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## A review on phytochemistry, health benefits and side effects of flaxseed, finger millet and pearl millet

**Kushmitha RG****Abstract**

Millet is an important cereal grain that is consumed by more than one-third of the world's population and stands in sixth position as a cultivated cereal crop in terms of world agricultural production. It is a highly nutritious food that comprises 60-70% carbohydrates, 12-20% dietary fiber, 6-19% protein, 2-4% minerals, 1.5-5% fat, and other beneficial phytochemicals such as phenolic acids and flavonoids. Millets are also a potential source of essential amino acids, making them a valuable addition to a healthy diet. Phenolic acids such as chlorogenic acid, ferulic acid, gallic acid, protocatechuic acid, and flavonoids such as kaempferol and quercetin are present in millet in significant amounts. These compounds are known for their anti-cancer, anti-diabetic, anti-inflammatory, antioxidant, and anti-oxidative properties, which make millet an ideal food for promoting health and wellbeing. Flaxseed, on the other hand, is considered a "superfood" due to its high concentration of essential nutrients such as lignans, omega-3 fatty acids, dietary fiber, vitamins, and minerals. It is an excellent source of plant-based protein and healthy fats, making it a popular choice among health-conscious individuals. Flaxseeds have three types of phenolic compounds, including phenolic acids, flavonoids, and lignan, which provide numerous health benefits. Additionally, finger millet and pearl millet have various industrial applications, making them valuable crops for economic development. However, antinutrients such as phytic acid, polyphenols, and tannins hinder the biofortification of millet, and strategies to reduce their levels need to be developed to increase the nutritional value of millet.

**Keywords:** Millets, finger millet, pearl millet, flaxseed, nutritional value, phytochemicals

**1. Introduction**

Nutritional value of food is an important factor for the overall health and well-being of a consumer striving for a healthy lifestyle. Millet is considered as one of the most important cereal grains and is consumed by more than one-third of the world's population. It stands in sixth position as a cultivated cereal crop in terms of world agricultural production (Kimbonguila *et al.*, 2019) <sup>[46]</sup>. Millets are said to be the "future crops" because of their ability to endure most pests and diseases and thrive in the tough conditions found in Asia and Africa's arid and semi-arid regions (Nanje Gowda *et al.*, 2022) <sup>[60]</sup>. The diverse range of millet varieties grown forms an important part of the ecological succession for many small-scale and traditional farmers, serving a crucial function in their agricultural practices, nourishment, lifestyle and cultural heritage (Annor *et al.*, 2014) <sup>[9]</sup>. Millet is small, seeded grains and belongs to the poaceae family thus it is categorized into major and minor millets. Major millet includes finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), Porso millet (*Panicum miliaceum*) and minor millet includes little (*Panicum sumatrense*), barnyard (*Echinochloa esculenta*) and kodo (*Paspalum Scrobiculatum*) that could be utilized as a source of food, feed, and fodder in many countries (Kimbonguila *et al.*, 2019) <sup>[46]</sup>. These are nutritious and superior to several other major cereal grains. They contain abundant dietary fiber, antioxidants, gluten-free proteins, biologically active compounds and have a low glycemic index (Joshi *et al.*, 2021) <sup>[42]</sup>. Millet-derived foods have the potential to function as prebiotics and probiotics, providing health benefits, and are commonly used as traditional medicines. They are also an essential component of a healthy diet (Nithiyantham *et al.*, 2019) <sup>[63]</sup>. Since millets are free of gluten, they can alleviate the symptoms of gluten related disorders (GRD) such as Celiac disease (CD), wheat allergy (WA) and non-celiac gluten sensitivity (NCGS) or wheat intolerance syndrome (WIS) (Valenti *et al.*, 2017) <sup>[91]</sup>. According to the estimation global prevalence of gluten-related disorder is approximately about 5% (Taraghihah *et al.*, 2020) <sup>[88]</sup>. Finger millet (*Eleusine coracana*) ranks fourth globally in terms of production (Mbindha *et al.*, 2021) <sup>[55]</sup>.

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Pearl millet (*Pennisetum glaucum*) is ranked sixth among the world's major cereal crops and is extensively grown (Srivastava *et al.*, 2020) [87]. These are highly nutritious foods that are non-acidic, non-glutinous, and contain numerous nutraceuticals, high fiber content as well as health-promoting properties (Satyavathi *et al.*, 2021) [77]. Finger millet is considered the richest source of calcium, containing 10 times more calcium than wheat, maize, and rice, and three times greater calcium than milk (Jagati *et al.*, 2021) [39].

Pearl millet is a highly nutritious grain, apart from that it also contains 74% polyunsaturated fatty acids (PUFAs) and is particularly rich in sought-after omega-3 fatty acids such as oleic acid (25%), linoleic acid (45%), and linolenic acid (4%). These fatty acids are known to be beneficial for health. Moreover, they can also serve as a superior alternative to commercially used starch sources, such as corn, wheat, rice, and potato (Punia *et al.*, 2021) [68]. consumption of a variety of millet protects against some cancers, cardiovascular diseases, hypertension, diabetes, and age-related disorders (Rao *et al.*, 2017) [23]

Flaxseed (*Linum usitatissimum*) is also known as Linseed that belongs to the Liliaceae family. It is cultivated in various

regions of the world; Canada is the topmost country in the production of flaxseed (Parikh *et al.*, 2018) [66]. This is an annual crop grown for oil, fibre, food, and feed purposes. Flaxseed is considered a "superfood" due to its high concentration of essential nutrients like lignans, omega-3 fatty acids, dietary fiber, vitamins, and minerals (Nowak *et al.*, 2023) [64]. The significance of this crop has greatly improved in the modern world because of its exceptional nutritive content with a strong biological activity that has made its use possible in various applications such as functional foods, health supplements, and skincare products (Deng, 2022) [27].

