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Nutraceutical Potential of *Echinochloa Frumentacea* and their Value-Added Products

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Abstract

Underutilized crops possess promising nutritional importance for a variety of purposes for humankind, however, their commercial importance and market value of these crops are still unknown. Barnyard millet is such an underutilized drought-tolerant crop that can combat natural calamity and play an important role in nutritional management globally and thus can be considered as a future nutrient source. Here, in this review paper, we have mainly focused on the nutritional, therapeutic properties, and value-added products of barnyard millet. This grain can be consumed in different ways; as ready-to-eat food products or as different snacks along with fortification with other millets, pulses, or vegetables. Thus, the different value-added products of the underutilized grains can be opted for as a healthier version of the grains in the market.

Keywords: Barnyard Millet; Nutrition, Underutilized Grains; Bioactivities

Introduction

Echinochloa frumentacea is commonly known as Indian Barnyard millet or billion-dollar grass (English), Sanwa (Hindi), Shyama (Sanskrit), Oodalu (Kannada), Jhangora (Uttarakhand), Swank (Punjabi), Bhagar (Maharashtra), Samo or Morio (Gujarati), Kauda, Kautta, Kowda, Kowtta (Malayalam), Udali/Kodisama (Telugu), Shamula (Bengali) and Kuthiraivaali (Tamil) [1,2]. Barnyard (*Echinochloa frumentacea*) is an herbaceous annual that tillers sparsely. It is a plant that grows up to a height of 220 centimeters with a slender stem; flat, glabrous leaves; and fibrous and shallow roots. The inflorescence is a terminal raceme with variable shapes (i.e., cylindrical, pyramidal, and circular to elliptic) and colors (i.e., green, light purple, and dark purple) (Figure 1). Spikelets are tightly packed in three to five rows. The spikelets are subsided by two bracts within which there are two florets with different bract colors varying from white to red. The kernel remains enclosed inside the lemma and palea. The grains of barnyard millet are mostly yellow or white. It is one of the fastest-growing crops among all the millets, attaining maturity within 45 days from the sowing time under optimal atmospheric conditions [1,3,4]. It's a temperate zone crop, suitable for low and moderate rainfall ranging between 500 to 700 mm [3].

It is generally grown in the arid and semiarid regions of the world such as India, Nigeria, Niger, China, Japan Burkina Faso, Mali, Sudan, Korea, Uganda, Chad, and Ethiopia [2,5,6]. In China and Japan, it is said to be grown as a substitute for rice. It is also grown to some extent in Africa and the United States of America. In India, its cultivation is restricted to the hilly and semi-arid regions of the Southern peninsula of Tamil Nadu, Andhra Pradesh, Karnataka, and Northern states of Jharkhand, Madhya Pradesh, Maharashtra, Bihar, Uttar Pradesh, and Uttarakhand [2,3]. Globally, India is the biggest producer of barnyard millet (99.9%), both in terms of area (0.146 m ha^{-1}) and production (0.147 mt) with average productivity of 1034 kg/ha during the last 3 years [7]. In Uttarakhand, barnyard millet is produced on 48151 hectares of land, with a yield of 13.08 q/ha as the average grain output in 2019. This yield results in a total yearly production of 62996 MT [8]. The district-wise production details of barnyard millet in Uttarakhand are represented in (Figure 2).

Figure 1: (a) Barnyard Millet (*Echinochloa frumentacea*) plant.
(b) Raw seeds of barnyard millet.

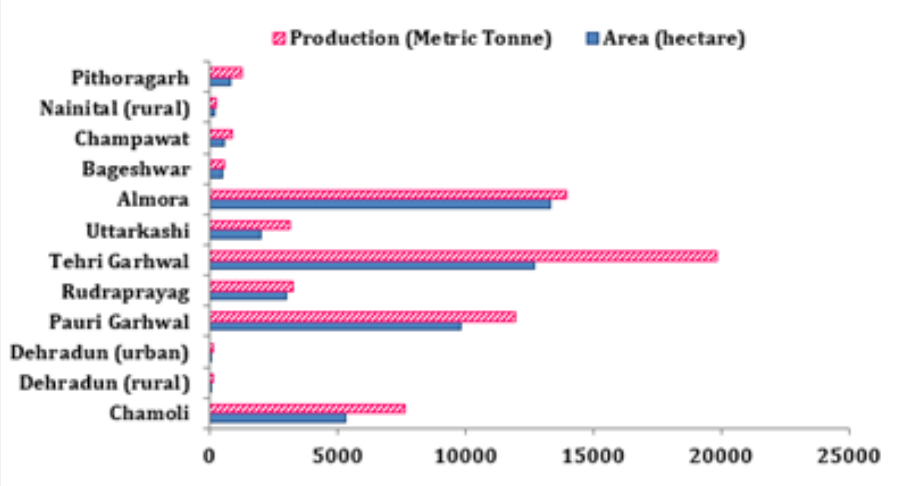

Figure 2: Production details of barnyard millet in Uttarakhand (2018-19).
Source: [8].

