INFORMATICS JOURNALS

Short Review

Journal of Natural Remedies
DOI: 10.18311/jnr/2026/54487

eISSN: 2320-3358 | Vol 26(4), 2026 | pp. 961-975

Overview of Nutritional Value and Pharmacological Properties of Millets

Pratit Kanchan Sahu[1,2], Shyamalendu Tripathy[3], Sujit Kumar Martha[2], Diptimayee Jena[1], Kirtimaya Mishra[1], Ashirbad Nanda[1*] and Biswa Mohan Sahoo[1]

[1]School of Pharmacy and Life Sciences, Centurion University of Technology and Management, Bhubaneswar - 752050, Odisha, India; ashirbadnanda@gmail.com

[2]Department of Pharmacology, Jeypore College of Pharmacy, Rondapalli, Jeypore - 764002, Odisha, India

[3]School of Pharmacy, Parul University, Vadodara - 391760, Gujarat, India

Abstract

Background: Millets are small grains grown in arid climates and are rich in minerals, vitamins, and phytochemicals, making them highly nutritious. Their nutritional profile, which includes vitamins, dietary fibre, protein, and antioxidants, supports health and helps prevent disease. **Aim:** Millets are beneficial for managing lifestyle diseases because of their therapeutic properties, which include anti-diabetic, anti-inflammatory, antioxidant, and anti-Alzheimer's agent properties. **Methods:** Additionally, their low glycemic index, gluten-free status, and ability to tolerate a variety of climates make them ideal for a range of nutritional needs and environmental sustainability. **Results:** The polyphenolic content of millets, namely finger millet, highlights their pharmacological potential by exhibiting antibacterial, antioxidant, and anti-diabetic properties. **Conclusion:** More research and studies into the use of millets in the food and pharmaceutical industries are necessary to fully realise their potential as nutrient-rich crops with significant health benefits.

Major Findings: Millets, known for their high nutritional value of proteins, dietary fibres, vitamins, and minerals, are also valuable substances for improving human health and well-being. This study also reports the effects of millets on intestinal health and their possible future contributions to sustainability and global food security.

Keywords: Active Constituent, Health, Millets, Nutrition, Pharmacology, Therapy

(Article Chronicle: Article Received on: 22.01.2026; Revised on: 09.03.2026; Accepted on: 16.03.2026)

1. Introduction

In Ayurveda, millets are acknowledged as grains of exceptional qualities, referred to as "*Shridhanya*". Because of their pharmacological characteristics, which include promoting digestion, lowering cholesterol, promoting hypoglycemia, and having cardio-protective actions, they are recommended for the treatment of chemotherapy side effects. Millets are tiny grains with food value and are primarily cultivated in tropical and sub-tropical regions like India, China, Japan, Egypt, the Arab world, as well as Western Europe. In India, these are mainly harvested in Madhya Pradesh, the eastern regions of Andhra Pradesh, Karnataka, Maharashtra, Bihar, Uttar Pradesh, Tamil Nadu, and southern Odisha. Millets are conventionally utilised due to their nutritional and medicinal properties. Although further study has shown their distinct pharmacological properties and associated health effects, their nutritional value extends far beyond their use as conventional food sources[1]. In this study, the various aspects of millet are examined, with a focus on their nutritional worth, pharmacological characteristics, and wider health implications. Millets are an important component of a balanced diet since they are rich in proteins and other vital nutrients like vitamins, minerals, and dietary fibre[2].

Additionally, they are having wide range of bioactive substances, including flavonoids, lignans, and phenolic

*Author for correspondence

compounds, which provide them with different pharmacological qualities. Recent research has clarified the pharmacological properties of millets, which suggests that they may be used as functional foods for medical purposes[3]. Millets are useful for their potential health advantages as well as their nutritional content, which contains supplies of dietary fibre, carbohydrates, minerals, and vitamins. In recent years, millets have gained attention due to their exceptional nutritional value and possible health benefits. Additionally, it explores the gluten-free properties of millets, making them accessible to those who comply with specific dietary supplement requirements[4]. The ability of millet to prevent and manage chronic diseases, such as diabetes and cardiovascular issues, is the primary topic of discussion on its health benefits. Researchers are investigating the potential health effects of bioactive compounds like polyphenols and antioxidants present in millet (Figure 1). However, these mentioned effects are not just confined to antioxidant, antidiabetic, anti-inflammatory, and cholesterol-lowering qualities[5]. Scientists want to focus on global health by leveraging millets' therapeutic potential for controlling and preventing chronic illnesses by elucidating the basic mechanisms behind these pharmacological actions[6]. Additionally, adding millet to the diet has been associated with a number of health benefits, including improved glycemic control, cardiovascular health, and weight management. Their low glycemic index, gluten-free status, and high satiety value make them suitable for people with diabetes, celiac disease, or those trying to lose weight[7-10].

Additionally, millet is more resilient to adverse weather conditions and uses less water and input resources than other cereal crops, making its cultivation more environmentally friendly. As interest in millets rises for environmental and nutritional reasons, more research is needed to understand their pharmacological properties and possible health implications[11]. This study aims to develop more on this field by providing information on the potential health benefits and pharmacological activity of millets. By combining current information and offering ideas for future research, it also seeks to advance a more comprehensive

