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Review article

Pinnacles of Proso millet (*Panicum miliaceum* L.): A nutri millet

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Abstract: Proso millet is a self-pollinated crop and true millet of history that can grow well in many agro-climatic conditions. It is rich in many phytochemicals when compared to finger, foxtail and little millet. In terms of natural antioxidants, it is in the second position after finger millet. Proteins of proso millet suppress the activity of D-galactosomine induced elevation of serum activities of aspartate aminotransferase, alanine aminotransferase and lactate dehydrogenase and prevent the risk of liver injury also it elevates the HDL_2fractions. Fibre and resistant starch that is present in the proso acts as a probiotic and beneficial in many ways and can bring about an effective reduction in the levels of glucose and insulin with up-regulated expression of adiponectin and downregulating effect of tumor necrosis factor-α (TNF-α) and abetting type 2 diabetes, obesity, and cardiovascular diseases. Food and nutrition scientist show more interest towards millets and its health effects on combating lifestyle diseases and now millets are regaining its importance on achieving nutrition security.
Keywords: Proso Millet - Functional properties - Nutraceutical functions.

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INTRODUCTION

The UN Food and Agriculture Organization (FAO) have decided to observe 2023 as the International Year of Millets and year 2018 was declared as year of millets in India. Proso millet is grouped under C4 cereals that utilize more CO_2 from the air and convert that to oxygen, also possess high water efficiency (low straw to grain ratio), requires low input (shallow-rooted) and has good cold tolerance, therefore, can be considered as more environment-friendly crop. Millets are grown in several parts of the country but its production rate is not uniform throughout the decade, it may be due to various external and internal agro-climatic reasons.

The common millet was the earliest dry farming crop in East Asia, which is probably attributed to its excellent resistance to drought conditions (Lu *et al.* 2009). Proso millet was cultivated from ages and known for its legacy for long time and it's called by different names in various parts of the world like hershey millet, broom corn millet, common millet or hog millet etc. In India, Japan, China, Egypt, and Arabia and in some parts of Western Europe, it is widely cultivated for diverse purposes. Madhya Pradesh, eastern Uttar Pradesh, Bihar, Tamil Nadu, Maharashtra, Andhra Pradesh and Karnataka are the states where this millet is extensively grown.

Madhya Pradesh has the highest area of small millets (32.4%) followed by Chhattisgarh (19.5%), Uttarakhand (8%), Maharashtra (7.8%), Gujarat (5.3%) and Tamil Nadu (3.9%). Uttrakhand has highest productivity of 1174 kg ha^{-1} followed by Tamil Nadu (1067 kg ha^{-1}) and Gujarat (1056 kg ha^{-1}), details given by the structural break analysis by Anbukkani *et al.* (2017).

The seeds of proso may be creamy white, yellow; red or black. The grains are spherical to ovoid in shape, about 3 mm long and 2 mm diameter (Baltensperger 2002). The 1000 kernel weight is about 7.1 grams. During milling of proso millet bran and the husk layer gets removed and that yields about 79% of flour from small starchy endosperm (1.3 to 8.0 µm diameter) that are spherical (Malleshi & Hadimani 1994, Kumari & Thayumanavan 1998). Salient features of released varieties of proso millet crops from 1982 to 2011 were given in table 1.

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Table 1. Salient features of released varieties of proso millet crops (1982 to 2011).

S.N.	Name of the variety	Pedigree	Institute where developed	Year of release	Maturity (days)	Average Yield (qt ha^{-1})	Area of adaptation	Special features
1	K1	Selection from local	TNAU Cbe	1982	65–70	9–10	TN	Stay green character
2	Sagar	Selection from local	ANGRAU, Hyd	1989	85–90	18–20	AP	High seed yield
3	Nagarjuna	Pure line selection	ANGRAU, Hyd	1989	60–65	15–18	AP	Early maturity
4	CO4	Pureline selection	TNAU Cbe	1989	70–75	12–15	TN	Tolerant to shoot fly & drought
5	Bhawna	Pureline selection	CSAUAT, Kanpur	1992	65–70	12–15	UP	Early maturity
6	GPUP 8	S 7×L111	UAS Dharwad	2001	85–90	15–16	Karnataka	Resistant to brown spot
7	GPUP 21	GPUP 14×K1	PC unit, UAS, Bangalore	2003	65–75	15–18	Karnataka, TN	High yield, moderately tolerant to shoot fly
8	Pratapchenna-1(PR-18)	Pureline selection	MPUA & T, Udaipur	2006	65–70	15–17	National	Early duration , dual purpose
9	Co(PV) 5(TNAU 143)	PV1403× GPUP 21	TNAU cbe	2007	70–75	23–25	National	High yield, profuse tillering, drought tolerant
10	TNAU 145	PV 1454×TNAU 96	TNAU, cbe	2007	70–72	18–20	TN	High yielding, superior qly for value addition
11	TNAU 151	TNAU 96×PV1673	TNAU cbe	2008	70–75	18–20	National	Bold grains, tolerant to shoot fly
12	PRC 1	Selection from GPMS 519	Rani chauri, GPPUA & T, Pantnagar	2008	70–75	10–12	Uttarakhand hills	Resistant to leaf blight
13	TNAU 164	TNAU 137 ×Co4	TNAU Cbe	2009	70–75	18–20	National	Non lodging, tolerant to shoot fly & rust
14	TNAU 202	PV 1453 ×GPUP	TNAU Cbe	2011	70–75	18–20	National	Profuse tillering & bold grain

