The Nutritional Value of Millets in Future Eras

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Edited by

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CHAPTER ONE

MILLET AS FUNCTIONAL FOODS

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Due to their high fiber and protein content, which promote satiety, millets are now referred to as "ragi" by the wealthy elite and used as functional foods for weight loss. In addition to polyphenols and flavonoids, millets are also high in calcium, iron, magnesium, and B vitamins (Kumar et al., 2016; Puranik et al., 2017). In order to sustain cellular function and general health, the diet should contain relatively high amounts of the critical macrominerals calcium and magnesium. The demographic groups most at risk of calcium deficiency include elderly people, young children, pregnant women, and those who are nursing (Puranik et al., 2017). Increased dietary calcium intake might be the most economical strategy to address these inadequacies, which in the senior population appear as osteopenia and osteoporosis. A

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great choice for figuring out the genetic processes behind calcium buildup within cereal crops is finger millet, a plant having a naturally increased calcium content in its grain. Millets' high mineral, amino acid, and flavonoid content makes them ideal candidates for development as food-based nutritional supplements that may be used to create highly individualized treatments or medications (Kumar et al., 2016; Rome and Asuncion, 2018).

Compared to other commonly consumed grains, finger millet is an agricultural crop with significant potential but unexplored nutraceutical qualities. The FAO and WHO have said that finger millet should be developed as an innovative functional food in 2017 due to the rising division and disadvantage of food security via diversification of diets (Rome and Asuncion, 2018; FAO of the UNO, 2017). On top of that, by producing an abundance of functional food on an international scale, introduction of such characteristics in different main crops might enhance population health. In light of the global nutritional and health problem, finger millet's biofortification looks to be crucial for both western countries and nations with lower and middle incomes. Current biotechnology breakthroughs have improved millets' nutritional value as well as provided new directions for future millets study, which may be ordered in the area of nutritional biology (Puranik et al., 2017).

Millets are an essential food source for many tropical and semi-arid regions of worldwide, providing these places with functional food stability even in tough environmental conditions. They also have good nutraceutical characteristics. If the food sector is trained to employ millets in producing contemporary foods for modern populations, then increased millet output may be used to export it to developed nations for security of functional food (Gupta et al., 2017). Just a few studies have been done on finger millets for their improvement in genetics, but given their nutritional importance as a source of minerals and proteins, they provide a great example for studies on nutrition and agriculture. Millet improvement will be greatly aided by enhanced genetic modification of millets for increased nutritional content and tolerance to both abiotic and biotic factors (Gupta et al., 2017).

Role of Small Millets as Functional Food

The ideas around food intake have evolved, and today's health-conscious consumers with greater income levels are looking for wholesome meals. Consuming food containing nutraceuticals provides health advantages and wellbeing while lowering risks from chronic illnesses including cardiovascular diseases, certain malignancies, and obesity. The "antioxidants" found in nutraceuticals are really micronutrients with the power to counteract the effects of the free radicals, known to be potentially detrimental byproducts of a variety of physiological processes and are linked to the ageing of tissues and cells. Small millets have a sufficient amount of phenolics, a potent antioxidant, hence small millets with the additional value-added goods they produce are in great demand within customers.

Due to the high fibre content of finger millet in contrast to both wheat and rice, intake of finger millet-based foods also shown considerably reduced plasma blood sugar levels. The function of enzymes that break down food is reduced by the abundance of bonded polyphenols in small millets (Rohn et al., 2002). Certain polyphenolic substances, such as phenolic acids, proanthocyanidins and flavonoids are known to scavenge free radicals and avert a variety of illnesses and morbid conditions (Himansu et al., 2018). When ingested as a staple cereal or in products with value added, millets' high nutritional value has the potential to provide health advantages; as a result, these little grains are deserving of classification as nutri-cereals.

Health Benefits of Millet Consumption

The health benefits of millet consumption are described in Table 1:

