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Alternative Healthy Food Crops

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Abstract

Plants having diverse profile in terms of nutrition, availability, tolerance to harsh climatic conditions and possibility of usages as food, forage and biofuel usually referred as Alternative plants. This article will only be focused on the plants having value to reinstate themselves as alternative food crop for the burgeoning population. Indigenous communities across the globe are familiar with a large diversity of flora and fauna that provide sustenance in form of food and medicine. The 'plants for a future' website reveals a list of more than 7000 underutilized species with different values (PFAF website). Most of these plants thrive well on impoverished or marginal soils and dry weather conditions. Millets, Buckwheat, Oats, and Chenopods are coming up as imperative nutritious option. The multipurpose use of Millets, Buckwheat, Oats, Chenopods and Barley coupled with early maturity, low nutrient demand and ability to adapt well to marginal and degraded lands makes them an ideal crop for future sustainable agriculture.

Keywords: Millets; Chenopods; Oats; Buckwheat; Alternative food; Healthy food

Introduction

Need for alternative food crops

Hovering fear of losing well domesticated crop plants due to natural disaster, heavy socio-economic pressure on a few crops and estimated population growth i.e 8.5 billion by 2025 [1] are the valid reasons to be ready to prepare and grow other staple crops, which are equivalent to existing staple crops [2]. About 50% of world population suffers from micronutrient deficiencies specifically in developing countries. Deficiencies of Iron, Zn and vitamin A are critical nutritional issues and result in impaired physical growth, immune system function, mental and cognitive development and increase in anemia, maternal mortality and infection. Embracing of improved crop varieties, better equipment and farm mechanization, cultivation of more land, as well as increased fertilizer use for optimum growth is not sufficient anymore. Refining operations further degrade the nutritional value of cereals by removal of micronutrient rich germ and aleurone layers of the grains. Thus other optional crops viz. Millets, Oats, Buckwheat etc. must be consumed to maintain the micronutrient balance for good health. However, with an increasing population and demands for food, feed, and fuel, society is pressed to increase agricultural production whether by increasing production on already cultivated lands or by cultivating currently natural areas or to change current crop consumption patterns or to bring undermined nutritive crops in picture.

At present, 22 crops account for the food crops produced on earth with dramatic reduction in food diversity for across the globe. It should be understood, that the speedy change in cropping system has drastically declined the production of many traditional staple food that are much richer in micronutrients as compared to processed food crops like Millets, Oats, Buckwheat Chenopods and Pulses.

Judicious efforts are required towards the inclusion of alternative crops as part of our regular diet, throwing away the myth attached to their belonging to poorest of the poorest. These plants are resilient, well adapted to local environments, and for being wild, still retain highly diverse genetic bases and unique characteristics [3]. The short and easy route to approach food security fast is to explore diverse resources which are not utilized yet or wild relatives having nutrition at par.

Millets

Millets are indigenous to many parts of the world; most likely had an evolutionary origin in tropical western Africa, where they exist in wild and cultivated forms [4]. Often they have been included in the orphan crop list as they are not traded across the world and failed to seek attention of researchers at all. In addition, social stigma attached to these crops as "food for the poor", as well as the extra efforts required to dehusk and process the grains, to increase the attractiveness of millets.

Millets are small seeded grasses grown for food, feed or forage and cultivated mostly in developing countries in poor soil and dry conditions. India is the largest producer of many kinds of millets, which are often referred to as coarse cereals. Now, they have been gaining importance as nutri–cereals due to their nutrient composition being superior or comparable to major cereals [5]. Millet grains are attracting attention in developing countries in terms of utilization as food and nutrition but some developed countries exploring their potential for manufacturing of bioethanol and biofilms.

There are at least 10 genera and 14 species of millets belonging to the Poaceae (Gramineae) family (Table 1). Millets grown in India are sorghum (Jowar), pearl millet (Bajra), finger millet (Ragi) and many other small millets viz., Kodo millet, Foxtail millet, Little millet, Proso millet and Barnyard millet. They can grow well and tolerant to poor soil and dry conditions.