Source: www.millet.res.in by Indian Institute of Millets Research (IIMR)-ICAR.

Need for processing

Though the seeds are bestowed with nutritional benefits, better processing methods are required to make it edible and to increase the digestibility factors. Thermal and other processing methodologies inactivate natural toxins; paves way for prevention of food spoilage and increase food safety aspects. Processing of millets optimizes the organoleptic properties of the final product also it satisfies the consumer demand for convenience and easy meal solutions. Transformed consumer awareness and concern made a surge in the value-addition and processing capacities of millets. Prices of these small millets have become unpredictable. The price of procurement in one region is less expensive than the other but need to consider the transportation cost.

Moreover growing demands on the wholesome cereal and gluten-free products facade the millets to be on top. With the aim of improvising the agricultural and nutritional characteristics of proso millet, different varieties were released to cater the specific needs of the agrarian population in our country.

Small Millets: Not 'Small' in Nutrition

Waning State support (in terms of crop loans/insurance) has endured to the poor production and consumption status of millets in our country's agriculture that needs to be reversed. There is a current need for the policymakers to amend their attention towards millet farming systems and enact policies to create an enabling environment for the farmers.

Small millets being superior in nutritional properties when compared to commonly consumed crops like rice and wheat; their consumption needs to be promoted on a larger scale to address various nutritional challenges facing the country (Amadou *et al.* 2013, Saleh *et al.* 2013). But drudgery involved in dehulling and further processing has to be mitigated using processing technologies.

Millets are an important source of important nutrients like niacin, magnesium, phosphorus, manganese, iron and potassium. They contain high amounts of protein, fiber, essential amino acid methionine, lecithin, and vitamin E. Millets may be considered. Millets may be considered as therapeutic foods for the control of asthma, hypertension, CVDs and diabetes and obesity related health issues, since it has many advantages in terms of nutrients.

It is well documented that the proso millet has better nutritional values when compared to other staples. Proportion of starch in proso millet varies from 62 to 68 % with amylase content of 17% as dry basis and its starch hydrolysis is analogous with maize starch hydrolysis.

In vitro digestibility of proso millet protein is 80% and mostly constitutes prolamine out of total protein. This proso has about 60% of linoleic acid and 14% oleic acid composition with respect to fatty acids. Methanolic extracts of proso showed good antioxidant property and having polyphenol content of 29 µg / 100 g and carotenoids 74 µg / 100 g. With regard to anti-nutrients, proso millet apparently does not have protease inhibitory activity when compared with pearl millet, foxtail millet, and finger millet, however, chymotrypsin inhibitors have been detected (Ravindran 1991).

Millets are good source of micro minerals, macro minerals, polyphenols and total dietary fibre when compared with cereals (Devi *et al*. 2014, Gupta *et al*. 2012). Millets are gluten-free, ideal for people who are gluten-intolerant, though millet flour cannot be used for raised bread (Santra 2013, Amadou *et al.* 2013). Proso millet is gluten free and it has 11.6% of dry matter by weight and has some of the essential amino acids such as leucine, isoleucine and methionine comparable with wheat protein (Kalinova & Moudry 2006).

Pathak (2013) reviewed the presence of lecithin in millets have many beneficial health effects especially restoring the nerve cell activities. Also it contains good amount of methionine, except lysine and threonine it is a fair source of other essential amino acids given by Saleh *et al*. (2013). Bagdi *et al.* (2011) stated that dehulled proso millet has 12.2 g of leucine per 100 gram of protein in proso and with protein efficiency ratio (PER) of 1.1. Obilana & Manyasa (2002) stated that generally millets have total saturated fatty acids and mono saturated fatty acids when compared with maize, rice and sorghum. Nutritional parameters of Proso millet is itemized in table 2.

Table 2. Nutrient composition of Proso millet in comparison with staple cereals.

