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NUTRIMILLET INSIGHTS: A REVIEW OF MILLET VARIETIES AND ADVANCED PROCESSING TECHNIQUES FOR ENHANCED NUTRITIONAL IMPACT

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ABSTRACT: Millets are a group of small-seeded, grains that have gained renewed attention in recent years due to their high nutritional value and sustainable agricultural practices. This abstract provides an overview of millets, their processing methods, and their remarkable nutritional benefits, highlighting their potential to address global food and nutrition challenges. Millets have been cultivated for thousands of years, with a rich history of consumption in various cultures around the world. These drought-resistant crops are highly adaptable to diverse environmental conditions, making them an essential staple in many regions. Millets include varieties like finger millet, pearl millet, sorghum, foxtail millet, and more. The processing of millets involves cleaning, dehulling, milling, and can result in various products like flour, flakes, and ready-to-cook items. They are rich in essential nutrients, including fiber, vitamins, minerals, antioxidants and they are gluten-free. Millets are known for their low glycemic index and are also a good source of protein. Millets have gained recognition for their potential to combat malnutrition and food insecurity, particularly in developing countries. Incorporating millets into diets can improve overall nutrition and provide a sustainable source of income for small-scale farmers. Additionally, their ability to withstand adverse weather conditions and require minimal water and fertilizer makes them a valuable crop for climate-resilient agriculture. In conclusion, millets offer a promising solution to global food and nutrition challenges. Their rich nutritional content, adaptability, and sustainability make them a viable option for promoting food security and healthy diets.

INTRODUCTION: Millets are type of cereal in the grass family Poaceae belonging to sub-family Panicoideae. Millets are one of the earliest cultivated crops, a common term that includes a few grains of seeds. The word "millet" originates from French word "mille," meaning "thousand," as a single handful of millet can contain up to a thousand grains [1].

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They are the prime food source in dry and semi-humid regions of the globe. These cereals possess remarkable bionomic compatibility with arid regions, as they exhibit exceptional drought tolerance, they can be stored for prolonged periods without succumbing to pest damage [2, 3].

They are considered resilient crops with regard to growth prerequisites as they resist extreme meteorological aspects such as uncertain weather, low moisture, and nutrient-exhausted soils [4]. Millets are usually grown in borderline areas in agricultural environments where other cereals dwindle to yield significantly People in drought-prone areas have great desirability towards millets because of short cropping season and high productivity by utilizing minimum resources. Millets are rich source of amino acids, lipids, minerals, vitamins, roughage, and polyphenols. Classic millets carry large amounts of essential amino acids such as methionine, cysteine and have more fat content when compared to other cereals like sorghum, maize and rice. Though cereals, including millets, may have limited lysine and tryptophan content, they still contain the necessary amino acids, vitamins, and minerals. They are rich in antioxidants like phenolic acids, glycated flavonoids, and phytochemicals. Millets are abundant in calcium, dietary fiber, polyphenols, and protein[4]. Millet is said to possess numerous nutritional and medicinal properties. Millet-based foods have been identified as having prebiotic properties that can contribute positively to gut health by improving the survival and efficacy of probiotics [5].

Millets are a diverse group of grains that vary in appearance, plant characteristics, grain type, maturity, and morphological features. They are classified into two categories: Major Millets and Minor Millets. Major Millets include Foxtail millet, Pearl millet, Finger millet and Proso millet, which are the most commonly used millets for human consumption. The Minor Millets include a wide range of varieties such as Kodo millet, Little millet, Barnyard millet, Browntop millet, Teff, Fonio, Guinea millet, Sorghum, and Job's tears. Each type of millet has its unique set of characteristics, making them suitable for various uses and consumption preferences [6]. Millet is a nutritional powerhouse, packed with valuable vitamins like vitamin B, minerals such as magnesium, and antioxidants. It also contains important dietary minerals such as manganese, phosphorus, and iron, as well as essential fatty acids like linoleic, palmitic acids and oleic acids. Millet oil is a great source of linoleic acid and tocopherol. Additionally, millet is gluten-free and alkaline-forming, making it a healthy option for those with dietary restrictions. Millets are rich in vitamin B, including Niacin, folacin, riboflavin, and thiamine, as well as phosphorus, which play key roles in the synthesis of energy in body. Millet is composed of various layers, including the husk and bran. The husk makes up approximately 13.5% of the content of foxtail millet, while bran and germ together account for around 1.5-2%. When considering the edible portion of millet, it primarily contains carbohydrates (60-70%), proteins (7-11%), and fats (1.5-5%). Additionally, millet provides a range of minerals, vitamins, and other beneficial nutrients[7]. Millet's gums which is water-soluble mainly contain arabinose and xylose, along with minor quantities of mannose, galactose, and varying amounts of glucose. Hemicellulose A primarily comprised glucans with minor quantity of arabinose and xylose, while hemicellulose B consisted of xylose and arabinose with lesserquantity of glucose and galactose [8].

Major Millets:

Pearl Millet: Pearl millet (*Pennisetum glaucum),* originating in the central tropical regions of Africa, has been extensively disseminated in arid tropical areas, including India. Traditionally pearl millet has played a crucial role as a significant crop for grain, forage, and stover in the arid and subtropical regions of numerous developing nations. While the cultivation of the crop is expanding into non-traditional regions in temperate and developed nations, the increasing importance of production constraints arising from diseases is evident. Pearl millet thrives in regions with drought, poor soil fertility, and elevated temperatures, showcasing its excellent adaptability to such conditions. It excels in soils with elevated salinity or low pH levels and can be cultivated in regions where challenging growing conditions would typically render other cereal crops like maize or wheat unviable [9]. Pearl millet plants can grow from 0.5 to 4 meters in height, and the grains come in a variety of colors, includingcolors like almost white, light yellow, brown, grey, purple or slate blue. The grains of pearl millet have an oval shape and are approximately 3 to 4 mm in length, with an average weight ranging from 2.5g to 1.4g. Pearl millet kernels are roughly one-third the size of sorghum kernels, and the ratio of germ to endosperm is greater in pearl millet compared to sorghum [10].

Pearl millet is recognized as a highly nutritious grain, abundant in resistant starch, both soluble and insoluble dietary fibers, minerals, and antioxidants. Its dry matter composition includes 92.5% content, 2.1% ash, 2.8% crude fiber, 7.8% crude fat, 13.6% crude protein, and 63.2% starch. The unmalted pearl millet grain was found to have a phytic acid content ranging from 2.91% to 3.30%. Pearl millet has a dietary fiber content that falls within the range of 8 to 9% [11]. The starch content is similar to that of wheat (69%) but falls below the levels found in maize (78%) and rice (85%). Approximately 20-22% of the starch present in pearl millet is amylose [12]. Researchers carried out a study to examine the relative proportions of different components of pearl millet kernels in relation to their seed sizes. The findings indicated that the germ component accounted for larger percentage of the kernel weight than other frequently consumed cereal grains.