Function properties of millets	Studies	Reference
Helps reduce diabetes	Millets help manage diabetes due to their high fiber, polyphenol, and antioxidant content. Consumption of finger millet diets reduced plasma glucose levels significantly in 6 non-insulin dependent diabetes mellitus subjects. It could be due to the presence of antinutritional factors which reduce starch digestibility and absorption.	(Anitha et al., 2021) (Lakshmi Kumari & Sumathi, 2002)
Helps reduce cardiovascular diseases	Results of 19 studies showed that consumption of millets from 21 days – 4 months reduced levels of total	(Anitha, Botha, et al., 2021)

	cholesterol (TC), triacylglycerol, Low-density lipoprotein cholesterol (LDLC), very-low-density lipoprotein cholesterol (VLDL-C) and raised the level of high-density lipoprotein cholesterol (HDL-C good cholesterol).	
Antioxidant property	Millets are rich source of phenolic acids and phenolic compounds which can scavenge free radicals. It is also a rich source of flavonoids and carotenoids which can quench free oxygen and free radicals.	(Hassan et al., 2021)
Antimicrobial property	Phenolic acid from finger millet seed coat showed higher antimicrobial activity against *Bacillus cereus* and *Aspergillus flavus* compared to whole flour extract.	(Viswanath et al., 2009)
Helps reduce cancer	It helped to prevent colorectal cancer in mice models. Prosos and Barnyard millet exhibit anticancer properties owing to the presence of vanillin.	(Yang et al., 2020) (Ramadoss & Sivalingam, 2020)
Helps to reduce celiac disease	It helps to reduce celiac disease in humans owing to its gluten-free property.	(Das et al., 2019)
Helps reduce overweight and obesity	Millet-based food consumption can reduce the levels of overweight and obesity. A clinical trial by Ren et al., showed a significant reduction in body fat mass within 12 weeks of foxtail millet consumption.	(Ren et al., 2017)

Millets for Diabetes Mellitus

Diabetes is a long-term health disease characterised by hyperglycemia in the blood brought on by a change in metabolism. Increased blood sugar levels may be caused by inadequate insulin production or poor insulin function. Type 1 diabetes insipidus and type 2 diabetes mellitus are further classifications for diabetes. The beta cells in the pancreas are destroyed in diabetes type 1, which is an inflammatory disease, and as a result, the body produces insulin. Alternatively, resistance to insulin and the body's secretory reaction to it are the main contributors to type 2 diabetes. To understand millets' function in reducing the effects of diabetes, a lot of research has been conducted. Levels of glucose in the blood and lipid profiles of serum in rats with diabetes mellitus were considerably reduced when supplemented with pearl millet 33% and 66% (w/v) (Sada et al., 2016). Additionally, diabetic rat wounds were reported to heal when given the diet supplements of finger millet (Rajasekaran et al., 2004). Alterations in the activity of enzymes of antioxidants such as catalase (CAT) and superoxide dismutase (SOD) were also observed. In diabetic rats that were given finger millet, morphological and microbiological analyses discriminated between epithelialization, increased collagen production, stimulation of fibroblasts, and infiltration of mast cells. The activity of the yeast Saccharomyces cerevisiae was reported to be inhibited by extracts derived from the barnyard millet (Seo et al., 2015).

Luteolin and N-p-coumaroyl serotonin (CS) showed the -glucosidase inhibiting ability out of eight extracts of phenolics derived from barnyard millet. In Caco-2 cells, both FS and CS have the capacity to lower intestinal activity of sucrase and lower the amount of glucose (Seo et al., 2015). In comparison to wheat flour, independently, a mixture of millet and wheat flour substantially decreased the amount of glucose in the blood (Thilakavathy & Muthuselvi, 2010). Adiponectin along with a high level of cholesterol increased in the blood of those with type 2 diabetic KK-Ay mice fed millet and foxtail diet for a period of three weeks, whereas the level of insulin considerably decreased (Jali et al., 2012). Similar findings were made using proso millet, wherein adiponectin and HDL (high-density lipoprotein) cholesterol levels increased while the amount of glucose and insulin levels in the blood decreased (Park et al., 2008). Type 2 diabetes can be improved and mitigated by HDL cholesterol andadiponectin. Along with the dehusked seeds, the coat of the seed also possesses anti-diabetic qualities. In streptozotocin-induced diabetic mice, the use of black millet finger seed coat substance decreased the levels of -glucosidase and showed reduced diabetes activity (Okoyomoh et al., 2013).

Millets for Cardiovascular Diseases and Dyslipidaemia

Low-density lipoprotein (LDL), HC (higher cholesterol) and VLDL (very-low-density lipoprotein) levels increase as a result of the poor lipid metabolism, which also causes a decrease in HDL concentrations in the blood serum. Heart problems and hypertension are ultimately caused by the abnormal metabolic circumstances. According to several investigations, diets based on millets may be used to treat various metabolic diseases. Patients with type 2 diabetes were fed low GI biscuits composed of foxtail millet, and blood glucose, LDL, and VLDL levels were shown to drop (Thathola et al., 2011). The intake of a functional alcohol-free beverage composed of millet malts and fermented sorghum also revealed a similar tendency. Additionally, the beverage increased the activities of catalase, glutathione reductase, superoxide dismutase, glutathione peroxidase, and the activity of glucose 6-phosphate dehydrogenase within the livers of mice (Ajiboye et al., 2016). By modifying the expression of genes linked to lipid metabolism, such as SREBP-1C, FAS, and HMGCR, or by altering the makeup of the gut microbiota, millet may have a hypolipidemic impact (Li et al., 2019). Additionally, the increased concentration of dietary fibres in the grains of millet may be the cause of the decreased cholesterol levels in blood. It has been demonstrated that in proso millet the high concentration of the chlorogenic acid lowers the level of cholesterol in the blood (Bora et al., 2018).

