainly because of polyphenols, gluten free nature, certain minerals and dietary fiber content in it. Herein, some of the underutilized varieties of millets with special reference to their functional properties and future strategies for utilization of millets by mass populations. The novelty of the work is it also include some of the health promoting benefits of this underutilized crops and suggest various ways for its upgradation of millets industry in India.

Key words: Millets, underutilized, untapped, gluten free, dietary fiber, polyphenols

Introduction

With the fast depletion of natural plant resources and increasing population, it has become necessary to explore the possibilities of using newer indigenous plant resources (Zhu *et al.*, 2018). In today's context, indigenous agriculture sources are one of the most important sources of renewable wealth in the world. There are many plants species still lying unexplored and underexploited. Therefore, there has been focused attention by the researchers on exploiting alternative or underutilized plant species for multifarious use. Kunkel (1984) discussed that once underutilized food crops are properly utilized, they may help to contribute in food security, nutrition, health, income generation and environmental services when properly utilized. These underutilized plant species have a distinctive past, current, or potential use value, but their use is currently limited relative to their economic potential. Underutilized plants, in general, constitute those plant species that occur as life support species in extreme environmental conditions and threatened habitats, having genetic tolerance to survive under harsh conditions and possess qualities of nutritional and/or industrial importance for a variety of purposes (Thakur, 2014). There has been increasing interest in the development of policy statements about drought-tolerant grains in several developing countries such as India, China, and some countries of Africa because of water scarcity and increasing populations.

Millets belong to family Poaceae (grass) and is native to Ethiopia and Eritrea and has been successfully adapted to other parts of world such as USA, India and Australia (Bultosa, 2016). In 2013, the total world production of millets grain was 762,712 metric tons and India sharing about 43.85 % of the total production. The millets are rich in calcium (0.34%), dietary fiber (18%), phytates (0.48%), protein (6%–13%) minerals (2.5%–3.5%), and phenolics (0.3%–3%). It is rich in thiamine, riboflavin, iron, methionine, isoleucine, leucine, phenylalanine and Catechin, gallocatehin, epicatechin, epigallocatechin, taxifolin, vitexin, tricin, myricetin, Leuteolin, quercetin, apigenin, Kempherol, diadzein, Pyrocyanidin B1, Pyrocyanidin B2, consequently is designed as 'Nutritious grains' because of their nutritional properties and also been classified as Functional Foods (Shumoy and Raes, 2016). Millet is one of the most important drought-resistant crops and the 6th cereal crop in terms of world agriculture production (Assefa *et al.*, 2015). Millets have resistance to pests and diseases, short growing season, and good

***Author for correspondence :** E-mail : mthakur1@amity.edu; monika.harsh05@gmail.com

productivity under drought conditions in comparison to other staple crops. Therefore, millet grains have now been receiving specific attention in terms of utilization as food as well as in the manufacturing of bioethanol and biofilms (Li *et al.*, 2008). Millets have been the major source of energy and protein for millions of people in various developing countries. In addition to their nutritive value, several potential health benefits as anticancer and as anti-diabetic (type 2 diabetes mellitus), anti-diarrheal, antiulcer, anti-inflammatory, antitumerogenic (K562 chronic myeloid leukemia), atherosclerogenic effects, antimicrobial and antioxidant properties have been reported from millets and is known to be drought resistant crop (Zhu *et al.*, 2018). Since the people are nowadays more conscious about their health, hence, focus has been shifted to coarse grains from refined ones. The present reviews summons some of the underutilized varieties of millets with special reference to their functional properties and future strategies for utilization of millets by mass populations. The novelty of the work is it also include some of the health promoting benefits of this underutilized crops and suggest various ways for its upgradation of millets industry in India.