Endosperm constituted 75.1% of the kernel weight for medium-sized kernels (measuring between 2240-2920 μm), while the germ and bran (pericarp + aleurone) constituted 17.4% and 7.5%, respectively. The amount of bran was observed to differ depending on the size of the seed and the type of pericarp. Bran content was 7.17% in kernels larger than 2920 μm, while smaller kernels measuring less than 2240 μm had a bran content of 10.64%. Kernels of smaller size possessing thick pericarps exhibited a bran content of 12.3%, while those with thin pericarps had a bran content of 9.3%. The protein, fat, and ash content of both the entire grain and its fractions were examined. The findings indicated that the germ exhibited the highest levels of protein (24.52%), fat (32.18%), and ash (7.18%).

Following closely, the bran showed 17.07%, 50.4%, and 3.20% for protein, fat, and ash, respectively. The endosperm had the lowest protein (10.88%), fat (0.53%), and ash (0.32%) content among all fractions analyzed (Abdelrahman *et al.*, 1984). Compared to maize and sorghum. Pearl millet grains possess a higher lipid content, approximately 6.4%. The primary fatty acids in these lipids include palmitic acid (C16:0) at 20-21%, oleic acid (C18:1) at 21-27%, and linoleic acid (C18:2) at 39-45%. Although lipids rich in unsaturated fatty acids may adversely affect flour stability, they can have beneficial effects on human health and metabolism. Pearl millet grains exhibit a substantial phenolic content of 1478 μg/g, exceeding the levels found in other frequently consumed grains like oats (472 μg/g), maize (601 μg/g), sorghum (746 μg/g), wheat (1342 μg/g), barley (1346 μg/g), and rye (1366 μg/g) [13].

Foxtail Millet: Foxtail millet, scientifically known as *Setariaitalica*, has garnered significant recognition as a prominent millet globally, primarily due to its impressive grain yield ranking it as the sixth highest among all grains. As a member of the Setaria genus within the Poaceae family, it distinguishes itself as a cereal grain that can be easily cultivated. Foxtail millet, with its average height ranging from 2 to 5 feet, presents a viable option for cultivation in comparatively drier and cooler regions, distinguishing it from other millet varieties.

This adaptable crop flourishes in both sandy and loamy soils, showcasing its capacity to yield about one ton of forage with just 2.5 inches of moisture, necessitating roughly 33% less water compared to corn. Moreover, it exhibits adaptability across various altitudes, thriving at elevations around 1.5 kilometres and also prospering in lower-lying areas close to sea level, with a harvest time of 75 to 90 days after planting, foxtail millet holds significant economic importance in the semi-arid tropics. In foxtail millet, aside from proteins, it contains a significant functional component known as antioxidants, they play a crucial role in minimizing the generation of free radicals within our bodies. Foxtail millet contains phenolics, a primary antioxidant.

Phenolics function by chemically providing hydrogen atoms, using hydroxyl groups on benzene rings, to free radicals that lack electrons. This process leads to the creation of a resonance-stabilized and less-reactive phenoxyl radical. Additionally, phenolics obtained from foxtail millet and various other millets have shown their ability to function as reducing agents, neutralizers of singlet oxygen, and agents that bind to metals. This highlights the diverse antioxidant properties exhibited by phenolics in foxtail millet and their potential health benefits. Fat plays a crucial role as a significant energy source for individuals, providing twice the number of calories compared to carbohydrates. Notably, foxtail millet's fat content is composed of over 80% unsaturated fatty acids. Foxtail millet exhibited a prevalence of fatty acids, with linoleic acid being the most abundant, succeeded by oleic acid, linolenic acid, palmitic acid and stearic acid.

These findings shed light on the fatty acid composition of foxtail millet and highlight the prevalence of beneficial unsaturated fats within this grain[14, 15]. In a study conducted by Yang *et al.,* [16]on 259 samples of foxtail millet obtained from six provinces in China, the reported values for various nutritional components were as follows: crude protein content ranged from 11.85 to 20.58 g/100 g, crude fat content ranged from 2.82 to 4.47 g/100 g, total starch ranged from 65.59 to 74.12 g/100 g, and amino acid content ranged from 0.25 to 4.31 g/100 g.

Finger Millet: Finger millet (*Eleusinecoracana*) comprises 81.5% carbohydrates, 18-20% fiber, 65% - 75% starch, 9.8% protein, 1% - 1.7% fat, 2.7% minerals, and 4.3% crude fiber, comparable to other millet varieties and cereals [17]. It was believed that certain components present in finger millet, such as polyphenols, dietary fiber, phytates and tannins, act as anti-nutrients due to their ability to bind to metals and inhibit enzymes. However, it is now confirmed that these constituents can actively contribute to antioxidant activity, playing a pivotal role in addressing aging and metabolic diseases. Furthermore, finger millet has demonstrated advantages in addressing diverse physiological disorders such as diabetes mellitus, hypertension, vascular fragility, hyper-cholesterolemia, and the prevention of low-density lipoprotein (LDL) oxidation.

Finger millet contains neighbouring ingredients and is a rich ingredient Calcium (344 mg/100 g), Phosphorus (283 mg), Iron source (3.9mg), vitamin B (1.71mg), vitamin E (22mg), etc. Finger millet contains significant amounts of bound phenolic compounds, with ferulic acid and p-coumaric acid being the major ones. Ferulic acid constitutes around 64% to 96% of the bound phenolics in finger millet, and p-coumaric acid makes up approximately 50% to 99%.Finger millet offers multiple benefits for diabetic individuals due to its high phenolic content and dietary fiber. Additionally, its low glycemic index (GI) makes it an ideal snack choice, particularly preventing late-night food cravings and maintaining stable blood sugar levels. The combination of high fiber and phenolic content, along with the low GI, makes finger millet a valuable inclusion in the diet of diabetic patients, as it has the potential to control blood sugar levels and prevent variations both during the day and at night. The dietary fiber and polyphenols present in finger millet have been acknowledged for their numerous health benefits. Consistent intake of finger millet and its derivatives has demonstrated anti-diabetic properties, safeguarding against chronic diseases linked to diet, reducing cholesterol levels, exhibiting antioxidant activity, and displaying antimicrobial effects. Additionally, finger millet is a rich source of carbohydrates, energy, and essential nutrients, making it an important component of a balanced diet. Incorporating finger millet into the regular diet can help manage various body disorders by maintaining blood glucose levels. Furthermore, finger millet products based on whole grain meals are notably advantageous because of the protective qualities offered by the seed coat, contributing additional health benefits [18, 19, 20].

Minor Millet:

Sorghum: Sorghum *(Sorghum bicolor*) grain holds a significant historical significance as one of the oldest cereal crops and Sorghum holds the fifth position globally in terms of both production and cultivated land among the most crucial cereals, comprising diverse small-grain cereal crops, is ranked as the seventh most important cereal grain globally.

Around 90% of the worldwide sorghum cultivation and 95% of the global millet cultivation are concentrated in developing countries, with a notable emphasis on Africa and Asia. These crops are mainly grown in economically disadvantaged areas characterized by limited rainfall and drought conditions, making them unsuitable for cultivating other grains unless irrigation is accessible [21]. Sorghum serves as a significant dietary provider of B vitamins, excluding B12, and is a notable source of tocopherols (vitamin E). The aleurone layer and germ of sorghum grain contain abundant B vitamins and minerals. Nevertheless, the removal of these nutrient-rich components through decortication leads to a refined sorghum product that lacks a portion of these vital nutrients. Sorghum is acknowledged for its high potassium content and low sodium levels. Whole grains, including sorghum, are valuable sources of magnesium, iron, zinc, and copper. The presence of polyphenols and phytates in sorghum negatively affects the bioavailability of iron, reducing its absorption. Processes like germination, decortication, malting, and fermentation can enhance the nutritional value of sorghum and millet. The overall composition of sorghum grain and its constituents is generally similar to that of corn, except for a lower oil content. The grain typically consists of approximately 8% to 12% protein, 65% to 76% starch, and roughly 2% fiber. The germ, which represents a concentrated source of oil (making up 28% of the germ), is also abundant in protein (19%) and ash (10%). Sorghum grain's proximate composition and nutritional characteristics have undergone thorough examination in numerous studies.