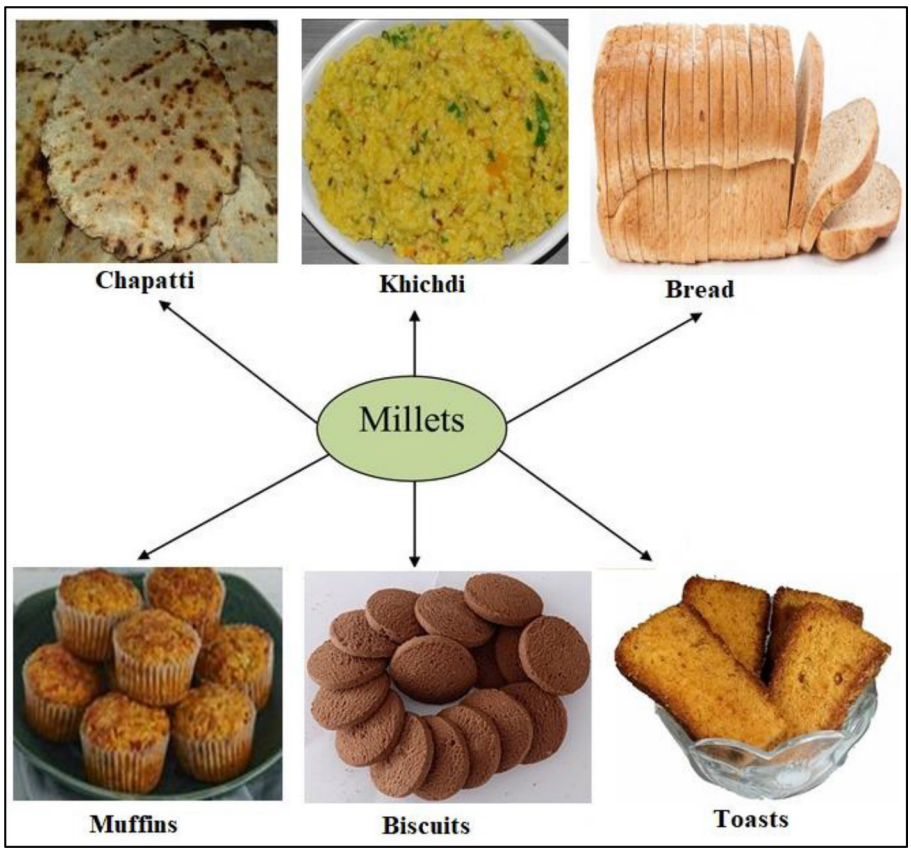


Figure 1. Nutrient-rich millets.

understanding of millets as nutrient-rich grains with possible pharmacological effects. The ultimate goal of the study is to incorporate millets into public health campaigns and dietary recommendations[12,13].

2. Materials and Methods

The methodology section of a review article plays a crucial role in establishing the credibility and rigour of the review. Conducting a review on millets involves a systematic and comprehensive approach to gather, analyse, and synthesise existing information related to various aspects of millets.

According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement, PRISMA offers guidelines for systematic reviews. It is a standardised approach for reporting systematic reviews that aims to increase completeness and transparency. PRISMA offers a flowchart and checklist to assist researchers in finding, screening, choosing, and transparently reporting pertinent studies (Figure 2)[14].

2.1 Search Strategy

Several databases (PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, conference proceedings) are searched for relevant articles. It is essential to determine the criteria for including or excluding studies (*e.g.*, peer-reviewed articles, publication date range, and type of study).

2.2 Study Selection

Study selection involves identifying, screening, and choosing studies that meet predefined criteria to ensure

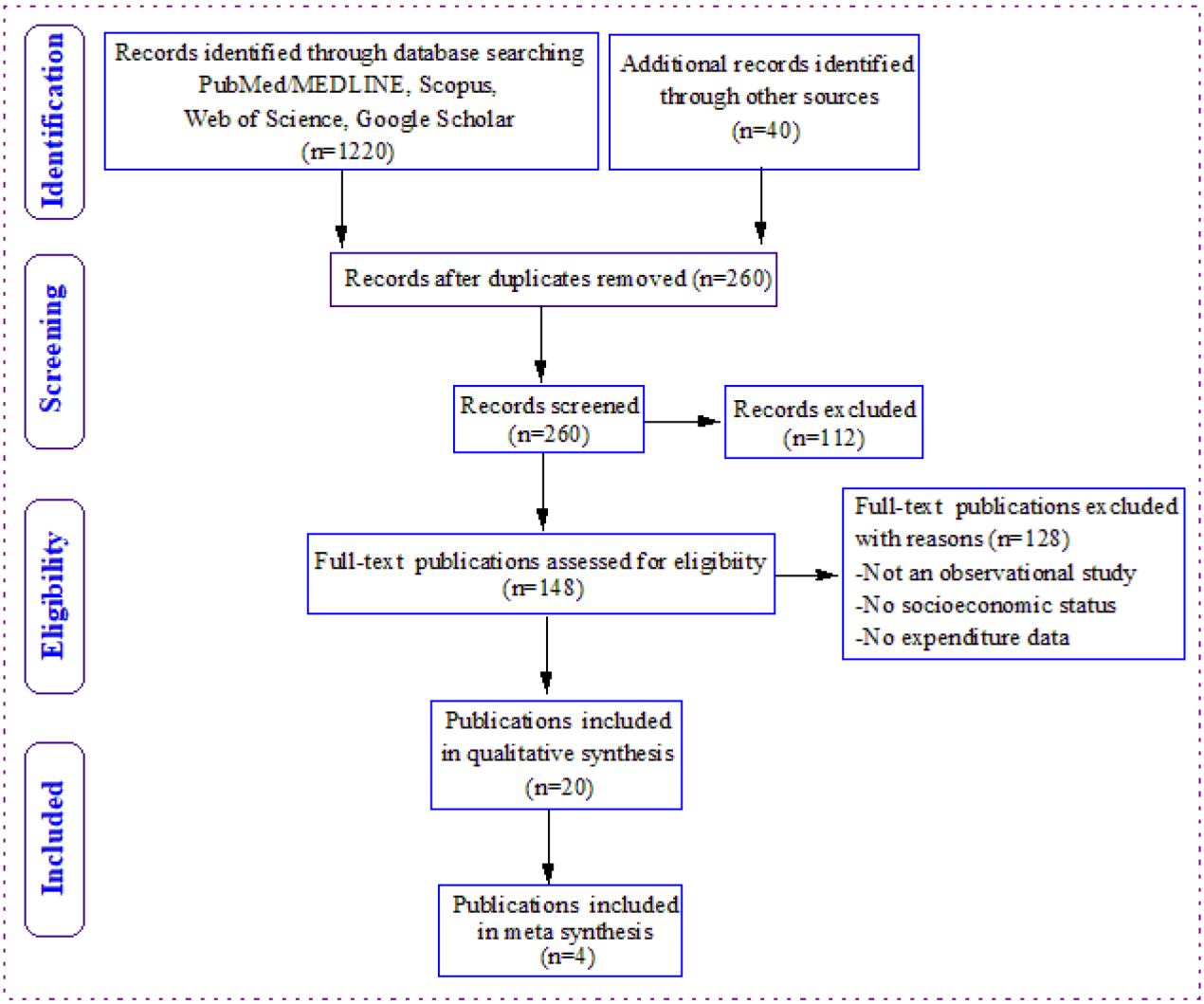


Figure 2. PRISMA flow chart.

that the review is comprehensive, relevant, and high-quality. It is required to assess the quality of the included studies using appropriate tools or checklists. A matrix or database is created to organise data from the studies, including study design, findings, and metrics.