Crop	Protein (g)	Carb (g)	Fat (g)	Dietary fibre (g)	Mineral matter (g)	Calcium (mg)	Phosphorous (mg)	Iron (mg)
Proso millet	12.5*	70.4	3.1*	14.2*	1.9*	14	206*	10.0*
Wheat	11.8	71.2	1.5	12.9	1.5	41	306	3.5
Rice	6.8	78.2	0.5	5.2	0.6	45	160	1.8

Adapted from: Saha *et al.* (2016).

Nutraceutical and functional properties

The pinnacles of small millets need to be subjugated in view of its health benefits. The unprecedented change in the lifestyle and dietary pattern has led to widespread nutritional deficiency both in terms over and under-nutrition that made a double burden to our country. The prevalence of micronutrition deficiencies even in affluent sects of the population is a matter of concern. Consumer preference of small millets in food basket had been declining over the years and it is high time to revive the strategies to mitigate the slow departure of native foods from our dietary habits (Mathanghi & Sudha 2012). Being one of the largest producers as well consumers of millets in the world, we need to develop and standardize millet based pre-validated functional food to meet the global demand. Healthy effects of millets are vested with their phytochemicals, polyphenols and abundant existence of micro and macro mineral that are scientifically proven. But still epidemiological and experimental studies are needed for further authenticity (Himanshu *et al.* 2018).

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). Biodiversity and nutraceutical quality of millets are well documented with diverse studies and it can be categorized on the basis of poverty eradication/source of income, health management, food security and natural resource management (Gupta *et al.* 2012).

Therapeutic intervention in diabetes

Proso millet protein (PMP) has an important role in cholesterol metabolism as it can increase the concentration of the high-density lipoprotein (HDL) cholesterol level, especially the isomer HDL_2, and adiponectin without affecting the concentration of low-density lipoprotein (LDL) cholesterol (Nigro *et al*. 2014). Adiponectin is important in accelerating insulin sensitivity and promotes lipid metabolism and indicates up-regulation in the expression of adiponectin in PMP diet modules (Park *et al*. 2008).

Health benefits in CVD

Shimanuki *et al.* (2006) fed the rats with proso-millet protein concentrate for 21 days and studied the plasma levels of HDL cholesterol, HDL sub fractions and lecithin: cholesterol acyl transferase (LCAT) activities and found a clear elevation of plasma levels of HDL_2 cholesterol. According to their study, there was an increase in HDL cholesterol concentration is substantially due to the elevation of HDL2 particles which have a principal role in protection against CHD and therefore proso millet may have advantageous effects over CVDs. The Framingham Heart Study was conducted to found the relation between lipids and risk of coronary heart disease and elucidated that low concentrations of HDL_2 cholesterol are strongly associated with a high risk of atherosclerotic heart disease (Gastelli *et al*. 1992). Effect of processing on the phytochemical content and antioxidant capacity of proso millet was studied by Bora *et al*. (2018) and found total phenolic and flavonoid content were highest in whole and dehusked grain flours than polished grain flours while phytate content was highest in dehusked (682.50 mg / 100 g) grain flours than whole (574.74 mg / 100g) and polished (194.00 mg / 100 g) grain flours. Whole grain flour possessed significantly highest total antioxidant capacity (281.79 mg TE / 100 g) than dehusked (156.93 mg TE / 100 g) and polished (144.94 mg TE / 100 g) flours. Choi *et al.* (2005) stated that proso millet flour consumption elevates the HDL levels in animal models.

Lee *et al.* (2010) studied the triglyceride concentration and C-reactive protein effects on hyperlipidemic rats by feeding finger millet and proso millet. The result showed rats fed with proso millet has significantly lower concentrations of serum triglycerides than rats fed with white rice and sorghum. Reduction in plasma triglyceride in hyperlipidemic rats indicates that proso may have beneficial effects on CVD risks.

Antioxidant properties

Cell signaling, gene regulation are influenced by oxidants and the presence of primary and secondary antioxidants. The polyphenols and nutraceutical components present in proso millet such as lignin contents, phytic acids and condensed tannins should be considered for antioxidant protection. Role of bound phenolics in the colon in the production of SCFs and B-complex vitamins are much valued. Oligosaccharides as prebiotics help in skeleton health. Other compounds such as α-linolenic acid, policosanol, melatonin, phytosterols and *para*-amino benzoic acid have to be researched more in terms of nutraceutical property. Nutrigenomic effect of proso millet as a cereal grain and its varied food products will definitely have a health potential.

The total antioxidant activities of the edible flours of proso millet varieties ranged from 0.5 to 5.7 mM tocopherol equivalent/g as studied by Asharani *et al.* (2009). Also, the antioxidant activities of the proso millet were evaluated on the basis of the scavenging capacity of DPPH2 radicals and reactive oxygen species (ROS) in vitro chemical assays by Chandrasekara & Shahidi (2010).