The hardness of sorghum grain is associated with a higher presence of the protein prolamin, ranging from 3.6% to 5.1%. Additionally, the lysine content in sorghum grain ranges from 1.06% to 3.64%. Protein fractionation studies have determined that sorghum grain's distribution of albumin-globulin, prolamin, and glutelin constitutes approximately 15%, 26%, and 44% of the total nitrogen, respectively. Starch dominates the composition of sorghum grain, making up 56% to 75% of the total dry matter. Soluble sugar content in sorghum grain varies from 0.7% to 4.2%, while reducing sugars range from 0.05% to 0.53%. Sorghum grain's fat content ranges from 2.1% to 7.6%, crude fiber from 1.0% to 3.4%, and ash from 1.3% to 3.3%. A separate study focusing on the physicochemical characterization of sorghum accessions revealed significant variation in protein (7.99% to 17.8%), lipids (2.52% to 4.76%), starch (51.88% to 85%), and amylose (12.30% to 28.38%) content. Major fatty acid constituents in sorghum lipids were identified as linoleic acid (18:2) and oleic acid (18:1). Sorghum grain is commonly consumed with the testa (outer covering), retaining the majority of nutrients. The mineral composition of sorghum grain displays a broad range, indicating its richness as a mineral source. However, it is crucial to acknowledge that environmental conditions can influence the mineral composition [22, 23].

Barnyard Millet: Barnyard millet (*Echinochloa frumentacea*) is a self-pollinating crop that belongs to the Poaceae family. Recognized as the earliest domesticated small millet, it is predominantly grown in various Indian states, including Orissa, Maharashtra, Madhya Pradesh, Tamil Nadu, Bihar, Punjab, Gujarat, and the hilly areas of Uttarakhand. Containing approximately 10.5% protein, barnyard millet functions as a valuable provider of readily digestible protein and is abundant in dietary fiber. In Uttarakhand, it is considered a minor kharif crop, grown under rainfed conditions. The moisture content of barnyard millet ranges from 8.7% to 9.63%. It has low carbohydrate content and the carbohydrates present are slowly digestible, making it an ideal food choice for individuals with diabetes mellitus. Despite its nutritional superiority over cereals and its potential to contribute to food and nutrition, the utilization of barnyard millet remains limited [24].

The elevated carbohydrate to crude fiber ratio in barnyard millet results in a gradual release of sugars into the bloodstream, aiding in the maintenance of stable blood sugar levels. Furthermore, the inclusion of resistant starch in barnyard millet has shown promise in reducing blood glucose levels, along with lowering serum cholesterol and triglyceride levels in animal studies conducted by Kumari and Thayumanavan [25]. Current evidence suggests that barnyard millet possesses a relatively higher protein content, varying between 11.2% and 12.7%, in comparison to other prominent cereals and millets. Although the overall mineral, ash, fat, and amino acid content in barnyard millet is similar to that of other cereals and millets, its iron content is notably higher. Additionally, barnyard millet showcases lower phytate content in its grains (ranging from 3.30 to 3.70 mg/100 g), and the dehulling process further diminishes phytic acid levels, thereby enhancing mineral bioavailability. This distinctive quality positions barnyard millet as a favourable dietary option not only for individuals with lifestyle diseases but also for anaemic patients and women, particularly in developing nations. The study by Renganathan *et al.*[26], highlights that barnyard millet grain is exceptionally nutritious, featuring substantial levels of protein, carbohydrates, fiber, and crucial micronutrients like iron and zinc.

However, despite its agricultural and nutritional advantages, barnyard millet has not been fully utilized. Furthermore, research indicates that barnyard millet grains contain antioxidant phenolic compounds, including serotonin derivatives and flavonoids. They also comprise both essential and non-essential amino acids such as lysine, methionine, threonine, isoleucine, leucine, histidine, tryptophan, aspartic acid, glutamic acid, arginine, alanine, cysteine, glycine, and proline. Barnyard millet is considered as a functional food with beneficial effects on human health. Its intake enhances the immune system, guards against lifestyle diseases, and contributes to overall physical and mental well-being. The existence of alpha-amino butyric acid hinders the growth of cancer cells and lowers blood pressure. The dietary fiber present in millets undergoes fermentation in the colon, producing short-chain fatty acids that support colon health, reduce the likelihood of colon cancer and inflammatory bowel disease, and hinder the synthesis of cholesterol and release of glucose [27]. As per research conducted by Saleh *et al.* [17], barnyard millet typically contains an average carbohydrate content ranging from 51.5 to 62.0 g per 100 g, which is lower when compared to both major and minor millets. Studies by Saleh *et al.*, [17] and Renganathan *et al.*, [26] have indicated that the iron content in barnyard millet grain is around 15.6 to 18.6 mg/100 g, significantly surpassing that of major cereals and millets.

Kodo Millet: Kodo millet (*Paspalum scrobiculatum*), is predominantly grown in the Deccan region of India, with its cultivation extending to the foothills of the Himalayas. This millet variety is distinguished by its rich dietary fiber, significant mineral content, including iron, and antioxidant properties. In comparison to other millets and major cereals, Kodo millet exhibits higher antioxidant potential but lower phosphorus content. It's important to acknowledge that processing methods like parboiling and debranning can influence the mineral and fiber content of kodo millet, albeit they also contribute to the reduction of anti-nutritional factors such as phytate. Within Indian culinary practices, Kodo millet is employed in a range of traditional dishes. It can be utilized independently or in conjunction with other cereal and legume flours to not only augment the nutritional composition but also enhance the flavor and functionality of the preparations. Kodo millet stands out as a highly nutritious grain, providing a viable substitute for rice or wheat. In comparison to primary cereals such as rice, its nutritional profile reveals notably higher levels of protein, fiber, and minerals. Among various millets, kodo millet possesses the least phosphorus content [28, 29]. Additionally, Hegde and Chandra [30] found that kodo millet demonstrates potent DPPH quenching ability, requiring only 18.5µl for 50% quenching. In comparison, Vitamin C and Vitamin E necessitate 0.946µmol/ml and 0.348µmol/ml, respectively, to achieve the same effect (50% DPPH quenching). Kodo millets are recognized for their elevated levels of polyphenols, phosphorus, antioxidants, and phytic acids. Nevertheless, these anti-nutrients can form complexes with essential micronutrients like calcium and zinc, diminishing their solubility and bioavailability. To enhance the availability of amino acids and minerals, as well as improve the digestibility of protein and starch in millet-based foods, recommended techniques include soaking, cooking, and fermentation. The antioxidant efficacy of Kodo millets tends to diminish following the processes of dehulling and cooking the whole grain. They also demonstrated that Kodo millet displays superior free radical scavenging characteristics in comparison to other millet types. Nevertheless, this effectiveness was noted to decline when the husk and endosperm of Kodo millet were separated.