Therapeutic Properties of Barnyard Millet

The barnyard millet (*Echinochloa frumentacea*) is useful in the treatment of biliousness and constipation [9,10] and allergic diseases such as atopic dermatitis [11]. It is best in lowering blood glucose and lipid levels therefore can be potentially recommended for patients with cardiovascular disease and diabetes mellitus [12]. It is also reported to have good antioxidant potential, anti-carcinogenic, anti-inflammatory, antimicrobial, and having a wound healing capacity [7]. Barnyard millet can be helpful for people suffering from anemia [4]. This millet seems to be an ideal food and appears to be beneficial for gluten intolerant patients thus preventing celiac disease [1,2,13,14].

Consumption Methods

Grain legumes/millets are neglected ancient grain that is re-introduced as 21st-century smart foods to build a global healthy society and provide nutritional security. These grains play an important role in the traditional diets of many parts of the world and they are low in fat; are excellent sources of protein, dietary fiber, a variety of micronutrients, phytochemicals as well as have various therapeutic properties. Barnyard millet (*Echinochloa frumentacea*) is either consumed as a dehulled splits, boiled, roasted, or ground into flour used for making a variety of recipes which is a common practice among the rural people in India [15]. Millets must first undergo primary processing to transform the grain into an edible form, improving its quality and customer appeal. Barnyard millet is difficult to process because their inedible husk must be removed before they can be de-branned to a satisfactory amount during primary processing. All the recipes are prepared after the processing step, mostly dehulling of millet. The processing steps undergo some nutritional losses. The protein and fat content remain unaffected by dehulling process whereas crude

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fiber, mineral content, polyphenols, antioxidant potential and antinutrient content are significantly reduced. Roasting significantly increases the nutritional content. To overcome this limitation, fortified products are developed by incorporating nutritionally rich ingredients [16,17].

Several recipes of millets have been reported from ancient times and have been a staple food particularly in the diets of African and Asian people. In southern India, it is used in traditional preparations such as idly, dosa, puttu, adai, and chakli [14]. In the Indian Himalayan region, barnyard millet has been traditionally used as a substitute for rice. These grains are used for the preparation of traditional as well as novel foods. Various traditional and newly developed products have been developed using barnyard millet. Barnyard millet is generally used in the preparation of different value-added products such as popping meals, vermicelli, roti/chapati, noodles, biscuits, cookies, malt based weaning food, extruded products, snack food, Ladoo, halwa, biryani, dosa, alcoholic and non-alcoholic beverages [4,13,18-25,26,27]. In addition to food products barnyard millet is also used as fodder for cattle and can also be used for making hay or silage [7,28].

Nutritional Properties of Barnyard Millet

Barnyard millet is a good source of protein, fat, carbohydrates, and crude fiber, minerals, vitamins, and some essential amino acids [3,11,12,29,30]. It has total ash, crude protein, crude fat, crude fiber, and carbohydrate at a level of 4.27, 10.76, 3.50, 3.90, and 71.87 % respectively (Figure 3). The low carbohydrate content and slow digestibility of barnyard millet makes it an appropriate food for people who are involved in sedentary activities [25]. It also contains some antinutrient constituents such as a-amylase inhibitors, trypsin inhibitors, phytate, and tannins known for hindering the bioavailability of nutrients (Figure 4) [12]. Barnyard millet is a rich source of several vitamins such as thiamine, riboflavin, niacin, ascorbic acid, α-tocopherol (Figure 5) [12,31] and minerals such as iron, zinc, calcium, copper, manganese, and magnesium, containing 23.16 mg/100 g calcium and 15.6^{-1}8.6 mg/100 g iron [12,31,32]. It also contains phytochemicals, such as phenolics (bound phenolic acid-ferulic acid, free phenolic acid-protocatechuic acid), lignans, β-glucan, inulin, resistant starch, phytates, sterols, tocopherol, carotenoids, flavonoids, and tannins which serve as a good source of natural antioxidants [12,14,33,34]. It is a good source of free fatty acids comprising linoleic acid as the predominant fatty acid followed by oleic, palmitic, stearic acid, and linolenic respectively [35]. The major amino acids found in barnyard millet seed are isoleucine, leucine, lysine, methionine, phenylalanine, histidine, threonine, tryptophan, and valine [36,37]. Various traditional and newly developed products developed using barnyard millet are also reported to be highly nutritious and are shown in (Table 1) along with their nutritional properties.