Indian Status of Millets

Millets are important crops of highly variable small-seeded grasses, widely grown in the semi-arid tropics like India (McDonough *et al.*, 2000). The crop is favored due to its productivity and short growing season under dry, and high-temperature conditions. Table 1 enlists the millets species grows in India, and their state wise production. India is the world's largest producer of millets. In 1970s, all of the millet crops harvested in India were used as a staple food. By the 2000s, the annual millet production had increased in India, yet per capita consumption of millet had dropped by between 50% to 75% in the different regions of the country. Most of the millet produced in India is being used for various alternative applications such as livestock fodder and alcohol production. Various government organizations have been advertising and finding out ways to increase millet use as food so as to encourage its production; however, many consumers now prefer the taste of other grains also. Millets have grown in various states of India, but still there has been loss of production of millets in our country. Due to change in the lifestyle patterns, the people are more dependent upon processed foods. There has been nutritional shift almost in every part, which is called as Nutrition Paradigm. Fig. 1 showed the Decline in production of millets in comparison to other staple food crops.

Nutritional composition of Millets

Millets are a major food source in arid and semi-arid parts of the world. They provide protein, fatty acids, minerals, vitamins, dietary fiber and polyphenols (Alaunyte *et al.*, 2012). The starch is main component of millet and contains about 70% of the dry weight. The details of which are described in Table 2. Typical, millet protein contains high quantity of essential amino acids especially the Sulphur containing amino acids (methionine and cysteine). Catechin, ferulic and rosmarinic acids are the

Table 1: Millet crops in India

S.No	English Names	Species	Local Names	Top 5 states in terms of total production
1	*Pearl Millet*	*Pennisetum glaucum*	Bajra, Bajri, sajja, Sajje, Cumbu	Rajasthan, Uttar Pradesh, Haryana, Gujrat, Maharashtra,Tamil Nadu
2	*Finger Millet*	*Eleusine coracana*	Ragi, Mandua, Keppai, Kaelvaragu, Nagli, Nachni, Mandiya, Marwa	Karnataka, Uttarakhand, Tamil Nadu, Maharashtra, Andhra Pradesh
3	*Foxtail Millet*	*Setaria italica*	Kaon, Kang, Kakon, Kangni, Navane, Thena, Rala, Kangam, Kanghzu, Kangani, Korra, Tenai	Andhra Pradesh, Karnataka, Arunachal Pradesh, Maharastra, Uttar Pradesh, Rajasthan,Tamil Nadu
4	*Kodo Millet*	*Paspalum scrobiculatum*	Kodra, Kodon, Harika, Varaku, Kodra, Kodua, Arika, Varagu	Madhya Pradesh, Chhattisgarh, Tamil Nadu, Maharastra, Uttar Pradesh
5	*Little Millet*	*Panicum miliare*	Gajrao, Kuri Kutki, Sava, Same, Save, Sama, Sava, Suan, Samalu, Swank, Sama	Madhya Pradesh, Tamil Nadu, Karnataka, Chhttisgarh, Jharkhand
6	*Barnyard Millet*	*Echinochlo* spp	Koni dhan, Shyama, Banti, Sanwa, Oodalu, Khira, Swank, Oodalu, Kutdiravali	Uttarakand, Arunachal Pradesh, Nagaland, Madhya Pradesh, Uttar Pradesh, Tamil Nadu
7	*Sorghum*	*Sorgum bicolor*	Jowar, Jondhla, Jola, Jonna, Cholam, Juara, Rotla	Maharstra, Karnataka, Madhya Pradesh, Andhra Pradesh, Tamil Nadu
8	*Proso Millet*	*Panicum miliaceum*	Cheena, Chena, Bari, Baragu, Vari, Bachari, Panivaragu	Maharashtra, Bihar, Orissa, Rajasthan,TamiNadu

Table 2: Nutritional contents in various millets available in India

S. No	Crop	Scientific Name	P (g)	F (g)	Fibe (g)	M (g)	I (mg)	C (mg)	Cal (Kcal)
1.	Pearl Millet	*Pennisetum glaucum*	10.6	4.8	1.3	2.3	16.9	38	378
2.	Finger Millet	*Eleusine coracana*	7.3	1.5	1.5	2.7	3.9	34	336
3.	Foxtail Millet	*Setaria italica*	12.3	4	8	3.3	2.8	31	473
4.	Kodo Millet	*Paspalum scrobiculatum*	8.3	3.6	9	2.6	0.5	27	309
5.	Little Millet	*Panicum miliare*	7.7	5.2	7.6	1.5	9.3	17	207
6.	Barnyard Millet	*Echinochloa* spp	11.2	3.9	10.1	4.4	15.2	11	342
7.	Sorghum	*Sorgum bicolor*	10.4	3.1	2	1.6	5.4	25	329
8.	Proso Millet	*Panicum miliaceum*	12.5	2.9	2.2	1.9	0.8	14	356