The bran of Kodo millet encompasses roughly 112 µmol ferulic acid equivalents per gram of defatted meal, contributing to its antioxidant attributes. Additionally, the complete Kodo grain exhibited reduced starch and EGI digestibility compared to refined grains [31]. Notably, Remarkably, kodo millet distinguishes itself as a notable fiber source, boasting a 9% content, surpassing rice with 0.2% and wheat with 1.2%. In the realm of macronutrients, kodo millet offers 66.6g of carbohydrates and 353 kcal per 100g of grain, aligning with other millets. It also encompasses 1.4% fat and 2.6% minerals. The iron content in kodo millet falls within the range of 25.86ppm to 39.60ppmaccording to Chandel *et al.*, [32].

Little Millet: Little millet (*Panicum sumatrense*) holds significant importance as a minor cereal in tropical regions, serving as a staple for low-income communities across various countries. This adaptable grain is comparable to major cereals like rice and wheat in its protein, fat, carbohydrate, and crude fiber content. Additionally, it provides essential minerals, vitamins, and beneficial phytochemicals like phenolic acids, flavonoids, tannins, and phytate [33]. Furthermore, it has been observed to reduce fasting blood glucose levels and enhance blood glucose and lipid parameters in individuals with diabetes [34]. Little millets, also known as saamai or kutki, are short-duration millets capable of thriving in both drought and water logging conditions. These annual crops feature a hollow jointed stem, ranging from 30 to 90 cm, with a slender and sturdy base. The linear leaves measure between 15 and 50 cm in length and 12 to 25 cm in breadth, and the nodes are glabrous. Typically sown between June and July or February and March, the seeds have an approximate size of 2.5 x 1.5 mm, a kernel weight of approximately 1.9 g, an oval shape, and a creamy color with a shiny appearance.

Little millet is sometimes referred to as "Cool food" due to its cooling effect on the body when consumed during the summer. Its high fiber content aids in reducing fat deposits in the body and facilitating the movement of food and waste through the digestive system. Little millet surpasses cereals in dietary fiber content (37–38%) and contains more polyunsaturated fatty acids (PUFA). Certain varieties may exhibit a faintly yellowish color, indicative of carotenoid presence, with a total carotenoid content ranging from 51 to 104 µg /100g. Despite its nutritional superiority over cereals, the consumption of little millet remains limited.

Little millet extract demonstrates a total phenolic content (TPC) of 429.9 mg GAE per 100 grams. Nutraceuticals such as resistant starch, phenolics, sterols, lignans, and gamma-aminobutyric acid are also present in little millet. Studies indicate that the significant presence of phytates in little millet contributes positively to health, offering potential benefits such as antidiabetic and anticancer properties, along with antioxidant effects. It also aids in preventing constipation and alleviating various stomach problems [33]. The proximate compositions of little millet exhibit variability among different genotypes. The carbohydrate content ranges from 61.48 to 68.57g/100g, protein content ranges from 6.36 to 9.15g/100g, ash content ranges from 3.15 to 9.07g/100g, fiber content ranges from 5.54 to 7.84g/100g, and fat content ranges from 3.61 to 5.56g/100g [35].

Browntop Millet: Browntop millet (*Brachiaria ramosa*) exhibits versatility, finding multiple applications as a food source for human consumption, forage for animals, feed for birds, and raw material for industries. In regions such as India and Africa, small millets are frequently consumed either in their whole state or as flour, mainly for food and related uses. In the southern region of India, non-shattering varieties of browntop millet are utilized by boiling the whole grains, preparing porridge, kheer (sweet pudding), or unleavened bread and dosa (a type of pancake)., as described by Nesbitt [36]. Browntop millet (BTM) is abundant in minerals, particularly magnesium, recording a notable level of 94.5 mg/100 g, as noted by Kishore *et al*., [37].

Magnesium is pivotal in enhancing the efficacy of insulin and glucose receptors, supporting enzymes involved in carbohydrate digestion, and improving insulin action, as highlighted by Hemamalini *et al.,*[4]. Magnesium aids in alleviating pressure on blood vessels, offering benefits in managing the consequences of myocardial infarction and migraines[38]. Additionally, BTM serves as a substantial source of phosphorus, containing 276 mg per 100 g, according to Kishore *et al.,* [37]. Phosphorus holds vital importance in the composition of every cell in the body, contributing to the mineral structure of bones, and playing a fundamental role as a component of adenosine triphosphate (ATP), the body's energy currency, as highlighted by Hemamalini *et al.* [4] and Singh, S., *et al.,* [39].

BTM features carbohydrate, crude fiber content, fatsand protein. Browntop millet is rich in phytochemicals such as flavonoids, quinones, tannins, and resin [40]. This suggests the appropriateness of grains for storage, impacting their shelf life and various aspects related to their physical, sensory, and functional characteristics. As per the 2011 guidelines from the Food Safety and Standards Authority of India (FSSAI), the moisture content of grains/millets should not surpass 16.0% by weight. Nagaraju *et al.,* [41] conducted a study revealing a moisture content of 11.2 ± 0.16% for BTM on a wet basis. In a study 7.32% moisture content was oserved in BTM [4], while a another research study documented a moisture content range of 3.08-5.99% of [2].

Browntop millet (BTM) is highly nutritious and provides a substantial amount of energy. It serves as a plentiful source of natural fiber, constituting 8.5% of its composition, as indicated by Kishore *et al.*, [37].

The intake of dietary fiber has long been linked to various health advantages, including promoting regular bowel movements and maintaining healthy blood cholesterol and glucose levels. Furthermore, BTM is rich in micronutrients such as iron, calcium, potassium, magnesium, zinc, phosphorus, and B-group vitamins, as emphasized by [42]. A study by Kishore *et al.*, [37]emphasize that browntop millet (BTM) is rich in various minerals, making it a valuable dietary source. In every 100 grams of BTM, it contains approximately 28 mg of calcium, 7.72 mg of iron, 276 mg of phosphorus, 60 mg of potassium, 94.5 mg of magnesium, 1.99 mg of manganese, 7.60 mg of sodium, 2.5 mg of zinc, and 1.23 mg of copper. These mineral contents position BTM as a potential component in diets aimed at preventing and managing certain non-communicable diseases [37]. Study by Niharika *et al.*, [40] identified the presence of flavonoids, tannins, resins, and quinones in browntop millet (BTM). The study also examined the nutritional characteristics and grain yield of 30 different indigenous collections of browntop millet (BTM), scientifically known as *Brachiariaramosa* (L.) Stapf.

Biological Significance: The diverse dietary compounds present in different types of millet, particularly polyphenols, offer a broad spectrum of health advantages. These encompass antimicrobial, antioxidant, antidiabetic, and hypocholesterolemic effects, playing a vital role in preventing diet-related diseases, particularly in rural populations. Chronic diseases like diabetes, heart disease, cognitive issues, and cancer, among others, have been linked to the oxidation of cellular molecules by reactive oxygen and nitrogen species, impacting normal human functions. To counteract this oxidative damage and maintain a healthy physiological balance, various phytochemicals function as dietary antioxidants. Dietary plant polyphenols have garnered significant attention in recent years from health professionals, nutrition scientists, and consumers due to their extensive health benefits, including a reduced risk of cancer, cardiovascular and neurodegenerative diseases, infections, aging, and diabetes. The functional characteristics of Pearl Millet starch, crucial for the food industry and its hypoglycemic effects, rely on the proper composition of starch and amylose, with a particular prominence on gelatinization [43].