2.3 Data Extraction and Synthesis

Data extraction and synthesis are crucial steps in conducting a review on millets, as they allow for collating and interpreting findings from diverse studies. The goal of data extraction is to systematically collect key information from the studies reviewed. Once the data extraction is completed, synthesising the findings is the next essential step. Based on the synthesised findings, it is required to develop conclusions that encompass the collective insights gained from the review.

3. Results

Millets are a type of cereal that belongs to the grass family, i.e., Poaceae. These are categorised into different types such as Pearl millet (*Pennisetum glaucum*), Foxtail millet (*Setaria italica*), Kodo millet (*Paspalum sorbiculatum*), Little millet (*Panicum sumatrense*), Finger millet (*Eleusine coracana*), Barnyard millet (*Echinochloa corona*), Brown top millet (*Urochloa ramosa*), and Porso millet (*Panicum miliaceum)* (Figure 3).

Millets contain polyphenols, phytosterols, tannins, and anthocyanins, which are used to treat metabolic disorders. It has anti-ageing and antioxidant properties. It contains potassium, which controls the function of the heart and kidneys. Potassium also helps in nerve transmission. It contains Vitamin A, Vitamin B, Potassium, phosphorus, niacin, Calcium, Iron, *etc.*[15]. Details regarding nutrition are presented in Table 1.

3.1 Types of Millets

There are several types of pellets available naturally. The more prevalent types encompass Finger Millet, Foxtail Millet, Pearl Millet, Proso Millet, Little Millet, and Sorghum Millet (Figure 4 and Table 2)[16,17].

3.1.1 Finger Millet (Ragi)

In Ragi, high mineral content is observed. But it contains low fat and protein, and sulfur-rich amino acids. It contains a high concentration of calcium. It has antioxidant activities. So, it acts as a superfood.

3.1.2 Foxtail Millet (Kakum)

It is a rich source of copper and iron. Its protein content is twice that of rice. It is easily digested and a non-allergenic grain.

3.1.3 Kodo Millet (Kodon)

It contains Vitamin B, Niacin, Folic acid, Pyridoxin, Iron, Calcium, Potassium, Zinc, and Magnesium. It comprises low-fat, high-protein, and high-fibre foods. All these constituents boost the neurological system of our body.



Figure 3. Plant profile of millets.

Table 1. Details of nutrients present in millets

Nutrients	Content (%)
Protein	5-10
Fat	3-5
Carbohydrate	68-75
Dietary Fibre	15-20

3.1.4 Barnyard Millet (Sanwa)

It is rich in iron and fibre. It contains beta-glucan and gamma-aminobutyric acid, which both lower blood lipid levels and function as antioxidants.

3.1.5 Proso Millet (Chenna/Barri)

It contains protein, fatty acids, and carbohydrates. It has a high amount of calcium, which aids in the

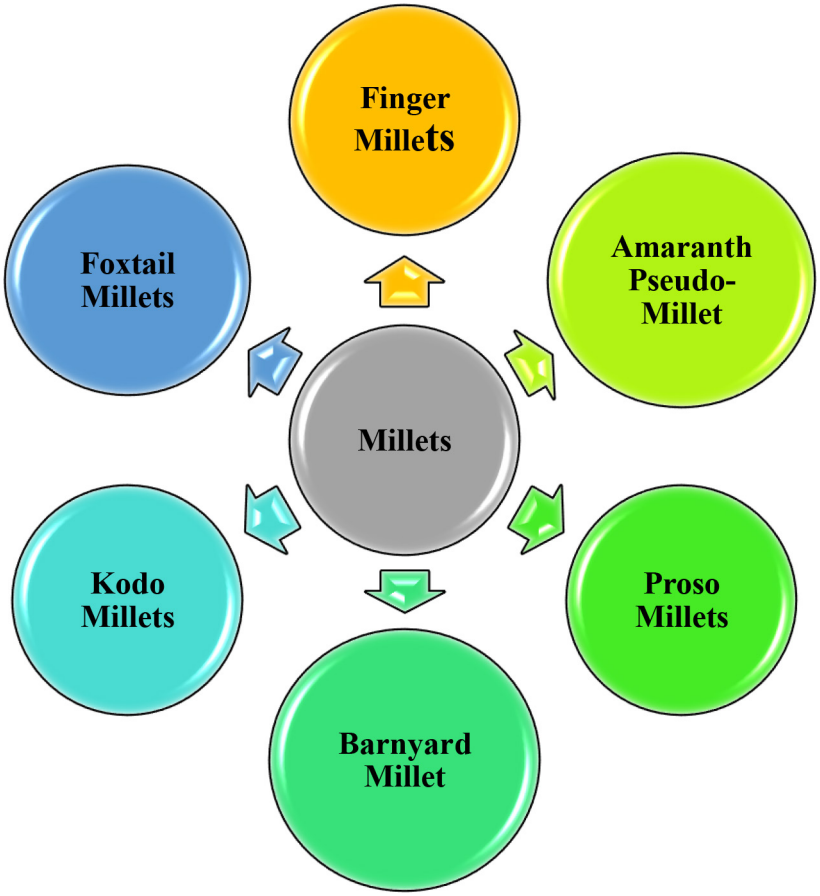


Figure 4. Types of millets.