major polyphenols in the soluble fraction of millets, whereas ferulic, rosmarinic, and p-coumaric acids are the majority in bound fraction. Protocatechuic, vanillic, syringic, sinapic, and naringenin but gallic, caffeic and salicylic acids were also detected in millets. Another study showed that trans-p-coumaric, protocatechuic, ferulic, and gallic acids are the major free phenolics in brown teff, whereas rutin, ferulic and pro- tocatechuic acids are the major ones in white millets (Kotaskova *et al.*, 2016). Ferulic and gallic acids, quercetin, and catechin are the major bound phenolics in millets, whereas ferulic acid, rutin, catechin, and quercetin are the majority in white millets (Kotaskova *et al.*, 2016). Therefore, the polyphenol composition is much dependent on millets variety. Small amounts of quercetin and luteolin are bound to the cell wall material of millets, which was revealed by hydrolysis of the covalent bonds in alkaline conditions. Naringenin, naringenin-40-methoxy-7-O-a-l-rhamnoside, and eriodictyol-30, 7-dimethoxy-40 -O-b-d-glucoside were also identified in millets. Processing of millet by milling removes the bran and germ layers that are rich in fibre and phytochemicals, and thus causing significant loss. Millets are highly nutritious, non-glutinous and like buckwheat and quinoa, is not an acid forming food so is soothing and easy to digest. It has been considered as one of the least allergenic and most digestible grains available and it is a warming grain so will help to heat the body in cold or rainy seasons and climates. Various functional properties of nutrients have been enlisted in Table 3. The concepts of food consumption have been changing from previous to present time. Previous emphasis was more on survival, hunger satisfaction, health maintenance and absence of adverse effects on health while current emphasis has been more on encouraging the use of functional foods which promise to promote better health and wellbeing thus helping to reduce the risk of chronic diseases such as obesity, diabetes, CVD and cancer etc. Millets have nutraceutical properties in the form of antioxidants, which prevent deterioration of human health.

Uses of Millets

There have been various uses of millets, culinary, medicinal, livestock etc. Some of the uses have been listed below:

Table 3: Functional Properties of Millets

Name	Functional Component	Potential Health
Pearl Millet	Phytonutrient – Lignin, flavonoid, Apigenin, Myricetin	Prevent hormone-dependent cancer (Breast Cancer) and cardiac arrests, anti-fungal, anti-ulcerative properties
Finger Millet	Catechin, gallocatehin, epicatechin, epigallocatechin, taxifolin, vitexin, tricin, myricetin, Leuteolin, quercetin, apigenin, Kempherol, diadzein, Pyrocyanidin B1, Pyrocyanidin B2	Anti-turmogenic, Anti- diabetic, anti-microbial, and antioxidant properties
Foxtail Millet	Catechin,quercetin, apigenin, Kempherol	Body detoxication
Kodo Millet	Apigenin, Kempherol,vitexin, isovitexin,leutolin,quercetin	Anti-diabetic, Anti-rheumatic, anti-cancerous
Barnyard Millet	Luteolin, tricin, N-(p-coumaroyl) serotonin	Anti-diabetic, Anti-rheumatic, anti-cancerous
Porso Millet	Apigenin, Kempherol,myricetin	Anti-diabetic, Anti-rheumatic, anti-cancerous
Little Millet	Apigenin	Anti Anti-diabetic, Anti-rheumatic, anti-cancerous

Table 4: Some industrial products from millets value addition

Crop	Food Product	IndustrialProduct
Pearl Millets	Roti, Ugali, fermented food products, pizza, roasted mix grains	Malting, high fructose syrup, starch, Jaggery, bakery, value added products for diabetics poultry and animal feed
Finger millet	Roti, dumpling, popped millet, malt food	Malting/ brewing, starch, bakery and food for diabetics
Small millets	Roti, cooked cereals	Calue added food for devotees (Bamyard millet), feed, value added food products for diabetics

