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Review Paper

A Compendious Review on Phytopharmacology of Pearl Millet

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ABSTRACT

Pearl millet (Pennisetum glaucum), commonly known as bajra, is an important cereal crop widely cultivated in arid and semi-arid regions due to its exceptional adaptability to harsh environmental conditions. It is a rich source of essential nutrients including proteins, dietary fiber, vitamins, minerals, and bioactive phytochemicals, which contribute to its significant nutritional and therapeutic value. The present review summarizes the botanical profile, nutritional composition, phytochemical constituents, traditional uses, and pharmacological activities of pearl millet. The grain contains various bioactive compounds such as phenolic acids, flavonoids, tannins, glycosides, sterols, and saponins, which are responsible for its diverse biological activities. Studies have reported that pearl millet exhibits several pharmacological effects including antioxidant, anti-inflammatory, antidiabetic, antimicrobial, antihypertensive, cytotoxic, and anticancer activities. Due to its high nutritional quality and health-promoting properties, pearl millet has gained increasing attention as a functional food and potential therapeutic agent in the prevention and management of chronic diseases such as diabetes, cardiovascular disorders, and metabolic syndrome. Pearl millet is therefore a valuable nutritional resource with strong pharmacological and nutraceutical potential, underscoring the need for more research and broader use in the food and health sectors. Because pearl millet (Pennisetum glaucum) contains goitrogenic phytoconstituents that impede thyroid hormone manufacture by blocking thyroid peroxidase activity, it has a significant anti-thyroid potential. Experimental research has shown decreased T3 and T4 levels together with an increase in TSH, indicating its potential use in the treatment of hyperthyroidism. To determine its safety and therapeutic efficacy in the food and health industries, more mechanistic research, chemical isolation, and clinical validation are necessary

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INTRODUCTION

A staple crop in arid and semi-arid regions, pearl millet (*Pennisetum glaucum*) has been grown for centuries, providing millions of people with sustenance and nutritional security. Its robust nature, adaptability to harsh environments, and rich nutrient composition make it a cornerstone of food systems in regions where other crops struggle to thrive. In recent years, there has been a resurgence of interest in pearl millet due to its remarkable nutritional profile and potential health benefits.

The goal of this review is to give a thorough overview of the nutrient and bioactive composition of pearl millet and to investigate its potential health benefits. We will delve into the rich nutritional content of pearl millet, including its protein, fiber, vitamin, and mineral content, highlighting its role as a valuable dietary component. Pearl millet can be used as food, feed, and fodder; it can be grown under harsh ecological conditions; it is superior to major cereals in terms of energy value, protein, fat, and minerals. Its use of pearl millet is restricted because it is mostly available as whole flour for making porridge or reties (unleavened Indian bread).

Pearl millet is a member of the Gramineae family. Linnarus divided it into two subspecies: Panicum glaucum and Panicumameicanium. In the past, the two names that were frequently used were *Pennisetumglaucum* (*L*) R.Br. and Pannisetumtypoidus (Burm). Nowadays, the crop is synonymous with the first name.[1]

In India, pearl millet is cultivated as a one-season crop. The majority of cultivation occurs on marginal and unirrigated land. The world produces 26,702,000 metric tons of millet from an area of 33,692,000 hectares, according to FAO statistics of all the millet varieties, pearl millet is acknowledged to be the most extensively cultivated. From 2000 to 2009, Nigeria was the second-largest producer of millets, after India. Over 10 million tons of pearl millet are produced annually worldwide, of which India makes up over half of the total. Because pearl millet (*Pennisetumtyphoideum*) can withstand difficult growth circumstances, it is frequently grown. Although Karnataka is one of the major Indian states that grows pearl millet, the area used for production has decreased over time. Gujarat, Maharashtra, and Rajasthan are other significant pearl millet-producing states with the largest pearl millet consumption. [2]

Because of its remarkable resistance to severe environmental factors like drought, high temperatures, and low soil fertility, pearl millet is highly prized. Pearl millet is a crucial crop for food security in climate-vulnerable areas since it can withstand and generate respectable yields under water-limited conditions, unlike other cereals like Triticum aestivum (wheat) and Oryza sativa (rice).[3]

Figure 1: Pearl millet

Figure 2: Pearl millet seeds

Taxonomical Classification: [4]