Table 2. Nutritional properties of millets

Types of Millets	Biological Source	Fat (g)	Starch (g)	Protein (g)	Crude fibre (mg or g)
Foxtail Millet	*Setaria italica*	4.3	60.09	15	8.23 mg
Barnyard Millet	*Echinochloa crusgalli*	2.2	65.55	13	13.6 mg
Pearl millet	*Pennisetum glaucum*	5.0	61.78	11.8	2.3 g
Finger Millet	*Eleusine coracana*	1.3	66.82	7.7	3.60 g
Kodo Millet	*Paspalum scrobiculatum*	1.4	66.19	10	8.2 mg
Proso Millet	*Panicum meliaceous*	1.1	67.09	13	8.47 mg
Sorghum Millet	*Sorghum Moench*	1.7	59.70	10.82	g

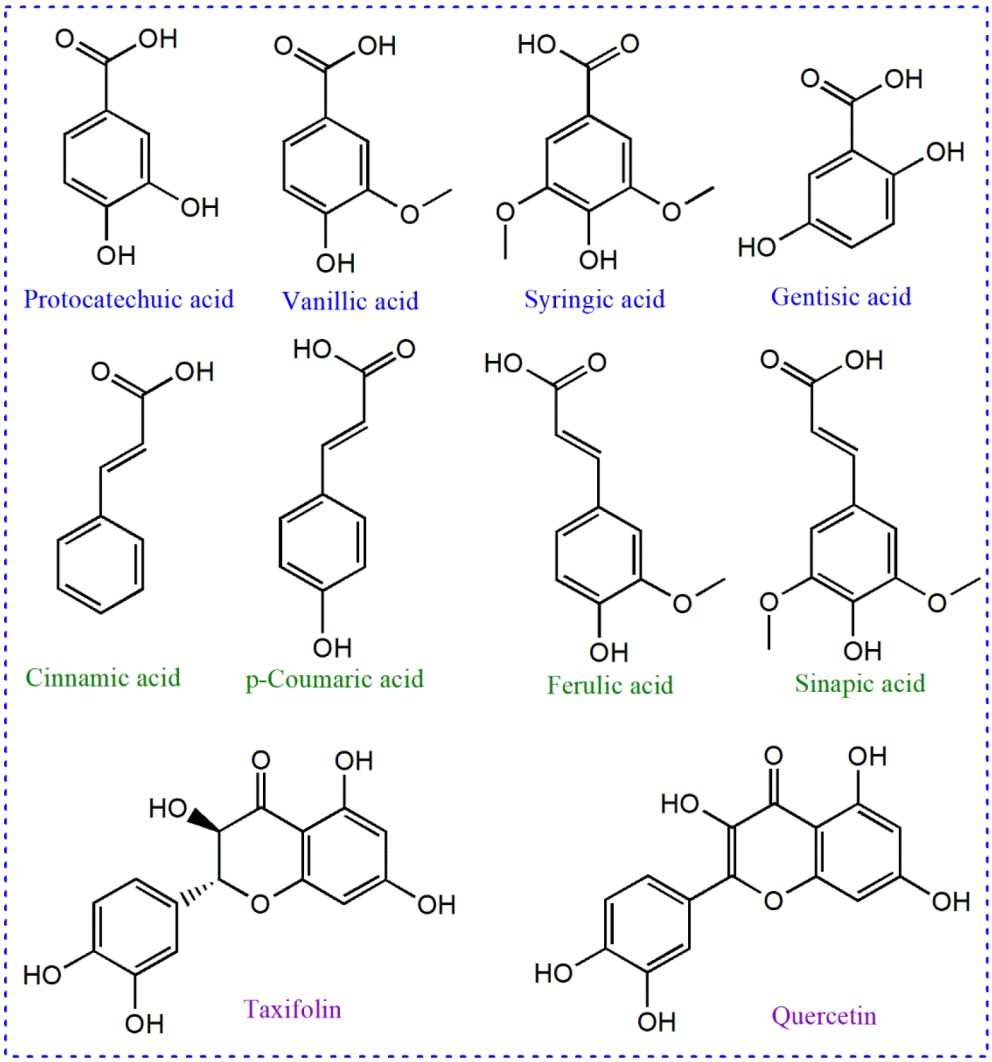


Figure 5. Chemical structures of phytochemicals of millets.

development of bones. Historically, it was utilised for its culinary properties as both seasonings and edible seeds. It reduces cholesterol levels along with the mitigation of risk associated with heart disease.

3.1.6 Amaranth Pseudo-millet (Ramdana/Rajgira)

It contains oil, dietary fibres, magnesium, phosphorus, iron, potassium, and calcium. It has cancer-preventive and anti-hypertensive properties. Unsaturated fatty acids and linolenic acid are present in Amaranth oil.

3.2 Phytochemicals of Millets

Plant-based substances augment the nutritional quality of millet. The Indian Institute of Minor Millets classifies these as Barnyard millet, Kodo millet, Porso millet, Little millet, and Foxtail millet. The availability of several phytoconstituents, such as tannins, saponins, alkaloids, and terpenoids, has been examined in millets (Figures 5 and 6)[18].

3.2.1 Kodo Millet

Kodo millet is referred to by various folk names, including Cow grass, Ditch grass, and Harka in Kannada. It has a rich content of proteins and dietary fibers, which is why easily digested[19]. Phytochemical analysis using methanol, ethyl acetate, ethanol, and chloroform extract indicates the availability of tannins, phenolic acid, and flavonoids. From the ethanolic extract, total phenolic and flavonoid content are 175.94±1.018 mg GAE/g and 16.48±1.57 mg RE/g, respectively[20]. The methanolic extract shows considerable amounts of tannins and phytic acid, as presented in Table 3.