According to the study, decreased expression of the gene for TNF-alpha (tumor-necrosis factor alpha) may contribute to lower blood LDL levels. Individuals with larger concentrations of CRP have a higher risk (three times) of developing heart diseases. CRP is a marker for heart-related illnesses. By regulating the amount of CRP within the blood of hyperlipidemic rats, foxtail millet diet may additionally decrease the risk of heart diseases (Lee et al., 2010). The significant magnesium concentration of grains of millet may help the body keep its ideal blood pressure.

Millets for Cancer

Cancer has emerged as a major, potentially fatal health condition in which one's body experiences unchecked cell development that impairs several metabolic processes. These diseases can be attributed to environmental or hereditary reasons. Millets are one of a number of food supplements that, in addition to medical treatment, can reduce the risk of developing cancer. The growth of malignant cells can be greatly inhibited by the insoluble linked phenol compounds from regularly produced millets (Chandrasekara and

Shahidi, 2010). Phenolic chemicals are frequently referred to be free radical and ROS (reactive oxygen species) scavengers in nature. According to reports, the polyphenols in foxtail millet bran inhibit the development of carcinogenic HCT-116 cells by causing oxidative stress, which in turn causes the cancerous cell lines to undergo caspase-regulated death (Shi et al., 2015).

Furthermore, the ROS, which are crucial in the development of tumours, blocked the NF-B pathway. The dose-dependent administration polyphenolic compounds of foxtail millet effectively reduced the growth of the MDA female breast tumour as well as HepG2 liver cell lines of cancer (Zhang and Liu, 2014). By causing the G1 phase stop in the cell cycle, a new protein known as FMBP (foxtail millet bran protein) has anti-cancerous characteristics (Shan et al., 2014). By the depletion of mitochondria's transmembrane capacity in colonic tumour cells, FMBP also causes caspase-dependent death. Linoleic acid is present in millets, which has anticancer properties. Histone deacetylases (HDACs), an essential histone modification enzyme, is effectively inhibited by it. It has already been proven that linoleic extracts of Japanese and proso millet is cytotoxic to prostate tumour cells and human leukaemia (Aburai et al., 2007).

The second most common type of cancer in people is colon cancer. Colon cancer risk can increase with a diet heavy in sugar and a lack of physical activity, but it can also be decreased with a diet rich in dietary fibre, vegetables and cereals (Slattery et al., 2000). Millets extracts had excellent antioxidant abilities that, dose and time dependent way, inhibited the growth of HT-29 cancer cells (Chandrasekara and Shahidi, 2011). The fatty acids of short chain that are produced when RS is fermented serve the function of prebiotic for the gut bacteria, greatly lowering the risk of cancer of the colon. Millets can therefore be considered a good nutraceutical agent for preventing the development of malignant mass and limiting its growth (Hylla et al., 1998).

Millets for Celiac Diseases

Because of intolerance to gluten along with other allergy problems, a significant proportion of people suffer celiac disease. Prolamin, a seed storage protein found in barley, rye, and wheat, is what causes gluten intolerance, an enteropathy (Cabrera-Chávez et al., 2008). Due to their generally high proline and glutamine concentrations, proteins made up of gluten are resistive to human digestive enzymes (Scherf et al., 2016). It is advised that people change their diet from one that contains a lot of gluten to one that is strictly gluten free to treat celiac disease (Talukder and

Sharma, 2015). Due to their high nutritional value and beneficial effects on health, millet grains are becoming increasingly popular by people (Woomer and Adedeji, 2020).

By 2023, it is anticipated that the worldwide market for gluten-free goods would have grown to nearly 6.5 billion USD from its estimated 5 billion USD value in 2017. A gluten-free diet category also includes a number of other grains besides millet, such as corn, pseudocereals and sorghum which include teff, amaranth and quinoa. In duodenum cultures from people with celiac disease, from millets the fraction of protein which is alcohol soluble, quinoa, teff and amaranth causes no immune reaction (Bergamo et al., 2011).