Culinary use of Millets

Whole Millets: They have mild flavor that blends well with other foods. It is often mixed with other grains or roasted before cooking to bring out the full flavor.An overallincrease in dietary fibre, minerals, protein and antioxidant content in the desired product has been seen by addition of millets in various studies (Ronda *et al.*, 2015). Further,the dietary fiber and polyphenols of millets could decrease the enzyme susceptibility of starch in the food products though interactions with the starch and enzyme (Zhu *et al.*, 2015). The millets starch may also be a source of resistant and slowly digestible starch fractions, which remain to be better studied.

Millet flour: They can be grounded into coarse flour, which lacks gluten. They have been used to make porridge, chapatis and unleavened bread (Collar, 2016). Millet flour is also added to baked foods to provide texture and flavour. It has also been used to make leavened pancakes called dosa and thinner, unleavened roti. *Dhebra*, millet bread popular in India, often made with chickpea and wheat flour for a lighter flavour and texture. Various blend has been prepared by incorporating wheat flour for production of bread, cake, cookie and biscuit. All in all the millets flour increase the nutrition value of the product. The millets lack gluten and hence decrease the specific volume, height to width ratio and sensory quality of bread and consequently increase crumb structure.

Millet grains: They can be boiled whole and eaten like rice. They have been available in three different forms as - fluffy, sticky and creamy millets. We can also substitute up to 30% millet flour in our favourite baking recipes, and also in foods like biscuits, cookies etc.

Health Benefits of Millets

Millets have various nutraceutical properties in the form of antioxidants which prevent deterioration of human health such as lowering blood pressure, risk of heart disease, prevention of cancer and cardiovascular diseases, diabetes, decreasing tumor cases etc. Various other benefits have been described below:

Gluten free: With the rise in demand for gluten-free grains, millets are growing in popularity. Besides being gluten-free, millets are one of the most non-allergenic grains around, and have an alkalizing effect on the body, making it a great choice for those with various food sensitivities and allergies. Various traditional gluten free products of millets are in use which include pasta, injera, sourdough bread, non-sourdough bread and various cookie, extrudate, fat replacer, eaping foods (Mancebo *et al.*, 2015)

Prebiotic properties: Millets are very easy on the digestive system, and also have prebiotic properties which support healthy gut microflora. Due to these properties, as well as their high fiber content also help preventing constipation and other digestive troubles. Millet foods are characterized to be potential prebiotic and can enhance the viability or functionality of probiotics with significant health benefits. Thus, their combination with probiotic can formulate a synbiotic (Thakur, 2014; Thakur, 2016; USDA Food Composition Databases, 2017)

Protein content: They have been long valued by vegetarians for their high protein content. Millets *al*so have lower glycemic index and they contain lignans, which may help reduce the risk of heart disease and breast

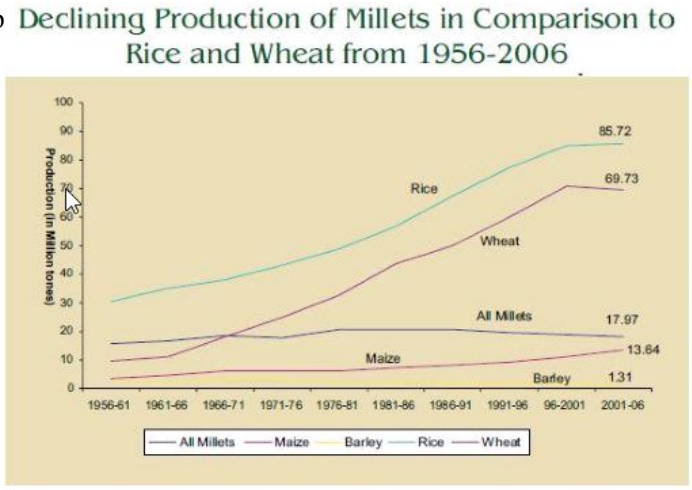

Fig. 1: Millets, Rice and wheat declining production

Fig. 2: Under-utilized crops & Subsistence agriculture

cancer (USDA Food Composition Databases, 2017; Kotaskova *et al.*, 2016). They also contain Niacin (vitamin B3), which helps in balancing cholesterol levels in individuals.

pH balance: Millets are alkaline forming food, which has been very often recommended to achieve optimal health by combining digestive enzymes. The soothing alkaline nature of millet helps to maintain a healthy pH balance in the body, crucial to prevent various illnesses.