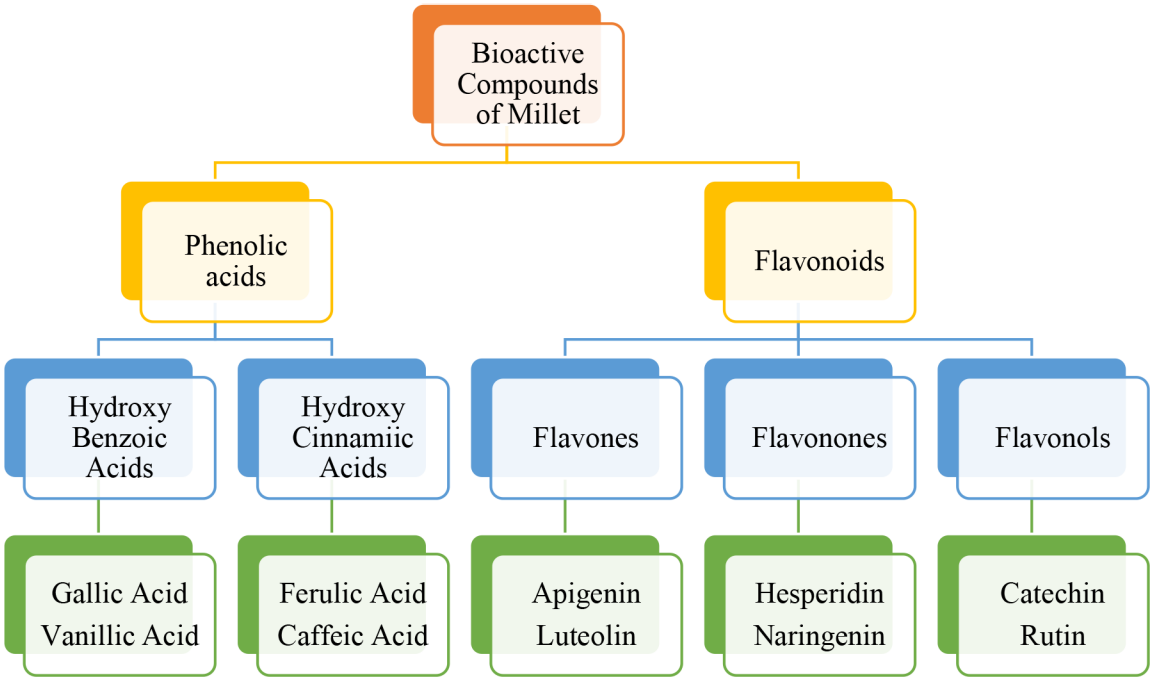


Figure 6. Bioactive compounds of millet.

Table 3. Phytoconstituents isolated from kodo millet

Phyto-constituents	Molecular mass (g/mol)
N-Propyl 9,12,15-octadecatrienoate	320.5
Campesterol	400.7
Hexadecanoic acid	256.42
Stigmasterol	412.7
9-octadecenoic acid	282.5
Pterin-6-carboxylic acid	207.15
Butyl 6,9,12,15-octadecatetraenoate	332.5
Pregnenolone	316.5
N-(5-Hydroxy-pentyl) arachidonoylamide	389.6
N (3,5-Dinitropyridin2yl)-L-aspartic acid ester	300.18

3.2.2 Barnyard Millet

Barnyard is abundant in both dietary fibre and protein. The millet can be extracted using water or methanol at various stages, such as soaked, germinated, and raw. These extracts contain flavonoids, saponins, phenols, alkaloids, terpenoids, & methanolic extracts having a high phenolic content, which possess antioxidant activities[21-24]. Ethanolic extracts of Japanese barnyard millet are used to isolate phytoconstituents. The elements were extracted using Sephadex LH-20 chromatography by HPLC, and each compound showed antioxidant activities (Table 4).

Table 4. Phytoconstituents isolated from Japanese barnyard millet

Phytochemicals	Compound name	Molecular mass (g/mol)
Flavonoid	Luteolin	286.2
Serotonin	N-(p-coumaroyl) serotonin	322.4
Flavonoid	Tricin	330.29

3.2.3 Porso Millet

It is mainly used as food by low-income populations in many countries. This millet contains proteins, vitamins, and minerals. These are gluten-free, so they are easily digestible. A study of phytochemicals indicates the availability of flavonoids, phenols, and phytates. Three varieties of Chinese porso millet, such as Gumi 20, Mizao 52, and Mi2504-6, contain phenols and flavonoids in aqueous extracts (Table 5)[25].

3.2.4 Little Millet

It contains phytochemicals like phenols and flavonoids[26]. Methanol extract fractions of phenolic compounds exhibit different phytochemical compounds (Table 6)[27].

Table 5. Phyto-constituents isolated from porso millet

Phytochemicals	Compound name	Molecular mass (g/mol)
Phenol	Chlorogenic acid	354.31
	Syringic acid	198.17
	Caffeic acid	180.16
	p-coumaric acid	164.16
	Ferulic acid	194.18
Carotenoid	β-cryptoxanthin	552.85
	Xanthophyll	568.9
	Zeaxanthin	568.8

Table 6. Phenols and flavonoids isolated from little millet

Phenol and flavonoid	Compound name	Molecular mass (g/mol)
Phenol	p-Coumaric acid	164.04
	Gentisic acid	154.12
	Vanillic acid	168.14
	Syringic acid	198.17
	Cis-Ferulic acid	194.18
	Kaempferol	286.23
	trans-Cinnamic acid	148.15
	Sinapaldehyde	208.07
	Ferulic acid	194.18
	Methylvanillate	182.17
	Vannilin	152.15
	Gallicacid	170.12
	p-Coumarylpentose	913.68
	Sinapic acid	224.21
	p-Hydroxybenzoic acid	138.12
	Trans-Ferulic acid	194.18
	Proto-catechuic acid	154.12
Flavonoid	6-C-glucosyl-8-Carabinosyl-apigenin	564.5
	Apigenin	270.05

3.2.5 Foxtail Millet

It has nutraceuticals like protein, starch, vitamins, fatty acids, and minerals. HPLC study of methanol extract showed the availability of phytochemicals such as phenolic, carotenoids, and flavonoid compounds (Table 7)[28-31].