Of all the species Pearl millet and Sorghum in India have total area of 23 – 24 million ha and have wide acceptability as food crop, while ragi and other small millets account for about 2.7 million ha area. Their cultivation is extending from sea level in Coastal Andhra Pradesh to 8000 feet above sea level in hills of Uttaranchal and Northeastern states [6]. Despite being a highly nutritive, drought tolerant, water saving crop

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Millets	Common name
Brachiaria ramosa	Browntop millet
Coix lachryma jobi	Job's tears
Digitaria exilis	Hungry rice
Digitaria ibura	Fonio or Hungry rice
Echinochloa colona	Jungle rice
Echinochloa utilis	Japanese millet
Echinochloa frumentacea	Indian barnyard millet
Eleusine coracana	Finger millet
Eragrostis teff	Teff, Lovegrass
Panicum miliaceum	Proso millet
Panicum miliare	Little millet
Paspalum notatum	Bahia grass
Paspalum scrobiculatum	Kodo millet,Samak
Pennisetum glaucum	Pearl millet, Bajra
Setaria italica	Foxtail millet

Source-Kothari et al. [6]

Table 1: Botanical name and common names of different millet species.

Crop / Nutrient	Protein(g)	Fiber(g)	Minerals(g)	Iron(mg)	Calcium(mg)
Wheat	11.8	1.2	1.5	5.3	41
Rice	6.8	0.2	0.6	0.7	10
Corn	9.5	7.3	NA	2.71	7
Barley	2.3	3.8	NA	1.3	11
Proso millet	12.5	2.2	1.9	0.8	14
Pearl millet	10.6	1.3	2.3	16.9	38
Little millet	7.7	7.6	1.5	9.3	17
Kodo millet	8.3	9	2.6	0.5	27
Foxtail millet	12.3	8	3.3	2.8	31
Finger millet	7.3	3.6	2.7	3.9	344*
Barnyard millet	11.2	10.1	4.4	15.2	11
Teff	11.1	3.6	NA	59*	140*

*They are correct figures exceptionally high.

Table 2: Nutrient content of various millets in comparison with Wheat, Rice, Corn, and Barley(Source network of India ,http://www.milletindia.org & references cited in text).

its production had seen drop after green revolution in favour of cash crops. Now it is time to recognize and retrieve these important crops for future use. Millets are the 6th cereal crop in terms of world agriculture production. Compared to major cereals, millets have resistance to pests and diseases, short growing season, and productivity under drought conditions [7], to be deserving crops of interest.

Nutritive value of Small millets

The small millets are cheap sources of nutritive food for poor and the labour class people and hence their health depends on the quality of food consumed. The research on the evaluation of nutraceutical properties and nutritional value of grains is now gaining momentum. Being non gluten crop the most millets are good food for people facing colon health problem. Four selected small millets *viz.* finger millet, foxtail millet, prosomillet and kodo millets have been examined for the presence of phenol, tannins, alkaloids, flavonoids and saponins. All these compounds have notable effect as immunity modulators, anti carcinogen, regulator of cell proliferation, delaying gastric emptying, and supplying gastrointestinal bulk and free radical scavengers along with control over cholestrol activity [8-10].

Despite being rich in dietary fiber, minerals, and sulfur containing amino acids compared to present major staple grains viz. rice, wheat and corn, recent studies show lower consumption of millets in general by urban Indians. This is due to lack of awareness and innovative processing technologies specifically in case of millets 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 [11] (Table 2).

Of all the cereals and millets, finger millet has the highest amount of calcium (344 mg %) and potassium (408 mg %). It has higher dietary fiber, minerals, and sulfur containing amino acids compared to white rice, the major staple in India. Despite finger millet's rich nutrient profile, recent studies indicate lower consumption of millets in general by urban Indians. *In vitro* and *in vivo* (animal) studies indicated the blood glucose lowering, fighting bad cholesterol, antiulcerative, wound healing properties, etc., of finger millet. However, appropriate intervention or randomized clinical trials are lacking on these health effects [12,13] reported maximum phenolic content (10.3%) in kodo millet followed by finger millet (7.2%) and foxtail millet (2.5%). As far as reducing property (RP) is concerned finger millet is having the highest (5.7%) followed by foxtail millet (4.8%) and least in prosomillet (2.6%). Presence of high RP in all the millets can help in reducing the oxidative damage caused by free radicals.

The sugar reducing index in four tested millets ranges from 130.43 to 391.30 mg/g. Of these highest is with finger millet (391.30 mg/g). The high-crude fiber in the millets may enhance their digestibility and also aid the peristaltic movement of the intestinal tract. The water-soluble protein content is maximum in foxtail millet (305.76 mg/g).