Other health benefits

The millets are source of antioxidants (phenolic acids and glycated flavonoids) and rich in minerals. Among these Mg has been linked to reducing the risk of heart attacks, lowering high blood pressure, easing asthma symptoms and reducing the number of occurrences of migraines in migraine sufferers. Phosphorus is crucial to bone health and is also key to the health of cells and fat metabolism and is a component of adenosine triphosphate (ATP), which is the main transporter of energy at the cellular level (Zhu *et al.*, 2018; Shumoy & Raes, 2016). Millets are particularly high in minerals like iron, magnesium, phosphorous and potassium. Among all the classified Millets, Finger millet (Ragi) is the richest in calcium content, about 10 times that of rice or wheat. Therefore, on the basis of the above listed health benefits, they can be very well acclaimed to be functional foods.

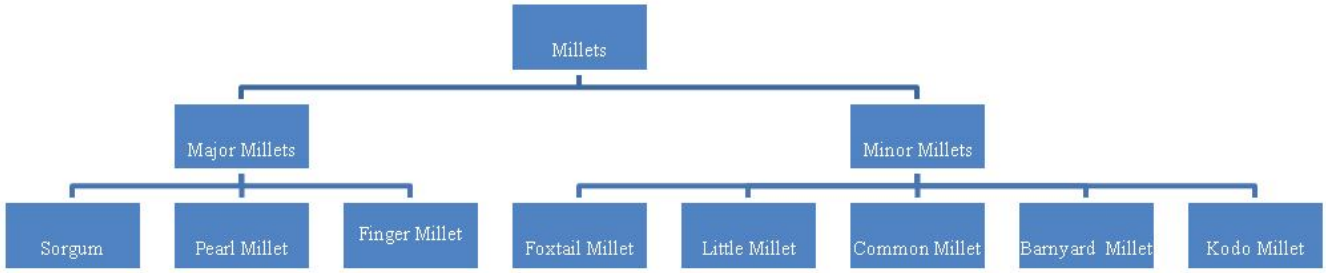

Fig. 3: Classification of Millets

Fig 4: a1, a2: Pearl Millet; b1, b2 : Finger Millet; c1, c2: Little Millet; d1, d2: Kodo Millet; e1, e2: Sorgum; f1, f2: Porso millet; g1, g2: Foxtail millet

Importance of Millets

Millets may not match rice and wheat in grain quality, but they certainly score over them in nutritional value and, these are now often categorised as "nutri-cereals". While the protein content of many millet is close to that of wheat, they are richer in vitamins, especially vitamin B, Fe, P and many other key micronutrients. Besides, these are gluten-free alternatives to finer cereals, which make them alkaline rather than acidic in nature. That explains why coarse cereals a preferred staple food in many parts of the country have been, especially in rural areas. Underutilized crops have the potential to play a number of roles in the improvement of food security in India (Mayes *et al.*, 2011). Some of the potential roles have been enlisted as a part of a focused effort to help the poor for subsistence and income, a way to reduce the risk of over-dependency on very limited numbers of major staple food crops, a way to increase sustainability of agriculture through a reduction in inputs, increase the food quality, a way to preserve and celebrate cultural and dietary diversity, a way to use marginal and wastelands

for agricultural purposes to meet the ever increasing food demand.

Agricultural relevance of Millets

Millets are found in a variety of environmental conditions including the subtropical and tropical regions of the world. They have a relatively short growing season for 3 – 4 months. Their high genetic diversity and self – fertilization results in lower human input. Millets grow very well in dry – land farming systems and respond well to irrigation. The small millets are especially adaptive ecologically, in that they grow well in a wide variety of soil. With limited input, these species can survive in sub-marginal areas of limited rainfall and relatively high temperatures. Figure 2 explains the millets as the future of food and farming.