Table 7. Phytoconstituents isolated from foxtail millet

Phenol and flavonoid	Compound name	Molecular mass (g/mol)
Phenols	Protecatechulic acid	154.12
	2-Methylisocitric acid	206.15
	Vanillic acid	338.2
	Protecatechulic aldehyde	138.2
	p-Hydroxybenzoic acid	138.12
	p-Hydroxy-benzaldehyde	122.12
	2-Methylisocitric acid	206.15
	Vanillic acid	168.14
	Syringic acid	198.17
	cis-p-Coumaric acid	164.16
	trans-p-Coumaric acid	326.3
	Di-pcoumaroyl-spermidine	437.23
	Ferulic-truxillic acid	296.3
	Ferulic acid	194.18
	Apigenin	564.5
	Sinapic acid	224.21
	Homocitric acid	206.15
	Caffeic acid	180.16
	Caffeoylspermidine	142.5
	Kaempferol	286.24
Carotenoids	Zeaxanthin	568.88
	Xanthophyll	586.9

4. Discussion

Millet is found to possess several potential pharmacological effects, including antioxidant, antimicrobial, antidiabetic, Anticancer, Anti-inflammatory, Hyperlipidemic and anti-Alzheimer's effect *etc*. Antioxidants like vitamin E and phenolic compounds found in millet can help in scavenging free radicals and lessen oxidative stress. For diabetics, millet may be helpful in controlling blood glucose levels because of its low glycemic index and high fibre content. Several studies reported that millet can improve cardiovascular health by lowering LDL cholesterol levels. The high amount of dietary fibre in millet promotes a healthy digestive system[32].

4.1 Antioxidant Activity

The availability of various phytochemicals in millet has antioxidant properties. They neutralise free

radicals through oxidation or reduction reactions. Antioxidants inhibit the free radical production that controls the progression of multiple diseases, including degenerative diseases[33-35]. The methanolic extract of Foxtail Millet exhibits a significant capacity to scavenge free radicals in the DPPH (2,20-diphenyl-1-picrylhydrazyl) test method. The Japanese Barnyard sample underwent screening employing HPLC analysis as well as Sephadex LH-20 chromatography. The most potent antioxidant action was demonstrated by N-(p-coumaroyl) serotonin. Little millet, by DPPH analysis and β-carotene inhibition, confirms antioxidant properties. The antioxidant capabilities of Kodo Millet are determined through spectroscopic research using Electron Spin Resonance (ESR). Porso Millet by DPPH assay reported the free radical scavenging effect and antioxidant properties[36-38].

4.2 Antimicrobial Effect

The methanolic extract of Kodo Millet showed inhibition over bacterial strains viz., *Enterococcus faecalis*, *Leuconostoc mesenteroides*, *Staphylococcus aureus, and Bacillus cereus. In-vivo* studies of Little Millet extract showed antibacterial effect over *Staphylococcus aureus*, *Bacillus megaterium*, *Pseudomonas a*eruginosa, and *Escherichia coli*[39,40].

4.3 Antidiabetic Effect

Alpha-amylase and beta-glucosidase are enzymes included in the breakdown of glucose during digestion, leading to an elevation in glucose levels after a meal, which is preferred as postprandial glucose levels. Barnyard Millet is rich in phenolic compounds such as apigenin, kaempferol, formononetin, dihydro quercetin, and catechin, which possess antidiabetic properties. The methanol extract derived from the Barnyard plant demonstrates potent inhibition of digestive enzymes, as seen by its low IC_{50} values. Additionally, it exhibits regulatory effects on type 2 diabetes. The ethanolic extracts of Porso Millet and Foxtail Millet, which contain phenolic compounds, reduce glucose levels by decreasing the IC_{50} value, resulting in an antidiabetic action[41].

4.4 Anticancer Effect

The therapy of cancer requires the suppression of abnormal cell proliferation. The Foxtail Millet suppresses the growth of HepG2 and MDA cells by containing phenolic substances such as coumaric acid, syringic acid, chlorogenic acid, carotenoids, including xanthophyll, along with ferulic acid, caffeic acid, and zeaxanthin. The antiproliferative or anti-antioxidant activity is measured using the MTT assay, in which a low IC_{50} value indicates a higher rate of inhibition. Foxtail Millet demonstrates inhibitory effects on the growth of the colorectal cancer HCT-116 cells in humans as well as HCT-116 cells in hairless mice, inducing apoptosis. Therefore, it exhibits anticancer efficacy against cancer in the colon. *p*-coumaric acid, along with ferulic acid, in Kodo Millet, can suppress HT-29 colorectal cancer. The phenolic extraction of Little Millet, Kodo Millet, Porso Millet, and Foxtail Millet significantly hinders the HT-29 anticancer activity, ranging from 28% to 100% inhibition[42].

4.5 Anti-inflammatory Activity

Foxtail Millet, which contains phytochemicals called polyphenols, can minimise the Nuclear Factor-κβ (NFκB)-p65 atomic translocation in HT-29 cells. Such inhibition is achieved by reducing the levels of pro-inflammatory cytokines (IL-1β, IL-6, and IL-8) and increasing the levels of an anti-inflammatory cytokine (IL-10). The ethanolic extract of Barnyard Millet, Foxtail Millet, and Porso Millet demonstrates the ability to inhibit COX-2 and reduce the production levels of inflammogenic cytokine genes, such as IL-1β1β, IL-6, & TNF-α in the LPS-stimulated RAW264.7 cells[43].

4.6 Hyperlipidemic Activity

Low-density lipoprotein levels in the blood influence the development of cardiovascular diseases by causing arterial blockages. It also initiates the agglomeration of fats in adipose tissue and causes fatty liver and obesity. Phenolic acid-containing Kodo millet extract raises HDL and reduces LDL. The methanol extract derived from Foxtail Millet can decrease the build-up of lipids in HepG2 cells by minimising levels of triglyceride along with cholesterol[44,45].