Table 1: Taxonomical Classification of *pearl millet*

Taxonomical Rank	Taxon
Taxonomy	*Pearl millet*
Domain	Eukaryota
Kingdom	Plantae
Phylum	Tracheophyta
Sub-phylum	Angiospermae
Tribe	Panciceae
Class	Magnoliopsida
Order	Poales
Family	Poaceae
Sub-family	Panicoideae
Genus	Pennisetum
Species	Pennisetum glaucum (L.) R. Br.
Common Name	Bajra

Profile of the Plant:

- **Habitat:**

Under unfavourable circumstances and poor soil, other cereals like rice, wheat, maize, sorghum, and barley may not be able to provide economic benefits, but pearl millet may endure and produce a significant amount of grain. It is a climate resilient crop for overcoming the negative effects of the changing climate because of its capacity to tolerate greater temperatures, survive in drought-prone areas, and be grown in portions of Gujarat and eastern Uttar Pradesh, India, during hot summers.

Pearl millet, or Bajra in Hindi, is the most widely grown millet. This summer cereal grass has large heads, leaves, and stems. It may be cultivated under both rain-fed and irrigated settings and has a short growing season.[5]

- **Distribution:**

After rice, wheat, and maize, it is the fourth most widely farmed cereal crop in India. 90% of India's entire production comes from the key pearl millet-growing states of Rajasthan, Maharashtra, Uttar Pradesh, Gujarat, and Haryana. Rajasthan makes up the largest portion of this roughly 4.283 million 5 tonnes followed by Uttar Pradesh (1.302), Haryana (1.079), Gujarat (0.961), Maharashtra (0.66), and Tamil Nadu (0.084). It is primarily grown during the rainy (kharif) season (June/July-September/October), but it is also grown in some areas of Gujarat, Rajasthan, and Uttar Pradesh during the summer (February-May). It is also grown on a small scale during the post-rainy (rabi) season in the states of Maharashtra and Gujarat.

Wheat, maize and other cereal plants in the area do not survive. Of all the millet types, pearl millet occupies more than 29 million hectares; nevertheless, its geographic distribution is mainly limited to Africa (15 million) and Asia (11 million), where it is the major producer. Over 95% of pearl millet is produced in developing nations, with India being the biggest producer.[6]

The crop is well adapted to low rainfall regions (200–600 mm annually) and can grow in poor, sandy, and marginal soils, where other cereals such as Triticum aestivum and Oryza sativa fail to perform efficiently. Due to its resilience, pearl millet is often cultivated in regions prone to drought, high temperatures, and erratic rainfall patterns.[7]

BOTANICAL DESCRIPTION:

Pearl millet, or Bajra in Hindi, is the most widely grown millet. This summer cereal grass has large heads, leaves, and stems. One of the most widely grown crops in India is bajra, a variety of millet. It may be cultivated under both rain-fed and irrigated settings and has a short growing season.

- **Habit:** Yearly herb.
- **Root:** There are many roots.
- **Stem:** The stem is sturdy, thin, and has noticeable nodes that may be hairy or glabrous. The base of the stem has a diameter of 1-3 cm.
- **Leaf:** The leaf-sheaths are typically glabrous, open above, and overlap at the base. Up to 1.5

m x 5-8 cm, the leaf blade is linear to linear-lanceolate.

- **Inflorescence:** The inflorescence is a terminal, cylindrical, compact, stiff panicle that resembles a spike and ranges in length from 5 to 150 cm.
- **Seeds:** White, yellow, blue-white, light, grey, brown, and occasionally purple are the colours of seeds. [8]

Vernacular Name:

- **Table 2: Vernacular names of *pearl millet***

Language	Name
English	Spiked Millet
Marathi	Bajri
Hindi	Bajra
Tamil	Kambu
Telugu	Sajjalu
Kannada	Sajjai
Malayalam	Kambam

AYURVEDA PROPERTIES: [9]

Table 3: Ayurveda properties of pearl millet

Ras	Madhur
Vipak	Katu
Veerya (potency)	Ushna
Guna	Guru
Karma	Balya, Punsatavhar, agnideepak
Effect on dosha	Vattapittakarak
Effect on dhatu	Medohar (reduces Meda), Kleda Shoshan (absorb fluids)

NUTRITIONAL POTENTIAL:

Pearl millet contains 62-70% carbohydrate, 5-8% fat, and 9-13% protein. Pearl millet contains calcium and phosphorus, two minerals essential for bone growth and development. The proximate composition of pearl millets was published by Ali et al. (2003) as follows: dry matter (92.5%), ash (2.1%), Fiber (2.8%), fat (7.8%), protein (13.6%), and starch (63.2%). Nutritionally, pearl millet is superior to major cereals with reference to energy value, high quality proteins, fat and minerals such as calcium, iron, zinc.[10]

Besides, it is also a rich source of dietary fiber and micro nutrients While, extensive information is available on proximate composition and mineral accessibility, information on antioxidant activity and its influence on processing in pearl millet is scanty. Research on the effect of processing on retention of bioactive components with potential antioxidant activity is very important. The objective of this investigation was to evaluate the effect of various processing methods (milling, heat treatments and germination respectively) on antioxidant components as well as antioxidant activities of pearl millet extracts. The methanolic extracts of raw and processed pearl millet were analyzed for DPPH free radical scavenging activity; reducing power assay (RPA) and ferric reducing antioxidant power (FRAP) assays respectively. The samples were also evaluated for tannin, phytic acid and flavonoid content and were correlated with the antioxidant activity assayed using three methods.[11]

TRADITIONAL USES:

Because pearl millet contains phytochemicals, it offers a number of medicinal advantages. Diarrhea, anemia, stomach ulcers, allergies, cancer, diabetes, obesity, and heart conditions can all be avoided by consuming pearl millet. Because of its alkalizing properties. Pearl Millet is also said to be helpful in preventing stomach ulcers, preventing cardiovascular diseases, controlling blood pressure, preventing migraine attacks, and relieving respiratory symptoms because of its high magnesium content. Magnesium and phytate molecules help prevent cancer, and its high phosphorus concentration is beneficial for bone formation.[12]

PHYTOCHEMISTRY:

Phenolic acid and flavonoids are the two main compounds found in pearl millet, along with tannins, glycosides, sterols, phytosterols, phytic acid, alkaloids, and saponins-the most significant phytochemical that was extracted from the grain. Following this table 4 name of the phytoconstituents and their structure.[13]

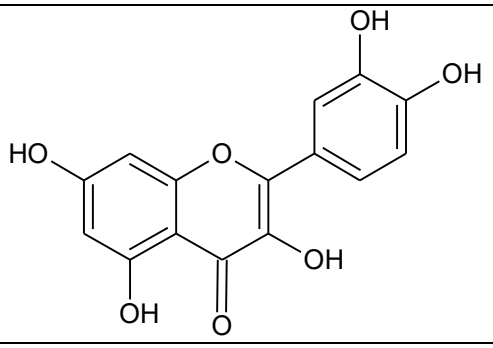
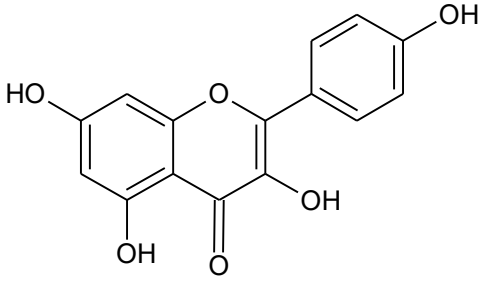
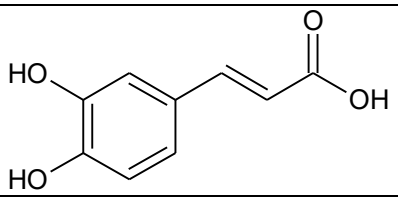
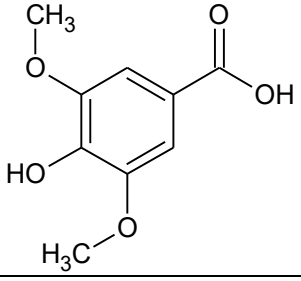
Phenolic compounds:

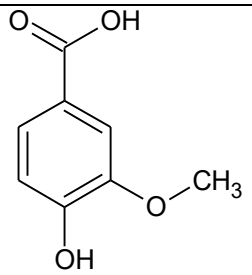
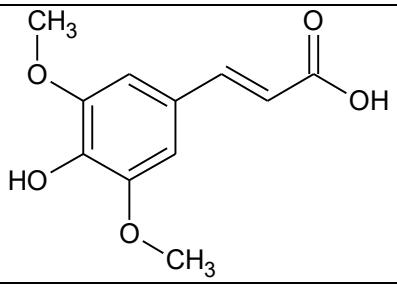
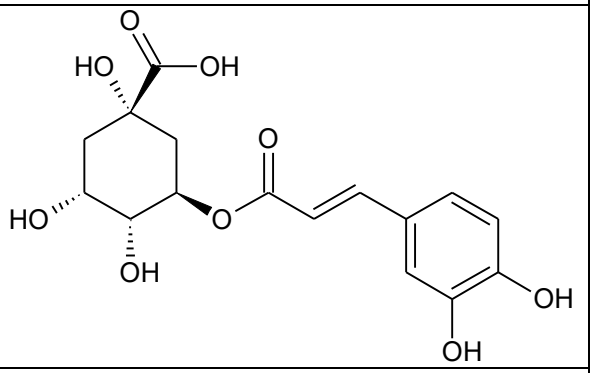
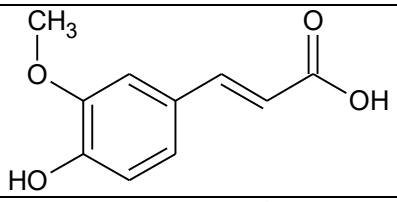
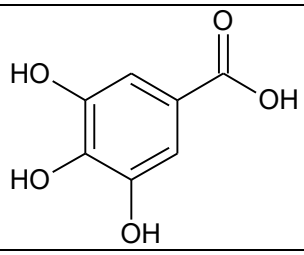
Caffeic acid, p-hydroxybenzoic acid, syringic acid, vanillic acid, sinapic acid, chlorogenic acid, ferulic acid, gallic acid, and protocatechuic acid are among the phenolic acids found in pearl millet.

Flavonoids:

Quercetin and kaempferol, two flavonoids found in pearl millet, may have anti-inflammatory and anti-diabetic effects. [14]

Table 4: Name of phytoconstituents and structure

Sr. No	Name of compound	Structure
1	Quercetin	
2	Kaempferol	
3	Caffeic acid	
4	Syringic acid	

5	Vanillic acid	
6	Sinapic acid	
7	Chlorogenic acid	
8	Ferulic acid	
9	Gallic acid	

PHARMACOLOGICAL ACTIONS:

Table 5: Pharmacological actions of *pearl millet*

Pharmacological Activities	Part Used	Reference
Antidiabetic	Grain	15
Anti-inflammatory	-	16
Antioxidant	-	17
Anti-microbial	-	
Anti-hypertensive	Seed	18
Cytotoxic	-	

Anti-cancer	Grain	19
Hypolipidemic (Cholesterol-Lowering)	Seed	20
Cardioprotective Activity	Seed	21
Gastroprotective and Digestive Health	Seed	22
Anti-thyroid	Flour	23
Anemia	-	24
Allergies	Grain	25

Antidiabetic Activity:

More popular grains like wheat and rice have frequently eclipsed pearl millet, despite its long history of cultivation and significant nutritional significance. Recent studies, however, have started to highlight its possible advantages when it comes to managing diabetes. the current understanding of pearl millet's function in the treatment of diabetes. We look at the nutritional makeup of the grain, how it affects metabolic health and glycaemic management, and practical reasons to use it in diabetic diets.[15]

Anti-inflammatory:

Metabolic syndrome, a group of disorders that includes elevated blood pressure, excessive blood sugar, extra body fat around the waist, and abnormal cholesterol levels, is frequently caused by chronic inflammation. Flavonoids and phenolic compounds are among the several antioxidants found in pearl millet that have anti-inflammatory properties. These characteristics may lower the risk of metabolic syndrome and enhance general metabolic health by lowering systemic inflammation.[16]

Antioxidant:

Numerous research has been carried out worldwide to show how beneficial plants used as medications are in managing or treating harmful diseases due to their antioxidant qualities.

Antimicrobial:

Serratia marcescens, Salmo Nella typhi, Proteus vulgaris, and Staphylococcus epidermidis were all reduced in their growth by Pennisetum glaucum (pearl millet).[17]

Anti-hypertensive:

The scientific baseline for the investigation of hypertension was established by estimating the capacity of P. glaucum extract to reduce blood pressure in rats given a normal egg feed diet and glucose treatment. At 500 and 1000 mg/kg doses, the crude extracts of P. glaucum seed decreased the systolic blood pressure (SBP), mean blood pressure (MBP), heart rate (HR), and diastolic blood pressure (DBP) of normotensive participants.