Antioxidative Properties of Millet Grains

Millet grains' increased polyphenol count confers significant health advantages, such as antioxidative characteristics, protection against the metabolic syndrome and difficulties associated with ageing (Bravo, 1998). Gentisic acid, vanillic acid, ascorbic acid, caffeic acid, sinapic acid and kaempferol are among the compounds that are bioactive recovered from millet grains (Ofosu et al., 2020; Xiang et al., 2019; Guo et al., 2018). By stopping the natural oxidation of unsaturated fatty acids by supplying reducing agents, such phenolic compounds support health advantages (Suma and Urooj, 2012). When compared to raw flours, the flour from barnyard, germinated foxtail and kodo millets had stronger antioxidant activity. In diabetic rats induced by streptozotocin, the finger millet seed coat material has been found to lessen oxidative stress damage (Sharma et al., 2016).

When millet phenolic extracts were subjected to high-performance liquid chromatography (HPLC) examination, it was discovered that the bonded fractions had larger concentrations of p-coumaric and ferulic acids compared to their soluble equivalents (Chandrasekara and Shahidi, 2010). It's interesting to note that the malting procedure of the grains affects how antioxidant-active the phenolic chemicals are. The phenolic acids that are produced and their activity vary depending on the process's time-points along with method (Saleh et al., 2013). Various millets' phenolic substances have demonstrated their antioxidant abilities by inhibiting up-to 41% of oxidation of LDL cholesterol (Chandrasekara and Shahidi, 2012). Compared with different millet species, kodo millet has the most inhibitory impact on the oxidation of lipids. Millets might therefore be used as an organic source of several antioxidants and nutritious food components.

Antimicrobial Activity

It has been demonstrated that millet grain extracts contain inherent antibacterial properties. Finger millet's phenolic seed coat extract shown strong antibacterial action against Aspergillus flavus and Bacillus cereus (Viswanath et al., 2009). Foxtail millet grains were used to make a new antifungal peptide having a molecular weight of 26.9 kDa that inhibited Fusarium oxysporum, Alternaria alternative, Trichoderma, Botrytis cinereal and viride. (Xu et al., 2011). Similar to this, peptides from fermented millet foxtail extract that were separated using the RP-HPLC technique showed antioxidative as well as antibacterial activity (Amadou et al., 2013). The millet gruel-derived LAB (lactic acid bacteria) were shown to have a wide spectrum of antibacterial activities. Pseudomonas aeruginosa, Bacillus cereus, Pseudomonas syringae, Bacillus licheniformis, Salmonella spp., Escherichia coli and Proteus spp. all showed growth inhibition by the isolated LAB (Wakil and Osamwonyi, 2012). Because they come from a source that is naturally occurring and have no negative adverse reactions, the metabolites produced by such fermenter bacteria are a fantastic substitute for preservatives. Millets can therefore be a great source of naturally occurring antibacterial agents, and additional research might be done to use them as natural preservative in the industry of food.

Millets and Phytochemicals

Millets are an excellent source of vitamins and phytochemicals. Millets include a variety of phytochemicals, including tocopherol, resistant starch, sterols, dietary fibre, carotenoids and phenolics. The polyphenols, which include phenolic acid, small amounts of flavonoids and tannins serve as antioxidants and contribute to the body's immune system (Chandrasekara and Shahidi, 2010). Most of the natural antioxidants in millet have a positive effect on scavenging additional toxic substances from the human body, including those present in both the liver and kidneys, as well as neutralising radicals known as free radicals, which may lead to cancer.