4.7 Anti-alzheimer's Effect of Millet

Millets are known as the first crops and the crops of the future, as mentioned in the Rig Veda. Millets have a high content of vitamins B complexes, minerals such as iron, magnesium, phosphorus, potassium, fibre,

and antioxidants, and aid in reducing oxidative stress and inflammation. Due to their low glycemic index and gluten-free content, millets enhance gut health and boost the brain axis. The gut's influence extends to the production of hormones and neuroprotection. Anomalies in gut flora promote the growth of harmful microbes, leading to conditions like leaky gut. These trigger the rise of non-communicable diseases like Alzheimer's and many other neurodegenerative disorders. According to various sources, people of advanced age often experience a decline in cognitive functions, and antioxidants present in the millets will delay the progression of neurodegenerative disease[46].

Researchers have proved various pathways, like the Tau hypothesis, neuro-inflammation, oxidative stress hypothesis, mitochondrial dysfunction hypothesis, and cholinergic hypothesis, for the prognosis of Alzheimer's disease. These are as follows. Active chemical constituents present in millets can delay the progress of various steps as described in these hypotheses (Figure 7).

4.7.1 Tau Hypothesis

The tau protein regulates the stability of microtubules, which are responsible for the movement of proteins within cells of the central nervous system. In Alzheimer's disease, the excessive growth of the Tau protein disrupts the functioning of the cytoskeleton, intracellular signalling, transport system, and mitochondrial integrity. Due to hyperphosphorylation, the Tau protein dissociates from the microtubule, and it binds with itself, generating paired helical filaments. This accumulation is observed as a symptom of Alzheimer's disease[47].

4.7.2 Amyloid Hypothesis

The agglomeration of oligomeric or fibrillar amyloid-beta (Aβ) peptide is a reasonable cause of Alzheimer's disease. Aβ is a peptide that originates from Amyloid Precursor Protein (APP) and is composed of about 38 to 42 amino acids. In the non-amyloidogenic route, α-secretase cleaves it to generate the secreted fragments, sAPPα. In the amyloidogenic process, ADP is first eliminated by β-secretase (BACE1), and then by γ-secretase, which produces Aβ peptides[48]. The accumulation of Aβ in the amyloidogenic pathway results in toxicity, with $Aβ_{42}$ exhibiting greater cytotoxicity compared to $Aβ_{40}$ and $Aβ_{43}$. The overproduction and buildup of Aβ may be caused by inherited & environmental factors like mutations in the APP, PSEN1 (presenilin1), and PSEN2 (presenilin2) genes, as well as deficits in Aβ clearance, oxidative stress, and mitochondrial dysfunction[49].

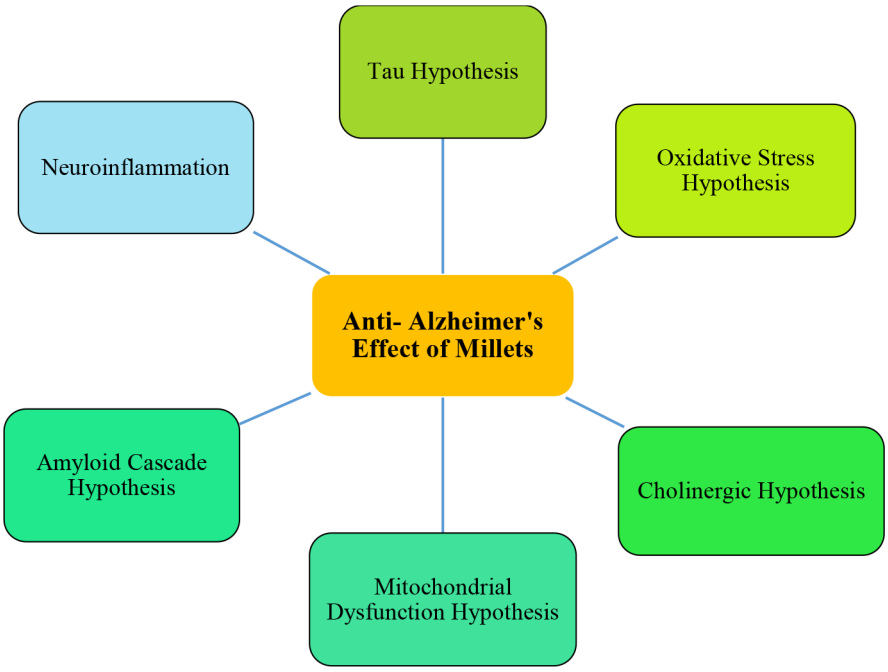


Figure 7. Hypothesis of Alzheimer's disease.

4.7.3 Neuroinflammation

Neuroinflammation leads to an increase in the activation of complement proteins and cytokines by microglia and astrocytes. In Alzheimer's disease, the presence of Aβ plaque and Neurofibrillary Tangles (NFTS) leads to a persistent state of inflammation and an increase in cytokinins, specifically Interleukin-1, which is a tumour necrosis factor, as well as prostaglandins, growth factors, thromboxanes, and ROS. These enhance amyloid precursor protein (APP) processing, leading to an increase in $A\beta_{42}$ levels in the brain[50]. Aβ also stimulates the COX 2 pathway, Inducible Nitric Oxide Synthase (INOS), and Nuclear Factor Kappa-B (NF-κB). This Aβ-linked inflammatory response causes neurological damage in Alzheimer's disease. So, long-term use of NSAIDs delays the progression of Alzheimer's disease[51].

4.7.4 Oxidative Stress Hypothesis

Alzheimer's disease is brought on by oxidative stress. ROS, i.e., Reactive oxygen species, are a form of oxidative stress. ROS are byproducts of oxygen metabolism, which uses oxygen intermediates such as singlet oxygen ($^1O_2$), superoxide (O_2^-), hydroxyl radical (OH^-), and Hydrogen Peroxide (H_2O_2). ROS oxidises lipids, proteins, DNA, and RNA. Aβ deposition is followed by oxidative stress. ROS contributes to the advancement of several health issues, including neurodegeneration, mutagenesis, cardiovascular problems, and cellular aging[52].