Energy Efficient plants: Millets are C4 plants which have a very efficient photosynthetic system for capturing carbon dioxide. Various benefits include improve carbon fixation in the crops, concentrate more of carbon's heavier isotopes compared with C3 plants, utilizes a more efficient form of carbon accumulation and improves the Water Utilization Efficiency (WUE) enormously, able to achieve large yields within 4-6 months over summer as compared to many C3 plants that are not able to do this over a whole year.

In spite of all benefits, millets have been gradually edged out of the food chain largely because the government began supplying highly subsidized staple food like wheat and rice at much cheaper rates. Despite policy neglect and lack of subsidies, millet and coarse grains have managed to survive, even if on a progressively shrinking acreage, because of their continued use as livestock, bird feed, and growing industrial uses (such as for production of starch and alcoholic beverages) etc. The biggest factor in their favor is that these crops are innately more efficient converter of energy and plant nutrients into biomass, including grains. Many among them are, therefore, capable of delivering higher tonnage per hectare than wheat and rice with modern agronomic technology and improved crop varieties, including hybrids, which are available in markets now. Apart from these benefits, promoting millet and other coarse cereals would also be needed given that crop yields in irrigated areas have almost reached a plateau. If India is to meet the rising demand for nutritious and healthy food and if rainfed agriculture has to experience a revolution in productivity, this is where research in agriculture and price policy should focus. Water-guzzling crops like rice and wheat should, in fact, give way to millet and other coarse cereals in areas where the former are irrigated with groundwater, causing rapid depletion of underground water aquifers, to prevent today's grain bowls from becoming tomorrow's deserts.

Millets and their types

Millet is the term for a group of small seeded grasses or a group of cereals other than wheat, rice, maize and barley. They are mostly tiny in size, round in shape and ready for usage as such. Nowadays, ANI (Millet Network of India) promotes millets as Nutri-cereals instead of Coarse Cereals. The millets include species in several genera. The most widely cultivated species in order of worldwide production are shown in Fig. 3 and Fig. 4 (a1 - g2).

Millets the best material for fortification

One of the major problems faced in our country is micro nutrient deficiencies. It can be combated by the cheapest, easiest and best way by the process of fortification. Bio fortified millets have a great potential to reduce micronutrient deficiency in the developing countries. Millets being less expensive compared to other cereals and staple food for the mass people could be chosen as the best vehicle for fortification. In Millets, micronutrient such as iron, zinc, calcium and vitamins can be used as fortificants (Collar *et al.*, 2015; Collar *et al.*, 2014; Collar, 2016; Giuberti *et al.*, 2016). Millets are more nutritious than refined flour therefore can be incorporated into bakery products as well and it is slowly started using in some of the bakery outlets. A study has revealed and concluded that to combat zinc deficiency, finger millet flour can effectively be used as a vehicle for zinc fortification to derive additional amounts of bio-accessible zinc, with reasonably good storage stability. Deficiency of zinc is believed to be as widespread as that of iron, with equally serious consequences. Fortification of staple foods with minerals like iron and zinc are one of the cost-effective method to combat the micro nutrient deficiencies.

Millets in food Industry

Millets have been used in the industry at various processing sectors (Table 4). The emerging principal uses of millets has been as industrial raw material include production of biscuits and confectionary, beverages, weaning foods and beer (Laminu *et al.*, 2011). Grits, flour and meals from cereals such as millet, sorghum, corn are now common items in the market. Soft biscuits and cookies are being made using sorghum, maize and wheat composites, while cakes and non-wheat breads have become a subject of increasing scientific and technological enquiry, showing encouraging results (Hama *et al.*, 2012; Laminu *et al.*, 2011). Only in the infant weaning food sector, in spite of unlimited potential, progress has been

slow, as the installed capacity for industrial malting is limited (Akeredolu *et al.*, 2005; Laminu *et al.*, 2011). Many innovative products like Bajra lassi, have been developed with nutritional supremacy of pearl mill*et al*ong with healthy lactic acid bacteria (NDRI, 2008). The process developed also enhances the mineral bio-availability and consumer acceptability. Millets act as food substrate for probiotics and improve flavor, texture and overall acceptability of the product (Charalampopoulos *et al.*, 2002). These millets also help in the production of synbiotics (Thakur, 2016).