Maintaining an optimal quantity of resistant starch (2.8-5.1%) and dietary fiber or non-starch polysaccharides (11.9-13.3%) is essential for controlling starch digestibility, managing cholesterol levels, and promoting bowel health. The protein in Pearl Millet is rich in glutamic acid, which is a non-essential amino acid [44] that serves as a neurotransmitter or a precursor for γ-aminobutyric acid (GABA). Additionally, it has been discovered to alleviate symptoms associated with menopause by mitigating estrogen deficiency. These phenolic compounds exhibit strong anti-inflammatory, antioxidant, and antiproliferative characteristics [45]. Pearl Millet grains contain phytic acid which is an anti-nutritional factor ranging from 0.58 to 1.38% [46], which aids in decreasing the bioavailability of crucial divalent metal ions like manganese, calcium, magnesium, iron, and zinc through chelation [47]. Pearl millet (PM) is abundant in essential minerals such as iron, copper, zinc, potassium, calcium, sodium, magnesium, and phosphorus [48, 45].

Pearl millet exhibits the capacity to function as a reducing agent and can serve as a source of antioxidants to combat the accumulation of detrimental free radicals in the body. It proves to be a valuable dietary inclusion due to its antioxidant content, which helps counteract the build-up of free radicals in the body. The presence of magnesium in pearl millet can aid in the reduction of respiratory problems in asthma patients and can also help alleviate the effects of migraines. Additionally, the fiber content of pearl millet may reduce the occurrence of gallstones by aiding in the reduction of excessive bile in the system, as the insoluble fiber helps to regulate bile levels [49].

Processing of Millets: Processing of millets is necessary because consuming them as uncooked whole seeds can be challenging due to their coarse nature [50]. Millets are processed for suitable consumption, and shelf life, and enhance their nutritive value. The processing involves partially separating or modifying the pericarp, the endosperm rich in starch, and the germ. During the processing, the inedible parts, known as offal, which includes the pericarp, and sometimes the germ is removed and this process, is referred to as dehulling or decortication. The reason millet-based foods are less common than wheat and rice is that millets are difficult to work with, have a unique flavour, and are harder to get in processed forms that resemble rice and wheat. Due to the lack of well-established machines producing white products from coloredmillet has become challenging. Decortication, often performed using rice dehullers or other abrasive dehullers, leads to a decrease in total lysine and protein content but improves the remaining protein's usability [51]. The loss of minerals during decortication is minimal. Furthermore, decortication enhances consumer acceptability and nutrient availability. Millets, in their processed or unprocessed form, can be used as traditional or novel foods by cooking them either whole or decorticated, or by converting them into flour using industrial or traditional methods. However, alternative uses for millets need to be explored. Unlike wheat flour and rice flour, millet flours do not contain gluten, hence they cannot form an elastic, cohesive, and expansive dough when combined with water. Consequently, utilising millets to make processed foods that are ready to eat or serve is known as fortification. Combining malted finger millet weaning meal (70%) with 30% green gram is one option; this combination offers low viscosity and high energy density. Inedible grains undergo processing to transform them into consumable forms while enhancing their quality for efficient use as food. The flour can be combined with other flours to create simple or complex food products such as soft and stiff porridges. Millets can be processed into flour, porridges, popped grains, salted ready-to-serve grains, sprouted cereals, roasted foods, and malted foods. Primary processing of millets such as cleaning, dehulling, sorting, polishing/pearling, grading, size reduction /grinding, drying, and storage by producers or in the vicinity of farms enhance the quality of grains and transform them into more useful forms [64].

Mechanical Processing Methods:

Dehulling or Decortication: Decorticated by hand pounding at the domestic level nowadays with slight modifications are milled using rice milling machinery. The texture of the endosperm is hardened through hydrothermal treatment, enabling decortication. Bioaccessibility of iron (26g/100g), zinc (24g/100g), and calcium 15g/100g will get enhanced by decortication while it decreases the total mineral content [52]. Additionally, protein digestibility increases, while dietary fiber, polyphenols, total phytic acid, and tannin levels significantly decrease. Although decortication may reduce certain nutrients such as fiber and minerals, it is carried out to enhance the appearance, edibility, and sensory properties of millet foods. The main step in the refinement of millet grains is milling, which divides the grain's anatomical components to create a food that is edible [53].

Milling: Milling is a common process that involves removing the bran, including the pericarp, seed coat, nucellar epidermis, and aleurone layer. Flour made from finger millet seeds and whole meal is commonly used in various food products after the removal of seed coat after crushing and sieving. This process allows the bran to toughen and reduce friability without affecting the qualities of the endosperm. The roller flour mill is suitable for obtaining fully refined millet flour. In the case of other small millets, milling involves the removal of husk and bran and sometimes grinding, depending on the desired outcome. Traditional methods such as the hand-operated pestle or denki method are used for dehusking and debranning whereas rice milling machines, such as the centrifugal sheller and disc huller, are used for milling small millets. Dehusking of millets was carried out using a plate mill method. Pulverization yielded semolina or flour. Composite flours can be produced by milling small millets and mixing them with wheat and other cereals. The bran obtained from milling millets can be combined with rice bran as an extender for oil extraction, as millet bran typically contains 15-20% oil. However, the presence of bran may lead to faster rancidity, thereby decreasing the palatability of the product while milling there may be a reduction in the nutritive content of cereal grains [54].

Traditional and Bioprocess Methods:

Germination and Malting: Grain germination and malting have been found to result in biochemical modifications that improve the nutritional quality of malt, making it suitable for various recipes. On germination proso millet has shown an increase in free amino acids and total sugars, while there was a decrease in dry weight and starch. Pearl millet had an vitro protein (14% to 26%) and starch (86% to 112%) digestibility through germination, surpassing the effects of blanching (Archana *et al.*, 2001). Protein digestibility was found to be increased with decrease in antinutrients such as polyphenols, phytic acid and tannins [55]. However, germination has shown varying effects on different millet varieties. Because of the oxidation of fatty acids during germination and the hydrolysis of lipids during soaking and rinsing, as well as the loss of nitrogenous substances, it was discovered that the crude protein and fat contents of foxtail millet decreased. However, the germination of pearl millet and finger millet resulted in a decrease in antinutritional elements like phytic acid and an increase in the extractability and bioaccessibility of minerals like calcium, iron, and zinc. Pearl millet malt has shown advantages for larger beer brewing compared to sorghum due to higher beta-amylase activity and free α-amino nitrogen. Finger millet, in its native or malted form, can be used as a source of dietary fiber in various health food preparations without compromising dough characteristics or end product quality [56].