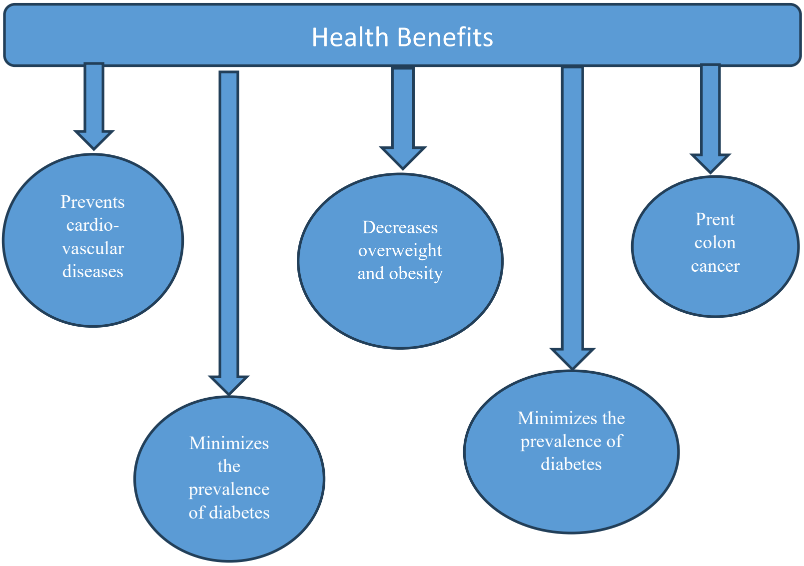
By encouraging correct excretion and reducing the activity of enzymes among those organs, ellagic acid, quercetin, curcumin, and other helpful catechins may assist in the removal of any unwanted substances and toxins from the body. Due of their importance to human health, polyphenols have received an abundance of research attention (Ambati and Sucharitha, 2019). Physiological and medicinal advantages of millets, the insoluble as well as soluble bonded phenolic compounds of numerous types of millet, including pearl, kodo, proso, small and finger millets, demonstrate the antioxidant and reducing properties (Chandrasekara and Shahidi, 2010). On a wet basis, foxtail millet has 3.34 mg of tocopherol and 47 mg of polyphenolics per 100 g; proso millet has 2.22 mg of tocopherol and 29 mg of polyphenols per 100 g. Millets are very rich in nutrients and provide a number of health advantages. Taking millets can help prevent obesity.

Obesity Control

The largest rising issue in India is obesity, which is linked to several chronic disorders like diabetes and cardiovascular disease (CVD). According to recent research, eating a diet high in dietary fibre reduces the prevalence of obesity (Alfieri et al., 1995). Dietary fiber-rich foods enhance intestinal function and slow down absorption and digestion, thus lowering the chance of developing chronic illnesses (Ali et al., 1982). Millets have a dietary fibre level of 22%, which is greater than the contents of various cereals such as wheat (12.6%), rice (4.6%), and maize (13.4%). According to (Chethan and Malleshi, 2007), finger millet grain contains 15.7% soluble dietary fibre and 1.4% insoluble dietary fibre.

According to (Shobana and Malleshi, 2007), finger millet contains 2.5% soluble dietary fibre, 19.7% insoluble dietary fibre, and 22.0% total dietary fibre. Dietary fibres are divided into insoluble and soluble types, as is common knowledge. Obesity is now a prevalent issue that is linked to a number of other disorders, including diabetes, cardiac issues and high blood pressure. According to studies, eating foods packed with fibre helps enhance the function of the bowels, lower the incidence of obesity, and lower the chance of developing chronic illnesses by enhancing the process of absorption and digestion of the body.

Millets aid in controlling weight and lowering obesity in addition to satisfying hunger. Millets' abundant fibre content reduces issues including constipation, abdominal discomfort, and cramping in the stomach. The prevention of digestive tract disorders including colon cancers and ulcers is possible with proper absorption and digestion (Reddy, 2017).



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CHAPTER TWO

MILLETS: AS A THERAPEUTIC FOOD

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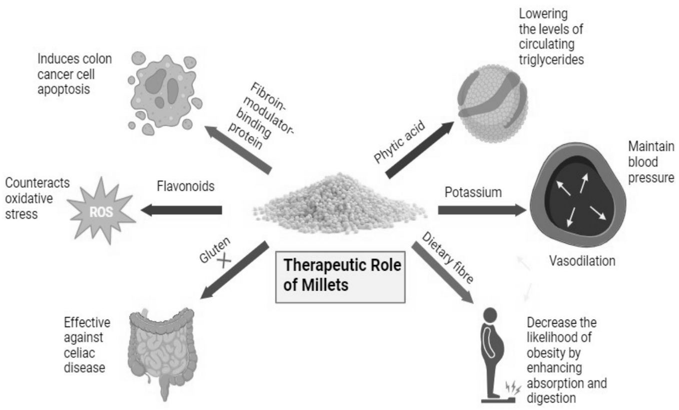

Figure 1: Graphical Abstract

Introduction

Malnutrition represents a significant global concern warranting comprehensive investigation, as inadequate diets are a primary contributor to mortality worldwide. A substantial portion of the population either faces insufficient food intake or consumes imbalanced and unhealthy foods, leading to various illnesses and health crises (Onis & Blossner, 2003). Neonates, children, and females of reproductive age are the most susceptible populations to malnutrition. Various types of millets, including pearl millet, the Kodo millet, finger millet, proso millet, foxtail millet, and tiny millet,