Zhang *et al.* (2014) tested the phenolic acid composition and found the bound fraction contributed to 65 % of the total phenols. Also, it contains ferulic acid, chlorogenic acid, syringic acid, caffeic acid and p-coumaric which contribute numerous antioxidant and anti-proliferative effects.

Dietary fibre

Nutrient Content of Puffed Proso Millet was studied by Pilat *et al.* (2016) and they found the elements phosphorus 377.50 mg / 100 g, potassium 235.1 mg / 100 g, magnesium 123.48 mg / 100 g. Also, they found the

samples hold neutral detergent fibre (NDF), consisting of cellulose, lignin, and hemicelluloses, amounted to 9.56} 0.15% for the puffed proso millet. The content of ADF fraction, *i.e.* acid detergent fibre consisting of cellulose, lignin, pectin, and tannin, was estimated at 7.57} 0.49% for the puffed proso millet grains.

There are many studies that proved fibre rich whole grains consumption that has positive effect in protection against lifestyle diseases. The specific effects include augmented satiety, reduced transit time and low glycaemic response, increased roughage, viscosity and SCFA production in rectum and Mg jointly with the antioxidant and anti-carcinogenic properties of numerous bioactive compounds present in the bran and germ are well-documented system (Fardet 2010).

A women's cohort study was conducted on pre-menopausal women to find whether any correlation between eating high fibre diet (>30 grams daily) and incidences of risk factors of breast cancer in UK by Cade *et al.* (2007). The study on Women's Cohort Study Steering Group showed people who consume more fibre had 52 % lesser breast cancer risk.

Preventive food for liver injury

Dietary protein from proso millet were given to liver injured rats (induced by D-galactosamine or carbon tetrachloride) using serum enzyme activities as indices. D-galactosamineinduced elevations of serum activities of aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase were significantly suppressed by feeding the diet containing 20% protein of proso millet when compared with casein protein levels. Nishizawa *et al.* (2002) suggested that proso millet protein is considered to be another preventive food for liver injury.

Anti-tumor activity

Aburai *et al.* (2007) studied the methonolic extracts of proso millet and Japanese millet for linoleic acid and evaluated against histone deacetylase inhibitor. That showed an uncompetitive inhibitory activity towards histone deactylase (IC_{50} = 0.51µM) and potent cytotoxicity towards potent leukemia K562 (IC_{50} = 68 µM) and prostate cancer LNCaP cells (IC_{50} = 193µM). It was concluded that proso millet and Japanese millet containing linoleic acid might have anti-tumor activity.

Value-added processed products

Mostly the grains and flour of small millets are important components of native diets and beverages, and even their grains and straw are used as feed stocks. All millets are usually cooked as rice after dehulling. Generally, millet flour is consumed as stiff porridge or as roti. Proso millet flour is also used as a substitute for rice flour in various snack product preparations. It is gluten-free; hence it is unsuitable as the sole material for the preparation of bakery products. It can even be streamed into idly as millet combination batter. Other foods such as flaked breakfast cereal, extruded products, puffed and popped millets are also produced and available in the market. Especially they are used as weaning food and supplementary food. The contribution of millets to national food security and their potential health benefits, millet grain is now receiving increasing interest from food scientists, technologists and nutritionists. Some of the schemes to increase millets production/promotion by governmental organisations include

- Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP);
- Rashtriya Krishi Vikas Yojana (RKVY) which is the only comprehensive initiative to support millet production;
- Rainfed Area Development Programme (RADP) - a component of the Rashtriya Krishi Vikas Yojana (RKVY); and
- Integrated Cereals Development Programmes in Coarse Cereals based Cropping Systems Areas (ICDP-CC) under Macro Management of Agriculture (MMA).

Maximizing their utilization value

New advanced processing technologies can be adapted to easily cook the millets and prepare various foods products that are easy to digest. Moreover, nutrients lacking in the diet can be added to millet grain-based foods (*e.g.* thiamine added to flour). Increase the profitability of farmers by developing on-farm technologies and primary processing. Lucrative use of millets in varied food and feed products will definitely fetch the interest of the farmers. This can be achieved through research and developmental activities in multivarious sectors of agriculture, livestock farming and food processing by providing an infrastructure to conduct the evolution. By

doing so, the complete exit of smallholding farmers from agriculture may be vetoed and revival of native foods is also possible.

Lack of technical know-how on processing methods can be shunned by giving demonstrations and hands-on trials at various levels of extension activities. Associated cultural issues in adoption into regular food habits have to be getting rid of and diversification of food products has to be encouraged.

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