Future Challenges

With an increasing population and thus increasing demands for food, feed, and fuel, society will be compelled to increase agricultural production-whether by increasing yields on already cultivated lands or by cultivating currently natural areas-or to change current crop consumption patterns. Moreover, diversification of food production must be encouraged both at national and household levels in tandem with increasing yields. More healthful and traditional whole-grain and multigrain substitutes for refined carbohydrates due to adverse health effect can be one important aspect of therapeutic dietary modification and promoting utilization of minor-grain foods. From the literature reviewed it has been observed that although nutritive value and potential health benefits of millet grains comparable to major cereals such as wheat, rice, were found to be more, yet the utilization of millet grains as food is still mainly limited to populations in rural areas at the household level. Besides, being small seeded and low-price commodity, the produce is not properly cleaned, graded and dried before they are brought to the markets, fetching low price to the farmers and poses storage problems. Various innovative processing technology are being required to provide easy-to-handle, ready-to-cook or ready-to-eat, and safe products and meals at a commercial scale that can be used to feed large populations in urban areas. In addition, there is a need for innovative processing technologies for decortication, milling, and other preparation treatments of millet grain food in order to produce high-quality products at commercial scale for urban consumers.

Conclusion

This article reviewed the millets as underutilized, untapped, nutritious functional foods. Millet is a crop with drought resistant qualities, very easy to digest, it contains a high amount of lecithin and is excellent for strengthening the nervous system. Millets are rich in B vitamins, especially niacin, B6 and folic acid, as well as the minerals calcium, iron, potassium, magnesium and zinc. Under the action of interstitial friendly flora, they are converted to mammalian lignans, which act against different types of hormone-dependent cancers, like breast cancer and also help reduce the risk of heart disease. Regular consumption of millet is very beneficial for postmenopausal women suffering from signs of cardiovascular disease, like high blood pressure and high cholesterol levels. Children's intake of whole grains like millet and fish has been shown to reduce the occurrence of wheezing and asthma. A high source of fiber, millet is very beneficial against breast cancer in post-menopausal women. According to research and recent studies, consumption of millet can help women combat the occurrence of gallstones, as they are a very high source of insoluble fiber. This form of cereal grain is very high in phosphorus content, which plays a vital role in maintaining the cell structure of the human body. Based on the research the millet grains contain many health-promoting components such as dietary fiber, minerals, vitamins, and phytochemicals that include phenolic compounds, and they are comparable to those of major grains and they also have several potential health benefits. However, novel processing and preparation methods are needed to enhance the bioavailability of the micronutrients and to improve the quality of millet diets. Research is also needed to determine the bioavailability, metabolism, and health contribution of millet grains and their different fractions in humans. Making millet food products that deliver convenience, taste, texture, color, and shelf-stability at economical cost for poor people is needed. In addition, for promoting utilization of millet grains in urban areas, markets for farmers to improve their income, developing highly improved products from millet is needed.

References

Alaunyte, I., V. Stojceska, A. Plunkett, P. Ainsworth and E. Derbyshire (2012). Improving the quality of nutrient-rich Teff (*Eragrostis tef*) breads by combination of enzymes in straight dough and sourdough bread making. *Journal of Cereal Science*, **55**:22–30.

Assefa, K., G. Cannarozzi, D. Girma, R. Kamies and S. Chanyalew Plaza-Wuthrich (2015). Genetic diversity in tef [*Eragrostis tef* (Zucc.) Trotter]. *Frontiers Plant Science,* **6**:177.

Bultosa, G., H. Wrigley, K. Corke, Seetharaman and J. Faubion, (2016). Teff: Overview In C. Encyclopedia of food grains (2nd ed., pp. 209–220). Oxford: Elsevier.

Davis, P.H. (1988). Flora of Turkey and East Aegean Islands. (3rd Ed) Edinburgh University Press, London.