In addition, the combination of germination and fermentation has shown promising results. Germination along with the fermentation of pearl millet reduced phytic acid significantly in instant fura, a Nigerian cereal food. Improved nutritional contents, such as thiamine, niacin, total lysine, protein fractions, carbohydrates, soluble dietary fibre, and in vitro availability of calcium, iron, and zinc, were seen in diets derived from germinated and probiotic-fermented pearl millet [57]. The increasein mineral availability during germination can be due to the increased phytase activity and the breakdown of antinutrients like polyphenols and saponins. Germination of foxtail millet exhibited a high concentration of minerals in the millet flour [58]. Overall, germination and malting of millet offer the potential for enhancing the nutrients and digestibility of various food products, including infant and complementary foods, and composite flours. However, further research and industrial-scale application of malting techniques are needed to promote the widespread utilization of millets and ensure high-quality malt products.

Fermentation and Enzymatic Hydrolyzation: Fermentation is widely utilized in Africa as a means of food preservation and flavor enhancement, particularly in regions where modern food preservation methods are not prevalent. It not only helps in preserving food products but also significantly enhances their nutritional properties. Fermented foods have global importance due to their value in human nutrition. Fermentation brings about chemical modifications in millet grains and their food products. Thus, they are commonly employed for the production of diverse traditional fermented foods in developing countries [59]. Fermentation plays a vital role in reducing antinutrients, improving protein availability, in vitro protein digestibility (IVPD), and nutritional value. According to research, processing pearl millet grains through fermentation greatly lowers antinutritional factors and increases IVPD [60]. This is because the fermentation process partially breaks down complex storage proteins into simpler, more soluble molecules. Fermentation of millet grains into ogi, resulted in reduced chemical components except starch while increasing starch and protein digestibility compared to the original grain.

During fermentation, pearl millet undergoes notable changes in its chemical composition, including moisture, ash, fiber, protein, and fat contents. However, fermentation leads to a reduction in mineral content such as Na, K, Mg, Cu, Fe, Mn, and Zn). Fermentation also enhances crude protein while reducing fat and crudefiber in fermented-cooked food. However, the effect of fermentation on the extractability of minerals in finger millet appears to be smaller or insignificant. A 24-hour fermentation of pearl millet showed no significant change in protein and lipid contents, a decrease in carbohydrate content, an increase in soluble sugars, and a decrease in glycine, lysine, and arginine contents. Fermentation also led to a reduction in trypsin and amylase inhibitor activities and phytic acid content, but an increase in tannin content. Higher protein efficiency ratios, feed efficiency ratios, apparent and true protein digestibilities, net protein retention, net protein utilisation, protein retention efficiency, and utilisable protein values were demonstrated by pure-culture fermentation of pearl millet flour [61]. Additionally, it was discovered that lactobacilli and yeast worked better together than pure culture fermentation to increase the digestibility of protein and starch. The breakdown of tannins, polyphenols, and phytic acid by microbial enzymes is responsible for this improvement in protein digestibility. Fermentation and enzymatic hydrolysis are promising techniques for producing fermented food products with high nutritive value from millet grains. These methods can be used individually or in combination with other techniques. However, their industrial application for commercial-scale production of millet food products is limited, with most applications occurring at the household level or in laboratory settings. There is a need for further research and the use of modern equipment under optimized conditions to facilitate the production of high-quality and safe millet food products on a larger scale. This includes the production of fermented beverages and millet fractions rich in functional components for therapeutic purposes and large-scale food production [65].

Popping or Puffing: Popping or puffing is a traditional method of food processing used to prepare expanded cereals and grain legumes, creating ready-to-eat products. Studies have shown that both traditional methods like popping and flaking, as well as methods like roller-drying and extrusion-cooking, can be successfully applied In the case of decorticated finger millet, a high-temperature short-time treatment was employed to produce expanded millet, a new-generation ready-to-eat product. It was found that achieving the desired shape and moisture content were crucial factors in obtaining millet with maximum expansion ratio.

It should be mentioned, nevertheless, that popping the foxtail millet produced far lower levels of crude fat and crude fibre when compared to raw millet, but much larger levels of carbohydrates and calories. The primary cause of this discrepancy is the higher fibre and fat levels in the grain's outer coat, which are more impacted by processing than the nutrients in the inner layer [62]. To promote the utilization of millet grains, novel technologies, and optimized puffing conditions can be employed, either as standalone strategies or in combination with other pretreatments, to produce ready-to-eat expanded products from millet grains on a commercial scale.

Soaking and Cooking: Soaking of grains is a widely used food preparation technique aimed at reducing anti-nutritional compounds, such as phytic acid, to improve the bioavailability of minerals. Several studies have investigated the effects of soaking on the degradation and leaching of phytates, phytase activity, and minerals in millet seeds and flours. In the case of pearl millet, soaking, milling and cooking grains resulted in a 25% loss of iron but also promoted the degradation of endogenous phytates and decrease in zinc content when cooked with kanwa. When pearl millet was soaked in acid, mineral contents, especially phosphorus, calcium, and iron, were reduced. However, HCl-extractability, indicates the bioavailability of minerals. Irradiation alone had no effect on tannin and phytate contents in pearl millet, but when followed by cooking, it significantly reduced the levels of antinutrients in both whole and dehulled flour.

Irradiation alone had no impact on protein digestibility but slightly improved the quality attributes of the millet cultivars. However, irradiation followed by cooking significantly reduced protein digestibility while still improving quality attributes [63]. Furthermore, simple processing techniques such as dehulling, soaking, and cooking of foxtail millet led to a significant decrease in antinutrients like polyphenols and phytate. Germination is a commonly used technique in legumes and cereals aimed at enhancing their taste and nutritional content by facilitating the degradation of antinutrients like protease and phytate inhibitors [66]. This processing also improved the bioavailability of minerals such as iron and zinc enhanced protein digestibility *in-vitro*. In summary, soaking and cooking of millet grains can be utilized as pretreatments under optimized conditions to reduce antinutrient content in millet grains. This approach enhances the bioavailability of nutrients and improves the nutritional quality of millet food products.

CONCLUSION: In conclusion, millets stand as a nutritional powerhouse with immense potential to address pressing global food and nutrition concerns. Millet contains large amounts of protein, fiber, minerals, and phytochemicals. Anti-nutrients such as phytic acid and tannins in this millet can be reduced to negligible levels by proper processing methods. Millet has also been reported to have hypolipidemic, low glycemic index, and antioxidant properties. Their adaptability to diverse environments, sustainable cultivation, and rich nutritional profile make them a sustainable and healthful choice. As a source of vital nutrients, millets can play a significant role in improving diets and combating malnutrition. Moreover, their low environmental footprint and resilience to adverse conditions make them a beacon for sustainable agriculture in the period of climate uncertainty. It is reasonable to assume that millet has a promising role in improving nutrition and food security. By recognizing the value of millets, we can not only enhance food security but also support environmentally responsible farming practices for a healthier and more resilient future.