The highest dietry fiber of kodo millet (14.3%) makes it ideal food for persons with insulin sensitivity or diabetes [13]. The improvement of turf quality by genetic engineering represents a promising alternative to over-expression of the *Arabidopsis ATHB16* transcription factor in bahiagrass (*Paspalum notatum* Flugge) significantly changes plant architecture [14].

In Finger millet some of the health benefits are attributed to its polyphenol contents [15]. It has a carbohydrate content of 81.5%, protein 9.8%, crude fiber 4.3%, and mineral 2.7% that is comparable to other cereals and millets. Its crude fiber and mineral contents are markedly higher than those of wheat (1.2%, fiber, 1.5% minerals) and rice (0.2% fiber, 0.6% minerals); its protein is relatively better balanced; it contains more lysine, threonine, and valine than other millets. In addition, finger millet contains 8.71 mg/g dry weight fatty acid and 8.47 g/g dry weight protein [16].

Latha et al. [17] developed finger millet resistant to leaf blast disease to make availability in abundance. Recently efforts were made to develop highly efficient transformation protocol for finger millets both with *Agrobacterium* [18] and Biolistic gun to open up new window to fight with the most devastating fungal disease [18,19].

Kodo millet and little millet were also reported to have 37 to 38% of dietary fiber, which is the highest among the cereals; and the fat has higher polyunsaturated fatty acids [20,21]. The protein content of proso-millet (11.6% of dry matter) was found to be comparable with that of wheat and the grain of prosomillet was significantly richer in essential amino acids (leucine, isoleucine, and methionine) than wheat protein [22]. Thus, the presence of all the required nutrients in millets makes them suitable for large-scale utilization in the manufacture of food products such as baby foods, snack foods, and dietary food and, increasingly, more millet products have entered into the daily lives of people, including millet porridge, millet wine, and millet nutrition powder from both grain and flour [5,23,24].

Foxtail millet protein characterization revealed the fact that its protein concentrate is a potential functional food ingredient and being rich in lysine makes it possible rich protein source to most cereals[25].

With an attractive nutrition profile *Eragrostis tef* has high dietary fibre, protein and calcium. It is popularly known as lovegrass. Injera a spongy fermented flatbread made of fermented *tef* grain is main source of providing energy and essential part of Ethiopian food. It has similarity to Dosa in South India. Its nutritional and amino acid contents in comparison to other major cereal crops studied by Jansen [26], Agren et al. [27], Alemayehu [28] with minor modification but almost disappeared due to lack of awareness from rest of the world except in some parts of East Africa [29]. Amino acid composition of the three tef types was reported to be the same [30,31] regardless of their seed color i.e red, black and white. It is also consumed in the form of porridge and bread. Its straw is a nutritious and highly preferred feed for livestock compared to the straw of other cereals particularly during dry season. Besides its local use, it is the major cash crop for the farming community as market price for both its grain and straw is higher compared to other cereal crops [32].

Eragrostis pilosa, a wild plant species, occur throughout the both world in tropical and temperate regions [33] is the closest relative of the cultivated *E. tef. E. pilosa* is also an allotetraploid and has a karyotype similar to *E. tef* [34]. These two species are morphologically similar. Shattering spikelet of *E. pilosa* is the only known consistent morphological distinction between two spp.

Fonio (*acha*) (*Digitaria exilis* (Kippist) Stapf. and *D. iburua* Stapf) is widely cultivated for human food in the semi-arid regions of West Africa. Fonio is not only drought-tolerant but also a very fast-maturing (75 days) crop [35,36]. The seeds of fonio are nutritious, especially in methionine and cysteine, the two amino acids essential for human health, but deficient in major cereals such as wheat, rice and maize [37]. In West Africa, fonio is used in traditional medicine but more as a source of food, which is used to prepare porridges, flours, alcoholic and non-alcoholic beverages [38].

Millets as an option to healthful and traditional whole-grain and multigrain substitutes for refined carbohydrates can be one important aspect of therapeutic dietary modification and promoting utilization of coarse-grain foods [39].

Buckwheat

Buckwheat originated in North or East Asia. The most common buckwheat species is *Fagopyrum esculentum* Moench (common buckwheat or sweet buckwheat), while *Fagopyrum tartaricum* is also available in some mountainous regions. It has been grown since at least 1000 BC in China and widely adapted in North America. Buckwheat *(Fagopyrum esculentum* Moench), family Polygonaceae, classified as a pseudo-cereal, is a crop adapted to cool, moist climates and to a growing season 60-70 days long. Based on RAPD analysis the place of origin of common buckwheat was also traced to the northwestern region of Yunnan, while that of the tatary buckwheat to the northwest part of Sichuan province in China [40].