Table 1: Nutritional profiling of barnyard millet-based food products.

S. No	Name of the Product	Protein (%)	Carbohydrate (%)	Fat (%)	Fiber (%)	Moisture (%)	Ash (%)	Energy (Kcal 100g^{-1})	Calcium (mg 100g^{-1})	Iron (mg 100g^{-1})	Magnesium (mg 100g^{-1})	Zinc (mg 100g^{-1})	Phosphorus (mg 100g^{-1})	Niacin (mg 100g^{-1})	Ascorbic Acid (µg 100g^{-1})	Reference
1	Vermi	8.09	-	1.91	3.45	7.78	-	263.44	67.9	13.99	102.5	-	-	-	-	[18]
	celli	10.1	80.3	1.7	-	6.4	1.4	-	-	3.81	-	-	-	-	-	[20]
2	Weaning Mix for infants	18.37	60.89	9	0.41	7.33	4	389	253.33	4.9	-	2.72	-	2.49	74.66	[24]
3	Halwa	1.26	30.61	9.29	0.53	-	-	211	4.2	1.27	-	-	-	-	-	[25]
4	Laddu	3.41	64	25.01	1.45	-	-	495	14.6	3.4	-	-	-	-	-	[25]
5	Biryani	3.12	21.63	6.75	1.52	-	-	159.75	16.9	1.4	-	-	-	-	-	[25]
6	Dosa	9.1	44	9.8	4.7	19.1	2.4	-	-	-	-	-	-	-	-	[26]
7	Chapati	7.32	53.9	11.5	4.68	-	-	-	12.2	3.96	-	-	254	0.0034	-	[48]
8	Barnyard millet cookies															
	Plain	1.96	64.78	23.6	0.72	4.33	4.6	479	10.7	2.42	16.5	-	140.25	-	1162	
	Pulse	6.61	62.68	26.4	0.71	4.7	1.11	508	22.65	2.5	33.82	-	193.75	-	1162	
	Vegetable	1.21	66.51	24.2	0.69	4.53	0.66	495	26.07	4.04	17.7	-	165.25	-	8139	[13]

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9	Barnyard millet Biscuits	6.11	52.2	-	2.03		1.31	487	-	-	34130	866.7	124270	1648.9	-	[27]
10	Barnyard millet Noodles															
	Plain	4.64	78.98	3.2	0.88	8.86	3.46	363	12.73	4.35	23.72	-	280	-	2325	[13]
	Pulse	15.54	65.17	2.26	0.84	9,23	2.26	386	51.11	2.95	61.6	-	387	-	1744	
	Vegetable	8.34	75.97	2.46	1.77	9.86	2.46	352	44.7	5.55	49.5	-	256	-	2906	
11	Barnyard millet and potato-based oil free, microwave puffed ready-to-eat fasting foods	8.16	-	5.416	-	-	2.91	-	-	-	-	-	-	-	-	[19]

Figure 4: Structure of antinutrients present in barnyard millet.

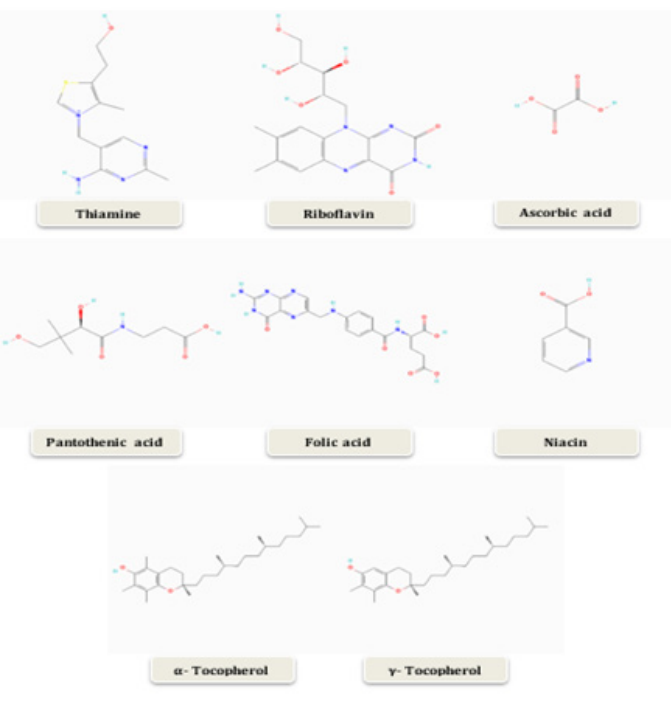

Figure 6: Structure of vitamins present in barnyard millet.