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REFERENCES:

1. Shahidi F and Chandrasekara A: Millet Grain Phenolics and Their Role in Disease Risk Reduction and Health Promotion: A Review. J Funct Foods 2013; 5(2): 570-581.
2. Saini S, Saxena S, Samtiya M, Puniya M and Dhewa T: Potential of underutilized millets as Nutri-cereal: an overview. J Food Sci Technol 2021; 58(12): 4465–4477. doi: 10.1007/s13197-021-04985-x
3. Sharma R, Sharma S, Dar BN and Singh B: Millets as potential nutri-cereals: a review of nutrient composition, phytochemical profile and techno-functionality. Int J Food Sci Technol 2021; 56(8): 3703-3718.
4. Hemamalini C, Sam S and Patro TSSK: Awareness and consumption of small millets. Pharma Innov J 2021; 10: 34-37.
5. Rani S, Singh R, Sehrawat R, Kaur BP and Upadhyay A: Pearl millet processing: A Review. Nutr Food Sci 2018; 30–44. doi: 10.1108/NFS-04-2017-0070
6. Lydia Pramitha J, Ganesan J, Francis N, Rajasekharan R and Thinakaran J: Revitalization of small millets for nutritional and food security by advanced genetics and genomics approaches. Front Genet 2023; 13: 1007552. doi: 10.3389/fgene.2022.1007552
7. Makuvara Z: Millets (pearl and finger) as nutritional interventions for COVID 19 with focus on Zimbabwe: mini review. Cogent Food Agric 2022; 8(1).
8. Wankhede DB, Shehnaj A and Raghavendra Rao MR: Carbohydrate composition of finger millet (Eleusinecoracana) and foxtail millet (*Setaria italica*). Qualitas Plantarum 1979; 28: 293-303.
9. Dayakar Rao B, Bhaskarachary K, Arlene Christina GD, Sudha Devi G, Vilas AT and Tonapi A: Nutritional and health benefits of millet. ICAR_Indian Institute of Millets Research (IIMR), Rajendranagar, Hyderabad 2017; 112: 33.
10. Odusola KB, Ilesanmi FF and Akinloye OA: Assessment of nutritional composition and antioxidant ability of pearl millet (*Pennisetum glaucum*). Am J Res Commun 2013; 1(6): 262-272.
11. Morya GC, Vinita V, Mishra HS, Shakya S, Bahadur R and Yadav KN: Millets: the indigenous food grains. Int J Adv AYUSH 2017; 6(1): 447-452.
12. Krishnan R and Meera MS: Pearl millet minerals: effect of processing on bioaccessibility. J Food Sci Technol 2018; 55(9): 3362–3372.
13. Al-Abdullatif A, Hussein E, Suliman G, Akasha M, Al-Badwi M, Ali H and Azzam M: Evaluating rice bran oil as a dietary energy source on production performance, nutritional properties and fatty acid deposition of breast meat in broiler chickens. Foods 2023; 12(2): 366.
14. Sharma N and Niranjan K: Foxtail millet: Properties, processing, health benefits, and uses. Food Rev Int 2018; 34(4): 329-363.
15. Sachdev N, Goomer S and Singh LR: Foxtail millet: a potential crop to meet future demand scenario for alternative sustainable protein. J Sci Food Agric. 2021; 101(3): 831–842. doi: 10.1002/jsfa.10716
16. Yang X, Wan Z, Perry L, Lu H, Wang Q and Zhao C: Early millet use in northern China. Proc Natl Acad Sci. 2012; 109(10): 3726-3730.
17. Saleh AS, Zhang Q, Chen J and Shen Q: Millet grains: nutritional quality, processing, and potential health benefits. Compr Rev Food Sci Food Saf 2013; 12: 281–295.
18. Chandra D, Chandra S and Sharma AK: Review of Finger millet (*Eleusine coracana* (L.) Gaertn): a powerhouse of health benefiting nutrients. Food Sci Hum Wellness 2016; 5(3): 149-155.
19. Maharajan T, Antony Ceasar S, Ajeesh Krishna TP and Ignacimuthu S: Finger Millet [*Eleusine coracana* (L.) Gaertn]: An Orphan Crop with a Potential to Alleviate the Calcium Deficiency in the Semi-arid Tropics of Asia and Africa. Front Sustain Food Syst 2021; 5: 684447. doi: 10.3389/fsufs.2021.684447
20. Kalsi R, Sakra A, Modak A and Choudhary B: Overview on Nutritional and Phytochemical Composition of Finger Millet (*Eleusine coracana*): A Review. Int J Environ & Agric Res 2022; 8(2): 30-35.
21. Abreha KB, Enyew M, Carlsson AS, Vetukuri RR, Feyissa T and Motlhaodi T: Sorghum in dryland: morphological, physiological, and molecular responses of sorghum under drought stress. Planta 2021; 255(1): 20. doi: 10.1007/s00425-021-03799-7
22. Abah CR, Ishiwu CN, Obiegbuna JE and AA: Sorghum grains: nutritional composition, functional properties, and its food applications. Eur J Nutr Food Safety 2020; 12(5): 101-111.
23. Tanwar R, Panghal A, Chaudhary G, Kumari A and N: Nutritional, phytochemical and functional potential of sorghum: A review. Food Chem Adv 2023; 3: 100501.
24. Kaur H and Sharma S: An overview of Barnyard millet (*Echinochloa frumentacea*). J Pharmacogn Phytochem 2020; 9(4): 819-822.
25. Krishna Kumari S and Thayumanavan B: Characterization of starches of proso, foxtail, barnyard, kodo, and little millets. Plant Foods Hum Nutr 1998; 53: 47-56.
26. Renganathan VG, Vanniarajan C, Karthikeyan A and Ramalingam J: Barnyard Millet for Food and Nutritional

Security: Current Status and Future Research Direction. Front Genet 2020; 11: 500.