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are utilized in a diverse range of culinary goods including bread, cookies as well as chappati in both developing and developed countries. Millet grains have a lower availability rate (13%) when compared with maize (62%) as well as sorghum (45%), despite their considerable potential (Parthasarathy & Basavaraj, 2015) which has resulted in limited research on millet flours (Tripathi et al., 2011). To promote a healthy lifestyle, it is crucial to select therapeutic food based on their physiological and biological role. A considerable proportion of the world's population (38%) resides in drylands where agricultural output is susceptible to Human action and global warming (Huang et al., 2016; Reynolds et al., 2007). Awareness about climatic situations and topsoil profiles can aid agriculturalists in selecting appropriate crops, and millet stands out as a significant cereal grain capable of thriving under such conditions. Numerous researches have shown promising results regarding the utilization of millets in various nutritious foods (Gong et al., 2018; Dias-Martins et al., 2019). The inherent gluten-free characteristic of millet has garnered attention from investigators and food processing manufacturers for creating recipes involving millet flour (Salar, Purewal & Sandhu, 2017; Siroha, Sandhu & Kaur, 2016). Additionally, millets are attaining significant interest from both scientists and ecological authorities, alongside major staple cereals like wheat, rice and maize. Various processing techniques, including solid-state fermentation germination, as well as thermal treatment, can be employed to process millets.

The four main millet varieties are Pearl millet also named Pennisetum glaucum, which accounts for 40% of global produce; Finger Millet (Eleusine coracana), while millet or proso millet (Panicum miliaceum) and Foxtail millet (Setaria italica). Pearl millet, which yields the biggest seeds, is mostly utilized for human food and dietary practices. The minor millets include Kodo millet (Paspalum scrobiculatum), Barnyard millet (Echinochloa spp.), Teff (Eragrostis tef), fonio (Digitaria exilis), Guinea millet (Brachiaria deflexa = Urochloa deflexa), Little millet (Panicum sumatrense), Browntop millet (Urochloa ramosa = Brachiaria ramosa = Panicum ramosum), and Sorghum (Sorghum spp.) and Job's tears (Coix lacrima-jobi) are sometimes classified within the millet category. The global millet production in 2007 amounted to around 32 million tonnes, with Sudan, Pakistan, Burkina Faso Nigeria, Mali, Uganda, India, Niger, Ethiopia, China and Chad being the leading nations in terms of production. Global production of pearl millet constituted over 54% in 2004 (Devos, Hanna & Akins, 2006).

Millets act as a crucial component in the agricultural and security of food networks among several impoverished peasants in Sub-Saharan Africa.

Pearl millet, especially prominent in India, serves as a significant food source across the Sahel. Millets are usually ground into flour and used to prepare beverages or porridge. In regions like Pakistan, Gujarat, and India, roti made from pearl millet is a staple food for farmers. Given the need to feed the rising global population, it is vital to explore locally grown and consumed plants such as millets, particularly in low-income family units in regions like the Sahel zone and India. Millet-based foods and beverages, widely known and consumed worldwide, remain essential components of diets in most African countries (Amadou & Gounga, 2013). This chapter aims to envisage the most recent scientific investigation regarding therapeutic health benefits imparted by various varieties of millet.

Health Benefits of Millets

Millet encompasses a variety of potential health advantages that extend beyond being a simple substitute for typical grains. It contains a significant number of phytochemicals, such as the phytic acid, which are associated with cholesterol reduction and lowered cancer risk (Coulibaly et al., 2011). Millets contain high levels of phytochemicals, which include antioxidant substances, which contribute to their beneficial effect on health status (Izadi et al., 2012). It is also known that millet offers a significant benefit due to its characteristic of being devoid of gluten, which makes it a highly suitable option for those suffering from celiac disease, or who have a sensitivity to gluten present in wheat and other grains. Furthermore, millet is beneficial for individuals with diabetes and heart problems (Gélinas et al., 2008).
Studies conducted by Choi et al. (2005) and Park et al. (2008) revealed that the proso as well as foxtail millet's protein concentration significantly raised HDL cholesterol levels and adiponectin while decreasing insulin concentration in type 2 diabetic mice compared against a casein diet. Moreover, proso millet demonstrated enhanced glycemic responses and could potentially serve as a therapy approach for type 2 diabetes. The protein concentrate was additionally found to possess protective properties against liver injury produced by D-galactosamine in the experimental rats (Ito et al., 2008).