Cytotoxic:

In the past, the *P. purpureum* extract made by boiling water decreased NO generation in LPS-induced RAW 264.7 macrophages, enhanced antioxidative enzyme activity in murine BNL hepatocytes, and prevented in vitro LDL oxidation.[18]

Anti-cancer:

Pearl millet has high concentrations of phenolic antioxidants that may have anticancer effects. Phenolic chemicals, especially flavonoids, have been demonstrated to stop tumor growth.[19]

Hypolipidemic (Cholesterol-Lowering):

The putative hypolipidemic (cholesterol-lowering) action of pearl millet (Pennisetum glaucum) has drawn a lot of interest as a functional food. Its rich content of dietary fiber, phenolic compounds, phytosterols, and unsaturated fatty acids—all of which enhance lipid metabolism and cardiovascular health-is principally responsible for this impact. Dietary fiber, both soluble and insoluble, is abundant in pearl millet and is essential for controlling cholesterol.

- In the gut, dietary fiber binds to bile acids.
- The liver produces these bile acids from cholesterol.
- The body uses circulating cholesterol to create new bile acids when fiber-bound bile acids are eliminated through the face.
- Total serum cholesterol, especially low-density lipoprotein (LDL), is lowered as a result.[20]

Cardioprotective Activity:

The cardioprotective action of pearl millet (*Pennisetum glaucum*), which lowers the risk of cardiovascular diseases (CVDs) like atherosclerosis, hypertension, and coronary artery disease, is well known. Its high concentration of dietary fiber, phenolic compounds, antioxidants, and essential fatty acids-all of which enhance lipid metabolism and safeguard the cardiovascular system-is primarily responsible for this function. One important aspect of cardiovascular health is the regulation of lipid metabolism, which pearl millet contributes significantly to**.**

- Lowers triglycerides, LDL (bad cholesterol), and total cholesterol.
- Helps maintain or increase HDL (good cholesterol)
- Enhances the overall balance of the lipid profile.[21]

Gastroprotective and Digestive Health:

Because of its high dietary fiber, resistant starch, and bioactive polysaccharide content, pearl millet (*Pennisetum glaucum*) is well known for its gastroprotective and digestive health promoting properties. These elements are essential for improving digestion, preserving gut integrity, and fostering a healthy gut microbiome. The gastroprotective and digestive health properties of pearl millet (*Pennisetum glaucum*) make it a valuable functional food. Its high quantity of resistant starch, dietary fiber, and bioactive polysaccharides-which enhance gut health and operate as natural prebiotics-is primarily responsible for these effects. [22]

Anti-thyroid Activity:

C-glycosylflavones, which inhibit thyroid peroxidase and hence decrease thyroid hormone synthesis, are the main cause of pearl millet's notable anti-thyroid activity. Reduced T3 and T4 synthesis, changed iodine metabolism, and goitrogenic effects are confirmed by both in vitro and in vivo research. Although there may be nutritional hazards in iodine-deficient populations, the activity is similar to that of conventional antithyroid medications, suggesting possible pharmacological importance.[23]

Anemia:

A major provider of micronutrients, especially iron and zinc, pearl millet (*Pennisetum glaucum*) is a nutrient-dense cereal. It has about 3.1 mg/100 g of zinc and 8 mg/100 g of iron, which can help treat anaemia and raise haemoglobin (Hb) levels. However, antinutritional substances such phytates and polyphenols, which form insoluble complexes with iron and decrease its absorption in the gastrointestinal system, limit the bioavailability of these elements.[24]

Allergies:

Because pearl millet is a naturally gluten-free cereal grain, people with coeliac disease and

gluten intolerance can eat it. Pearl millet lacks gliadin, the prolamin component that causes coeliac disease patients' immunological reactions, in contrast to wheat-based cereals. Furthermore, pearl millet is said to keep its alkaline qualities after cooking, which may help the body maintain its acid-base balance and is thought to be useful for people who are allergic to wheat. Additionally, pearl millet is abundant in calories and energy, supporting the nutritional needs of developing youngsters and expectant mothers. According to previous epidemiological estimates, 1 in 500 Americans suffer from coeliac disease, a chronic autoimmune illness brought on by gluten use.[25]

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