Research studies conducted have revealed about functionalities and properties of proteins, flavonoids, flavones, phytosterols, thiamin-inding proteins, and other rare compounds in buckwheat seeds [41]. Buckwheat proteins have unique amino acid composition with special biological activities of cholesterol-lowering effects, anti-hypertension effects, and improving the constipation and obesity conditions by acting similar as to dietary fiber and interrupting the *in vivo* metabolisms.

Nutrients	% Value
Manganese	34
Tryptophan	25
Magnesium	21.4
Copper	12.5
Fibre	18.1
Calories	8

Table 3: Nutrients in Buckwheat.

Experimentation with both animal models and human beings, have come to terms that buckwheat flour can improve diabetes, obesity, hypertension, hypercholesterolemia and constipation [42]. Polyphenol-rich buckwheat proteins are unique protein materials for the production of the hydrolysates with good nutritional and antioxidant properties [43]. Buckwheat provides livelihood and household nutritional security to farmers' in remote and inaccessible mountains big resource of food (Table 3).

Presence of rutin, a flavonol glucoside serving as part of the defense system against oxidative stress makes buckwheat unique among crops. Rutin is essential for the proper absorption and use of vitamin C; prevent vitamin C from being destroyed in the body by oxidation; beneficial in hypertension; help in hemorrhages and ruptures in the capillaries and connective tissue and builds a protective barrier against infections. Buckwheat transgenics were developed to investigate the molecular and metabolic regulation of rutin biosynthesis [44,45]. Green buckwheat tea has became used more since it is known for its content of rutin and its beneficial effects on cardiovascular disease, reducing risk of arteriosclerosis and also for its antioxidative effect [46].

The concentration of Rutin varied in different milling fractions of buckwheat seeds bran (131-146 ppm) and flour (19-168 ppm) as was determined using capillary electrophoresis. The same method was applied to confirm Rutin presence in stem, leaves, flowers i.e. 300, 1000, and 46000 ppm respectively which make them important nutritional source of flavonoids [47]. Having provided with 3 servings of whole grains daily had cut down risk of diabetes by 21% compared to those having one serving per week. Presence of chiro-inositol is responsible for lowering blood sugar. In a placebo-controlled study, a single dose of buckwheat seed extract lowered blood glucose levels by 12-19% in 90 and 120 minutes after administration when fed to laboratory animals with chemically-induced diabetes [44,48]. Chromatographic analysis of Buckwheat varieties indicated sufficient components of zinc, copper and manganese in buckwheat flour [49].

Oats

The common oat (*Avena sativa*) is a species of cereal grain grown for its seed, like rye, oats are usually considered as secondary crop, i.e., derived from a weed of the primary cereal domesticates wheat and barley. Oats are grown in temperate regions. Greater tolerance to rain than other cereals, such as wheat, rye or barley, make crop amicable in areas with cool, wet summers, such as Northwest Europe [50]. Oats are annual grasses; previously considered to be diseased wheat by Romans [51], and many other cultures believed them to be better suited to animals. Oats can be planted either in autumn or in the spring. Locally known as «jaiee», oats are grown on the foothills of Himalayas, such as in the Indian state of Punjab, Uttar Pradesh and Bihar.

Oat bran consumption is believed to lower LD («bad») cholesterol, and possibly to reduce the risk of heart disease. Presence of beta-glucans, a soluble fibre, has been proven to help lower cholesterol. Oats contain more soluble fibre than any other grain, resulting in slower digestion and an extended sensation of fullness [52].

The crop was swiped by soybean for the time being but in mid-80's recognized as healthy food and gained popular status for human nutrition (Whole Grains Bureau) storage protein [51]. The minor protein of oat is a prolamine and avenin.

Oat protein is nearly equivalent in quality to soy protein, which World Health Organization research has shown to be equal to meat, milk, and egg protein [53]. The most recent research indicates that some cultivars of oat form a safe part of a gluten-free diet [54].

Quinoa

Chenopodium quinoa Wild. is an Amaranthacean, stress-tolerant plant cultivated along the Andes for the last 7000 years, in highly challenging different environmental conditions ranging from Bolivia, up to 4.500 m of altitude, to sea level, in Chile.