Polyphenols and dietary fiber found in finger millet were reviewed by Devi et al. (2011), highlighting their role in conferring health benefits associated with millet. In their study, Chandrasekara and Shahidi (2010) found that non-processed brown finger millet showed the highest radical-reducing activity as opposed to the processed version. They attributed this activity to the presence of tannins and phytic acid (Devi et al., 2011; Kamara et al., 2012; Quesada et al., 2011). Extracts from millet seed coats showed strong antibacterial and antifungal activity owing to their high polyphenol amount (Viswanath et al., 2009; Xu et al., 2011).

Different millet varieties, including barnyard millet, kodo millet, little millet, foxtail, great and finger millet and their white assortments, were found to have substantial antioxidant capability by the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method (Devi et al., 2011; Quesada et al., 2011; Kamara et al., 2012). Furthermore, the study revealed that segregated foxtail millet hydrolysate of proteins had varying radical scavenging capabilities. The findings indicate that millets have significant potential as a source of beneficial chemicals that include antioxidant and health-enhancing properties (Kamara et al.,2012).

Therapeutic Effects of Millets on Diabetes

A comprehensive systematic review comprising 19 research papers has demonstrated that millets offer potential benefits in managing diabetes owing to the high fiber, antioxidant and polyphenol content (Almaski et al., 2019). Commonly used in Asian and African nations, millets have been largely replaced by maize, wheat and rice. Given the increasing incidence of chronic illnesses like diabetes and the challenges posed by climate change, it is imperative to advocate for the adoption of smart foods that fulfil the criteria of being helpful to human health, sustainable for the environment, and advantageous for farmers.

Numerous researches have indicated that millets have shown promising effects in controlling blood sugar levels and improving insulin sensitivity (Singh, 2020; Palanisamy & Sree, 2020; Thathola, Srivastava and Singh, 2011; Sobhana et al., 2020; Geetha, 2020). The glycemic index (GI) is a metric quantifying the impact of carbohydrates in food on postprandial glycemic response. The overall nutritional strategy for enhancing glycemic control involves the consumption of foods with low glycemic index (Narayanan et al., 2016). Glucose levels at post-prandial time are typically checked at regular intervals, usually 2 hours after a meal, while fasting blood glucose levels are typically acquired after abstaining from food overnight. Hyperinsulinemia, a condition characterized by elevated levels of insulin, elevates the risk of developing type II diabetes in individuals with insulin resistance (Lin et al., 2010). Therefore, it is necessary to measure the concentration of insulin to assess the ability of a diet to decrease insulin resistance. In addition, the HbA1c marker can be used to evaluate long-term glycemic management (Selvin et al., 2004).

Though numerous researchers have investigated the therapeutic effects of millets as shown in Table 1.1, however, the information remains diverse.

Hence, it is crucial to consolidate scientific evidence to ascertain whether millets indeed possess glycemic control properties, encompassing processing forms and types, can act as a nutritional guide, including cooking. With the escalating diabetes prevalence in both developed and developing countries across various socioeconomic groups, this paper aims to undertake a comprehensive meta-analysis and systematic review, investigate the glycemic index, postprandial and fasting blood glucose concentrations, HbA1c levels and insulin response linked with millet-based meals used simple regression analysis and descriptive statistics. This investigation used multiple processing methods and covers 11 varieties of millets as well as 1 mixed millet. The information collected will serve as the scientific foundation for any claim regarding the relationship between millets and diabetes, proving valuable to the food processors, dieticians, nutritionists, scientific community and governments in shaping health, nutrition, and agriculture policies and agendas (Anitha et al., 2021).

Table 1.1 Therapeutic effects of Millets

Type of Millet	Therapeutic effects	Reference
Foxtail millet	Exhibits chemo-preventative effects against cancer of the colon in rats. Helps to manage blood glucose and cholesterol levels. Have the capacity to mitigate acute liver injury in rats caused by ethanol.	(Pang et al., 2014; Ren et al., 2016; Yang et al., 2020;)
Little millet	Owing to the presence of polyphenols, it protects against various metabolic problems.	(Almaski, Thondre, Lightowler, & Coe, 2017; Srilekha Kamalaja, et al., 2019)
Finger millet	In diabetic rats, it reduces tissue damage and accelerates wound healing. It effectively reduces plasma triglycerides, therefore preventing cardiovascular illness in rats with hyperlipidemia.	(E.S. Sarita. & E. Singh, 2016)
Barnyard millet	It has the ability to act as an inhibitory agent by the destruction of the HT-29 division of large intestine cancer cells particularly the colon by stimulating apoptosis. Its polyphenol concentration suppresses amino acids glycation and glycoxidation, two processes	(Anis & Sreerama, 2020 and Ramadoss & Sivalingam, 2019;)