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Bioactivities

Anti-diabetes

According to the studies dehulled and heat-treated barnyard millet is advantageous for Type II diabetes. Its low glycemic index was recorded to be 50.0 for dehulled millet and 41.7 for heat-treated millet [1,38]. Vandana 2018 also evaluated the anti-diabetic potential of barnyard millet by undergoing two in-vitro inhibition assays, the results showed effective inhibition against α- glucosidase activity (59.01%) and α- Amylase 78.2% [39]. The antidiabetic properties of barnyard millet were further studied by using invitro α-amylase, α-glucosidase, and AGEs inhibition assay showing effective inhibition. They further suggested that soluble millet phenolics, which are predominantly flavonoids, act as potent inhibitors of α-glucosidase and α-amylase, which could help reduce the release and absorption of glucose in the small intestine, and thus provide beneficial effects in diabetes by mitigating postprandial glycemic response [40]. Studies on barnyard millets as low glycemic index foods have revealed their nutraceutical significance in lowering the post-prandial blood glucose level to prevent and treat type -2 diabetes. These studies used millets as food combinations with amaranth and buckwheat [41,42]. Researchers led by Seo investigated the anti-diabetic and anti-hyperglycemic effects of polyphenols extracted from barnyard millet. For this they studied the inhibitory effects of isolated compounds from barnyard millet grain on various a-glucosidase activities assay. Among all the isolated molecules feruloyl serotonin, N-p-coumaroyl serotonin, and luteolin were reported to be significantly inhibiting the activity of α-glucosidase. Thus, we can say that barnyard millet can be used to prevent type-2 diabetes [43].

Antioxidants

Millets are high in antioxidants and phenolics, such as phytic acid, phenols, and tannins, which can help to the antioxidant activity that is crucial for good health, preventing ageing, and preventing metabolic syndrome [39]. Japanese barnyard millet was reported to have luteolin and tricin [44]. Barnyard millet was studied in several forms, including raw millet: sprout millet, and soaking millet, for the presence of phytochemicals, total phenolic content, and antioxidant activity in aqueous and methanol extracts by Murugan and this team. A strong association between antioxidant activity and total phenolic content suggests that phenolic compounds are a major contributor to barnyard millet's antioxidant capabilities [45]. The role of phenolic compounds such as flavonoids, anthocyanin, tannins, and phenolic acid in millet act as an antioxidant and play a crucial role in strengthening the body's immune system. g). Ofosu 2020 reported flavonoid content (101.3 mg catechin/ 100 g) and phenolic content (129.5 mg FAE/100 g) of barnyard millet [41]. Cao et al and his team prepared edible films using barnyard millet starch and were reported to have antioxidant potential and can be used as an antioxidant packaging material [46].

Anti-cancer

Millets are well recognized for being high in phenolic acids, tannins, and phytates, which function as "antinutrients." However, in animals, these antinutrients lower the incidence of colon and breast cancer [39]. The anti-cancerous properties of vanillin (4-hydroxy-3-methoxybenzaldehyde), which was isolated from barnyard millet, were evaluated by Ramadoss and his colleagues. By employing the HT-29 and MCF-7 cell lines for the MTT experiment, the cell proliferative impact was evaluated, and it was discovered to be effective in reducing oxidative stress and cancer risk. Thus, the vanillin molecule has potential for usage as a powerful chemotherapeutic [33,47,48].

Antimicrobial activity

Antimicrobial activity has been discovered in the millets fraction and extract. The efficacy of seed protein extracts from barnyard millet to stop the development Rhizoctonia solani, Macrophomina phaseolina, and Fusarium oxysporum was tested in vitro [14].

Conclusion

Additionally, there is a growing trend among individuals to eat a better variety of both traditional and conventional foods. Efforts are being made to create awareness on the potential health benefits of barnyard millet which are recommended for obese, diabetic, celiac, and other lifestyle diseases. Along with good health benefits they are also reported as a reasonable source of protein, carbohydrates, fiber, antioxidants, and other bioactive components making them an important crop for the food industry and researchers. Nowadays they have been effectively used to develop a variety of value-added products that can assist people to combat malnutrition and are helpful for diabetic patients. They are also used to prepare malted weaning foods and nutritious meals for infants. As a result, there is a need to create awareness on how to incorporate barnyard millet into our daily diets and to popularize the value-added food products for promoting their consumption and utilization as these products are highly nutritious which may benefit people's health. Therefore, there is large scope for the food specialist to the development of various value-added foods from barnyard millet.

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