4.7.5 Mitochondrial Dysfunction Hypothesis

The dysfunction of cells results in several disease conditions such as cardiovascular disease, cancer, diabetes, and neurodegenerative disorders. Alzheimer's disease may be primarily caused by failure in mitochondrial function, aberrant phosphorylation of the Tau protein, development of amyloid plaques, degeneration of synapses, and oxidative stress. Alzheimer's disease is attributed to mitochondrial processes, including biogenesis, fusion, fission, and bioenergetics[53].

4.7.6 Cholinergic Hypothesis

Alzheimer's disease is characterised by structural modifications in the cholinergic synapses as well as loss of specific subtypes of the Acetylcholine (ACh) receptors. The death of Ach-producing neurons reduces cholinergic transmission in the brain. This summarises the aggregation of the Ach-hydrolysing enzyme,

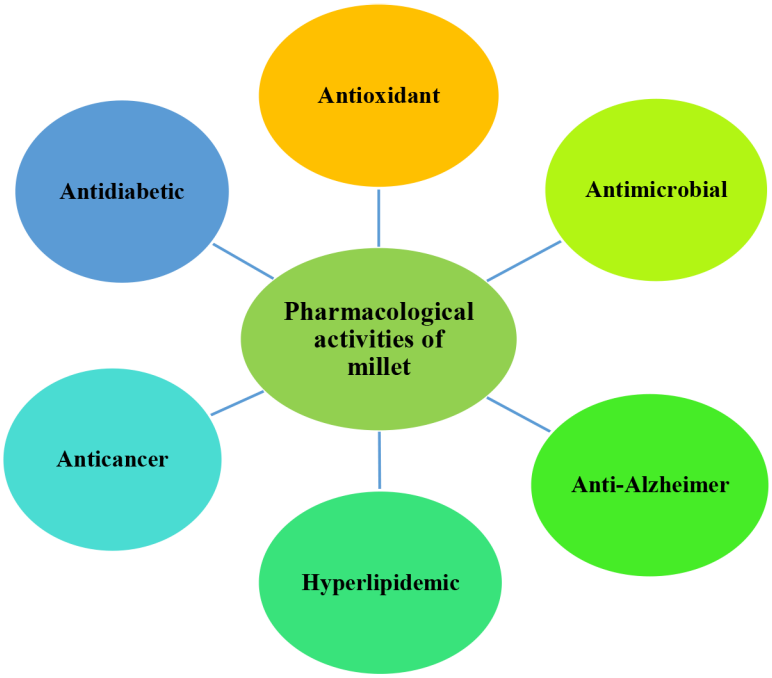


Figure 8. Pharmacological activities of millet.

Acetylcholinesterase, which causes Alzheimer's disease (Figure 8)[54].

5. Future Prospects

Future nutritional and health benefits of millets are encouraged by growing understanding about their nutritional value, sustainability, and potential to address global health issues[55]. Customers are looking for nutritious, environmentally sustainable food options as they become more health-conscious. Because millet is gluten-free and abundant in nutrients, it appeals to these tastes, so millet-based foods are in higher demand. Creating cutting-edge technologies that will reduce the cost of millet processing and allow for its efficient use in the food and pharmaceutical industries, allowing the creation of millet-based goods that are ready to eat and cook[56]. Launching additional studies in the food sector and carrying out additional research and development to investigate the possible processing opportunities, value-added utilisation, and nutritional and pharmacological aspects of millets is the main aim of this dissertation. Millets are a long-term and sustainable way to provide a steady supply of food and feed materials by highlighting their scientific qualities and nutritional value, biologically active chemicals, and medicinal qualities[57]. Regarding their ability to withstand harsh environmental circumstances, millets require less input and water than major cereal crops. Their cultivation can help mitigate the effects of climate change and promote sustainable agriculture. Because of their nutritional makeup, millets are a good option for treating dietary deficiencies and malnutrition, particularly in areas with few resources[58,59].

6. Study Limitations

There are several study limitations in studies on the pharmacological effects of nutrient-rich millets, and these largely rely on the particular study design. The results can be impacted by variations in millet types and processing techniques, which can change the nutritional content and bioavailability. Geographical location and related dietary patterns may influence the health benefits of millets. So, the understanding of the underlying mechanisms of the observed effects may be hampered by a lack of knowledge on the nutritional profile of the millet utilised in the study. Millets' effects on the body and bioavailability may be influenced by interactions with other dietary ingredients. The reported effects on health parameters may not be confirmed by comprehensive biomarker studies included in the study. The accuracy and reliability of results may be impacted by selection bias, participant bias, or researcher bias.

7. Conclusion

Millets are an essential, sustainable and health-promoting food source because of their pharmacological and nutritional properties. Nowadays, these are used as food as they comprise several nutritional components like carbohydrates, proteins, vitamins, essential amino acids, fat, minerals and dietary fibres. It also contains several phytochemical constituents, including polyphenolic compounds, flavonoids, and tannins, *etc*. Due to these reasons, millets exhibit several pharmacological activities, such as antioxidants and antidiabetic, antimicrobial, anticancer, anti-inflammatory, and hyperlipidemic, *etc*. As millets possess antioxidant properties, they may have an effect against the oxidative stress in the pathological condition of Alzheimer's disease. Millets are found to have anti-inflammatory properties by acting on the cyclooxygenase pathway. So, it may be effective against neuroinflammation. Due to the presence of several therapeutic potentials, millets hold great promise to improve human health. So, the incorporation of millets into the diet not only improves nutritional intake but also provides potential pharmacological benefits, making them a vital component of a healthy and balanced lifestyle.

8. Acknowledgement

The authors are thankful to Management, Centurion University of Technology & Management, Bhubaneswar, Odisha, for providing the necessary facilities to complete this review article.

9. References

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Author Contribution

The authors confirm their contribution to the paper: study conception and design: PKS, ST; data collection: SM, DJ; analysis and interpretation of results: KM, AN; draft manuscript: BMS. All authors have read and agreed to the published version of the manuscript.