	that are vital in the advancement of diabetes mellitus.	
Proso millet	It is devoid of gluten and has the potential to protect people from the condition known as celiac disease. due to their relatively less glycemic index, they can also act as beneficial agents in lowering the likelihood of developing type 2 diabetes mellitus in individuals.	(Das, Khound, Santra, & Santra, 2019; Tyl, Marti, Hayek, Anderson, & Ismail, 2018)
Pearl millet	Since it has a gluten-free composition, it is capable of preventing the development of celiac disease in human beings. Moreover, it increases the immune system's capability to shield against Shigella-induced morbidity in animal models.	(Akinola et al., 2017; Ganguly, Sabikhi, & Singh, 2019)
Kodo millet	It has the ability to act as an antioxidant as well as lowers the risk of developing diabetes mellitus by decreasing the glycemic index of food items. This was observed in a human female model indicating beneficial effects of kodo millet.	(Chaudhary Kanchan, 2013; Srilekha, Uma Maheswari, et al., 2019)

Therapeutic Effects of Millets on Cancer

Colorectal cancer is the third in terms of cancer prevalence among men and second among women globally (Center et al., 2009). Several studies have suggested that consuming more whole-grain meals can help lower the likelihood of developing colon cancer (Chatenoud et al., 1998, Li et al., 2013, Lv et al., 2012, Omar et al., 2009). The foxtail millet, originating in China, is now extensively cultivated worldwide, including in other regions of the United States Asia, India, Canada and Africa (Austin, 2006). Extensive research has shown that foxtail millet has a plethora of nutritious qualities, including tannins, glucosinolates, amylase inhibitors and polyphenols (Yamasaki et al., 2005). Furthermore, foxtail millet has exhibited several biological actions, such as its ability to lower blood sugar levels (Anju and Sarita, 2010), antifungal effects (Joshi et al., 1998), and antioxidant properties (Amadou et al., 2011).

Bran is a nutritious by-product obtained from cereal grain processing that consists of the hard outermost stratum of cereal grains and contains significant nutrients as well as different phytochemicals that are bioactive such as phenolics and alkaloids that function as 'antinutrients' to prevent illness. Numerous brans have gained recognition for their antioxidant and anticancer properties. Studies have indicated that millet bran contains fractions with the maximum antioxidant properties. Furthermore, fatty acids, phytochemicals and lignans in the bran of wheat, additionally phytic acid from the bran of rice, have excellent anti-colon cancer capabilities (Qu et al., 2005). Therefore, exploring the medicinal functions of cereal bran holds significant importance.

Recent research has highlighted the crucial role of proteins and peptides derived from bran cereal grains in the prevention and treatment of cancer. Rice bran’s bioactive peptides have shown effective activities against lung, liver, colon, and breast carcinomas (Kannan et al., 2010). However, research on millet bran biologically active fractions, particularly biological macromolecules from the bran of foxtail millet with anti-cancer effects, is scarce. The investigation involved the extraction and purification of a 35 kDa (kilodalton) protein from the aqueous extract of foxtail millet. This protein, known as FMBP (Fibroin-modulator-binding protein), shows similarity to peroxidase and has interesting health-promoting capabilities. Significantly, this novel protein selectively suppresses proliferation and induces colon cancer cell apoptosis while sparing healthy human colon epithelial cells (Shan et al., 2014).

Therapeutic Effects of Millets on Cardiovascular Disorders

Millets have shown promising results in impacting plasma lipid levels. The ingestion of porso-millet protein concentrate has demonstrated an increase in the concentrations of high-density lipoprotein, or HDL, cholesterol, and adiponectin in the circulatory system. Millets are abundant in magnesium, which is recognized for its capacity to decrease the likelihood of heart attacks. Phytochemicals present in millets, such as phytic acid, have been shown to contribute to cholesterol reduction and cardiovascular disorders prevention by lowering the levels of circulating triglycerides (Lee, et al., 2010). Several studies have indicated that incorporating whole grain millet into a daily diet can reduce the likelihood of experiencing a cardiovascular event among individuals. The inclusion of millet in one's diet can have a positive impact on heart health. This is mostly due to the high magnesium concentration found in millet, which aids in reducing hypertension and the risk of strokes and myocardial infarction, especially in individuals suffering from atherosclerosis. These grains are also a superb dietary source of potassium, functioning as a vasodilator to maintain low blood pressure. Ensuring an ideal blood pressure and proper functioning of the circulatory system is essential for safeguarding cardiovascular well-being.