Charalampopoulos, D., R. Wang, S.S. Pandiella and C. Webb (2002). Application of cereal and cereal components in functional foods: a review. *International Journal of Food Microbiology*, **79(1-2)**:131-141.

Collar, C. (2016). Impact of visco-metric profile of composite dough matrices on starch digestibility and firming and retrogradation kinetics of breads thereof: Additive and interactive effects of non-wheat flours. *Journal of Cereal Science*, **69**: 32–39.

Collar, C. and A. Angioloni (2014). Pseudocereals and teff in complex breadmaking matrices: Impact on lipid dynamics. *Journal of Cereal Science*, **59**:145–154.

Collar, C., T. Jimenez, P. Conte and A. Piga (2015). Significance of thermal transitions on starch digestibility and firming kinetics of restricted water mixed flour bread matrices. *Carbo Pol.*, **122**:169–179.

Giuberti, G., A. Gallo, L. Fiorentini, P. Fortunati and F. Masoero (2016). *In vitro* starch digestibility and quality attributes of gluten free 'tagliatelle' prepared with teff flour and increasing levels of a new developed bean cultivar. *Starch/ Stärke*, **68**: 374–378.

Hama, S.H. (2012). The microbial quality of processed date fruits collected from a factory in Al-Hofuf City, Kingdom of Saudi Arabia. *Emirates Journal of Food Agriculture,* **24(2)**: 105-112.

Kotaskova, E., D. Sumczynski, J. Mlcek and P. Valasek (2016). Determination of free and bound phenolics using HPLC-DAD, antioxidant activity and *in vitro* digestibility of *Eragrostis tef*. *Journal of Food Component and Analysis*, **46**:15–21.

Kunkel, G. (1984). Plants for Human Consumption. Koeltz Scientific Books. Koenigstein, Germany.

Laminu, H.H, S. Modu and A.I. Numan (2011). Production, *in vitro* protein digestibility, phytate content and acceptability of weaning foods prepared from pearl millet (Pennisetum typhoideum) and cowpea (Vigna unguiculata). *International Journal of Nutrition Metabolism*, **3(9)**: 109-113

Li, J., Z. Chen, X. Guan, J. Liu, M. Zhang and B. Xu (2008). Optimization of germination conditions to enhance hydroxyl radical inhibition by water soluble protein from stress millet. *Journal of Cereal Science*, **48**:619–24.

Mancebo,C.M., J. Picon and M. Gomez (2015). Effect of flour properties on the quality characteristics of gluten free sugar-snap cookies. *LWT Food Sci and Technology*, **64:** 264–269.

Mayes, S., P.G. Massawe, J.A. Alderson, S.N. Roberts, Azam-Ali and M. Hermann (2011). The potential for underutilized crops to improve security of food production. *Journal of Experimental Botany*, doi: 10,1093/jxb/err396.

McDonough, Cassandrea M., L. Rooney, W. Loyd, Serna-Saldivar and O. Sergio (2000) "*The Millets". Food Science and Technology*: *Handbook of Cereal Science and Technology,* 99 2nd ed: 177–210. CRC Press.

Ronda, F., W. Abebe, S. Perez-Quirce and C. Collar (2015). Suitability of tef varieties in mixed wheat flour bread matrices: A physico-chemical and nutritional approach. *Journal of Cereal Science*, **64:**139–146.

Shumoy, H. and K. Raes (2016). Antioxidant potentials and phenolic composition of tef varieties: An indigenous Ethiopian cereal. *Cereal Chemistry*, **93:**465–470.

Thakur, M. (2016). Significance of prebiotics, probiotics and synbiotics as health potentiators. *Food Science Journal*, **7(2):** 327-334.

Thakur, M. (2014). Underutilized Food Crops: Treasure for The Future India. *Food Science Research Journal,* **5(2): 174-183**

USDA Food Composition Databases (2017). <https://ndb.nal.usda.gov/ndb/search>. Accessed 14.06.17.?

Zhu, F. (2018). Chemical composition and uses of teff (*Eragrostis tef*). *Food Chemistry*,**239:**402-415.