It is considered a pseudocereal or pseudograin, has been recognized as a complete food due to its protein quality and exceptional balance amongst oil, protein and fat. Its high protein content (15%), great amino acid balance, presence of minerals (Calcium, Magnesium, potassium and Phosphorus) and vitamins (Thiamin, Riboflavin, Folic acid) makes it remarkable nutritional food to consume. Quinoa has a high water absorption capacity (147%) and low foaming capacity and stability [55]. Free tryptophan in quinoa flour showed values similar to those of wheat, oat and sorghum but higher than in rice, maize, rye, sorghum. The non protein tryptophan fraction, the only one able to enter the brain, that is more easily absorbed, makes guaranteed availability to the central nervous system.

Quinoa seed flour has high proportion of D-xylose (120.0 mg/100 g) and maltose (101.0 mg/100 g), and a low content of glucose (19.0 mg/100 g) and fructose (19.6 mg/100 g), suggesting that it would be useful in malted drink formulations. Protein isolates Q9 and Q11 has been reported to be high in essential amino acids, with high levels of lysine, can be used as a valuable source of nutrition for infants and children [56].

Its minerals work as cofactors in antioxidant enzymes, adding higher value to its rich proteins and also protect cell membranes, with proven good results in brain neuronal functions. It has also been found to contain compounds like polyphenols, phytosterols, and flavonoids with possible nutraceutical benefits. The proportion of omega-6 and notable vitamin E content provides consideration as oil crop. Quinoa starch has physicochemical properties (such as viscosity, freeze stability) which give it functional properties with novel uses [57].

To bring focus of world's attention on the quinoa's biodiversity and nutritional value and its role in providing food security, the USDA National Institute of Food and Agriculture in partnership with Washington State University have conducted International Quinoa Research Symposium to fulfill internationally agreed development goals of the eradication of poverty (International Quinoa Research Symposium 2013, Washington) [36].

Barley

Barley is considered as the world's most ancient cereal, stand in fourth as major cereal crop in acreage and production, surpassed only by wheat, maize and rice. Barley exhibits a broad range of adaptability, including the ability to grow at high altitudes and latitudes, under a wide range of day length variation and marginal conditions such as salinity and limited rainfall. It grows within a considerable range of environments that vary from northern Scandinavia, to the Himalayan Mountains. Thus, barley is one of the most variable and adapted cereal crops with continued prominence in today's agriculture.

Chung had reported complete nutritional profile of mature barley grains [58]. However, having low lysine and threonine limit its nutritional value for humans consumption but in turn, reports several health benefits, especially for obese and diabetic patients. These benefits are mainly attributed to the high content of β-glucans in barley grains [59]. Furthermore, Behall et al. [60] showed that a daily diet containing 3 or 6 g barley-derived β-glucan causes a significant decrease of total cholesterol, which may result in a reduced risk of cardiovascular diseases. Diet enriched with β-glucan results in a reduced rate of sugar absorption, a decrease of postprandial glucose and an attenuated glycemic response [61].

Barley has the highest levels of phosphorus, calcium, potassium, magnesium, sodium, copper, and zinc, and the second highest content of iron following millets [62].

Prospects

The shrinking diversity in the world's food basket has lowered the availability of the foods rich in many micronutrients with obvious increase in production at the cost of losing micronutrients as result of modern practices. At present load on a few crop species has brought down the diversity index globally.

The changes like replacement/abandonment of traditional crops, domestication of new crops, abandonment/expansion of agricultural land use, increase in livestock population has affected the socio-ecological environment. Modifications on traditional farming systems have force farmers to be innovative in handling new conditions.

Conclusion

Different Millets, Chenopods, Buckwheat, Barley as well as Oats can serve as complementary food, and as food blends seems to be the best option for the preparation of nutritional, safe, high-quality, and shelf-stable products at household and commercial scales to promote utilization of millet grains as "healthy food".

The crops viz. millet grains, buckwheat, chenopods and oats have been left out since long but now gaining important place in food bowl due to lack of gluten content, rich in micronutrient, high glycimic index and presence of useful secondary metabolites. Therefore, there is significant increase in the demand of these commodities. Government policies of providing funds and inviting eminent scientist to conduct research on such orphan crops have paved the way for application of modern technique to streamline these crops for future use.

Evaluation of nutritive value and potential health benefits of millet grains, buckwheat, chenopods, Oats and their fractions in animal and human models should be tested in future to support efforts for promoting their utilization as food.

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