27. Singh A, Bharath M, Kotiyal A, Rana L and Rajpal D: Barnyard millet: the underutilized nutraceutical minor millet crop. J Pharm Innov 2022; 11(6): 115-128.
28. Deshpande SS, Mohapatra D, Tripathi MK and Sadvatha RH: Kodo millet-nutritional value and utilization in Indian foods. J Grain Process Storage 2015; 2(2): 16-23.
29. Bunkar DS, Goyal SK, Meena KK and Kamalvanshi V: Nutritional, Functional Role of Kodo Millet and its Processing: A Review. Int J Curr Microbiol App Sci 2021; 10(01): 1972-1985.
30. Hegde P and Ts C: ESR spectroscopic study reveals higher free radical quenching potential in kodo millet (*Paspalums crobiculatum*) compared to other millets. Food Chem 2005; 92.
31. Morya GC, Vinita V, Mishra HS, Shakya S, Bahadur R and Yadav KN: Millets: the indigenous food grains. Int J Adv AYUSH 2017; 6(1): 447-452.
32. Chandel G: Nutritional properties of minor millets: neglected cereals with potentials to combat malnutrition. Curr Sci 2014; 107(7): 1109-1111.
33. Dey S, Saxena A, Kumar Y, Maity T and Tarafdar A: Understanding the antinutritional factors and bioactive compounds of kodo millet (*Paspalums crobiculatum*) and little millet (*Panicum sumatrense*). J Food Qual 2022; 1-19.
34. Nithiyanantham S, Kalaiselvi P, Mahomoodally MF, Zengin G, Abirami A and Srinivasan G: Nutritional and functional roles of millets—A review. J Food Biochem 2019; 43(7): 12859.
35. Ganapathy KN: Genetic improvement in little millet. In: Millets and sorghum: biology and genetic improvement. 1st ed. Springer 2017; 170-183.
36. Nesbitt MG. In: The Cultural History of Plants. Prance G and Nesbitt MG: eds. Routledge Press 2005; 45-60.
37. Kishore AS, Rekha KB, Hussain SA and Madhavi A: Quality enhancement of nutri-cereal BTM through agronomic practices. Curr Sci 2021; 120: 468–470.
38. Ashoka P, Gangaiah B and Sunitha N: Millets-foods of twenty first century. Int J Curr Microbiol Appl Sci 2020; 9: 2404–2410. doi:10.20546/ijcmas.2020.912.285.
39. Singh S, Suri S and Singh R: Potential and unrealized future possibilities of browntop millet in the food sector. Front Sustain Food Syst 2022; 6: 974126.
40. Niharika V, Rao BG, Tushara M and Rao VS: Studies on performance of browntop millet indigenous collections for grain yield and nutritional traits. J Pharmacogn Phytochem 2020; 9: 2636–2638.
41. Nagaraju M, Ramachandra M, Nagarathna SB, Kalpana B, Palanimuthu V and Darshan MB: Physical properties of an underutilized crop: BTM (Urochloaramosa). Int J Chem Stud 2020; 8: 192–197.
42. Sarita ES and Singh E: The potential of millets: nutrients composition and health benefits. JSIR 2016; 5(2): 46-50.
43. Anberbir SM, Satheesh N, Abera AA, Kassa MG, Tenagashaw MW, Asres DT, Tiruneh AT, Habtu TA, Sadik JA, Wudineh TA and Yehuala TF: Evaluation of nutritional composition, functional and pasting properties of pearl millet, teff, and buckwheat grain composite flour. Appl Food Res 2024; 4(1):100390. doi: 10.1016/j.afres.2024.100390.
44. Sharma B, Chugh LK, Singh VK, Singh V and Sood M: Determination of major antinutritional factors in *Pennisetum glaucum* L. and their relationship with protein and content yield. Bangladesh J Bot 2020; 49(2): 401-405. doi: 10.3329/bjb.v49i2.49322.
45. Kumar M, Tomar M, Punia S, Dhakane-Lad J, Dhumal S, Changan S, Senapathy M, Berwal MK, Sampathrajan V, Sayed AAS, Chandran D, Pandiselvam R, Rais N, Mahato DK, Udikeri SS, Satankar V, Anitha T, Reetu, Radha, Singh S, Amarowicz R and Kennedy JF: Plant-based proteins and their multifaceted industrial applications. LWT 2022; 154: 112620. doi: 10.1016/j.lwt.2021.112620.
46. Boncompagni E, Orozco-Arroyo G, Cominelli E, Gangashetty PI, Grando S, Zu TTK, Daminati MG, Nielsen E and Sparvoli F: Antinutritional factors in pearl millet grains: Phytate and goitrogens content variability and molecular characterization of genes involved in their pathways. PLoS One 2018; 13(6): e0198394. doi: 10.1371/journal.pone.0198394. PMID: 29856884; PMCID: PMC5983567.
47. Marathe SK, Vashistht MA, Prashanth A, Parveen N, Chakraborty S and Nair SS: Isolation, partial purification, biochemical characterization and detergent compatibility of alkaline protease produced by *Bacillus subtilis*, *Alcaligenes faecalis* and *Pseudomonas aeruginosa* obtained from sea water samples. J Genet Eng Biotechnol 2018; 16(1): 39-46. doi: 10.1016/j.jgeb.2017.10.001. Epub 2017 Oct 12.
48. Krishnan R and Meera MS: Pearl Millet Minerals: Effect of Processing on Bioaccessibility. J Food Sci Technol 2018; 55: 3362-3372.
49. Ambati K and Sucharitha KV: Millets-review on nutritional profiles and health benefits. Int J Recent Sci Res 2019; 10(7): 33943-33948.
50. Priya, Verma RK, Lakhawat S, Yadav VK, Gacem A, Abbas M, Yadav KK, Park HK, Jeon BH and Mishra S: Millets: sustainable treasure house of bioactive components. Int J Food Prop 2023; 26(1): 1822-1840. doi: 10.1080/10942912.2023.2236317.
51. Birania S, Rohilla P, Kumar R and Kumar N: Post-harvest processing of millets: A review on value added products. Int J Chem Stud 2020; 8(1): 1824-9.
52. Jaybhaye RV and Pandari MA: Processing and technology for millet based food products: A review. Agric Food Sci 2014.
53. Sachdev N, Goomer S, Singh LR, Pathak VM, Aggarwal D and Chowhan RK: Current status of millet seed proteins and its applications: A comprehensive review. Appl Food Res 2023; 3(1): 100288. doi: 10.1016/j.afres.2023.100288.
54. Devisetti R, Yadahally SN and Bhattacharya S: Nutrients and antinutrients in foxtail and proso millet milled fractions: Evaluation of their flour functionality. LWT - Food Sci Technol 2014; 59(2P1): 889-895. doi: 10.1016/j.lwt.2014.07.003.
55. Wiedemair V, Scholl-Bürgi S and Karall D: Amino acid profiles and compositions of different cultivars of *Panicum miliaceum* L. Chromatographia 2020; 83: 829–837. doi: 10.1007/s10337-020-03899-8.
56. Choudhary M and Sahoo U: Importance of millets as nutri-cereals for nutrition purpose in present scenario: A review. Indian J Nat Sci 2022; 13(72): 44516-44522.
57. Arora VK, Singh CB, Sidhu AS and Thind SS: Irrigation, tillage and mulching effects on soybean yield and water productivity in relation to soil texture. Agric Water Manage 2011; 98(4): 563-568.
58. Coulibaly A, Kouakou B and Chen J: Phytic acid in cereal grains: Structure, healthy or harmful ways to reduce phytic acid in cereal grains and their effects on nutritional quality. Am J Plant Nutr Fertil Tech 2011; 1: 1-22.
59. Narayanasamy S: Efficacy of fermentation parameters on protein quality and microstructural properties of processed

finger millet flour. J Food Sci Technol 2021; 58(8): 3223-3234.

60. Sharma B and Gujral HS: Influence of nutritional and antinutritional components on dough rheology and *in-vitro* protein & starch digestibility of minor millets. Food Chem 2019; 299: 125115.
61. Samuel KS and Peerkhan N: Pearl millet protein bar: Nutritional, organoleptic, textural characterization, and *in-vitro* protein and starch digestibility. J Food Sci Technol. 2020; 57(9): 3467-3473.
62. Saraswathi R and Hameed RS: Value addition influenced in millet products - A review. Austin J Nutri Food Sci 2022; 10(1): 1161.
63. ElShazali AM, Nahid AA, Salma HA and Elfadil EB: Effect of radiation process on antinutrients, protein digestibility and sensory quality of pearl millet flour during processing and storage. Int Food Res J 2011; 18(4): 1401-1407.
64. Yousaf L, Hou D, Liaqat H and Shen Q: Millet: A review of its nutritional and functional changes during processing. Food Researc.
65. Kumari R, Bhatt S, Agrawal H, Dadwal V and Gupta M: Effect of fermentation conditions on nutritional and phytochemical constituents of pearl millet flour (*Pennisetum glaucum*) using response surface methodology. Appl Food Res 2022; 2(1): 100055.
66. Bhuvaneshwari G, Nirmalakumari A and Kalaiselvi: Impact of soaking, sprouting on antioxidant and anti-nutritional factors in millet grains. J Phytol 2020; 12: 62-66.

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