In addition to having a rich concentration of micronutrients, millet grains also contain significant levels of other beneficial Table 2: Nutritional composition of millets and flaxseed per 100g substances such as bound phenolic acids, free phenolic acids, flavonoids, lignin, insulin-resistant starch, and  $\beta$ -glucan (Rasouli *et al.*, 2017) [72]. The aim of this article is to give an overview of the nutritional composition, phytochemical constituents, millet and flaxseed-based food products studies. in the given table 1 shows the scientific name and common name and region of origin of different millets.

**Table 1:** Scientific name of different millets and with their region of origin

Common name	Scientific name	Region of origin	Reference
Finger millet, Ragi, Tamba	<i>Eleusine coracana</i>	Nepal, Sri Lanka, Bhutan, Himalayan regions of India, Africa	(Ramashia <i>et al.</i> , 2019) [70]
Pearl millet, Bajra	<i>Pennisetum glaucum</i> (L.)	Asia, Africa	(Punia <i>et al.</i> , 2021) [68]
Foxtail millet, Bhavaja, Priyaguka, Rajika	<i>Setaria italica</i>	China, southern Europe, India	(Sachdev <i>et al.</i> , 2021) [76]
Proso millet	<i>Panicum miliaceum</i> L	Asia, Australia, Europe	(W. Li <i>et al.</i> , 2021) [50]
Kodo millet, Araka, Cow grass, Ditch millet	<i>Paspalum scrobiculatum</i> L.	India, China, Russia, Japan, Africa	(Bunkar, 2021) [16]
Little millets/ Saamai, Kutki	<i>Panicum sumatrense</i>	tropical Africa, Eastern and Southern Europe, India	(Dey <i>et al.</i> , 2022) [28]

## 2. Nutritional composition

### Millet

Millets are potential source of both macronutrients and micro nutrients and essential amino acid (Sharma *et al.*, 2021) [81]. Millets are a highly nutritious food and comprises of 60-70% carbohydrates, 12-20% dietary fiber, 6-19% protein, 2-4% minerals, 1.5-5% fat, and other beneficial phytochemicals.

### Flaxseed

Flaxseed also contains several bioactive plant substances

including oil, protein, dietary fiber, soluble polysaccharides, lignans, phenolic compounds, and vitamins, making it a complex mixture of components. It also has the potential to extend health benefits for three primary reasons. Firstly, it is an excellent source of omega-3 alpha-linolenic acid. Secondly, it is rich in both soluble and insoluble dietary fibers. Thirdly, it contains a high level of lignans, which act as antioxidants and phytoestrogen (Morris 2007) [98]

In the given table 2 depicted the nutritional value of finger millet, pearl millet and flaxseed per 100 g.

**Table 2:** Nutritional composition of millets and flaxseed per 100 g

Millets	Energy (kcal)	Fat (g)	Ash (g)	Crude fibre (g)	Carbohydrate (g)	Protein (g)	Calcium (mg)	Iron (mg)	Riboflavin (mg)	Thiamin (mg)	Niacin (mg)	Reference
Flaxseed	450	37.1	3.67	10.77	28.9	20.3	230.88	5.13	0.07	0.23	1.0	(Kajla <i>et al.</i> , 2014; Noreen <i>et al.</i> , 2023) [4, 101]
Finger millet	336	1.20	3.10	3.73	71.23	9.10	350	4.56	0.19	0.42	1.1	(Arachchige & Jayawardana, 2019; Jan <i>et al.</i> , 2022) [10, 40]
Pearl millet	361-363	4.8-5	2.3	11.3	67-67.5	11.6-11.8	42	8	0.25	0.33	2.3	Ramashia <i>et al.</i> , 2019) [70]

## 3. Phytochemical constituents

Millet is rich in phytochemicals, which are natural, plant-based, active organic compounds that play a significant role in fighting against diseases and promoting health. By analyzing these phytochemicals, we can identify bioactive substances that influence disease by prevention due to their antioxidant, antidiabetic, cardiovascular disease, anti-cancer, anti-microbial, anti-tumor and antibacterial properties (Mounika *et al.*, 2022) [57]. Around 60% of the phenolic acids in millet are

in the form of conjugated compounds, while the remaining are either free or extractable form. These millets include phytochemical compounds such as phenolic acids - chlorogenic acid, ferulic acid, gallic acid, protocatechuic acid and flavonoids include kaempferol, quercetin. (Sharma *et al.*, 2021) [81].

Flaxseed is a significant seed crop grown globally (Yasmeen *et al.*, 2018) [94]. It is a major source of functional food or components. Alpha-linolenic acid (ALA) is one of the

primary bioactive components (Parikh *et al.*, 2019). Flaxseed is effective in reducing the risk of cardiovascular diseases such as atherosclerosis or ischemic heart disease because of its high content of these compounds. There are a substantial number of phenolic compounds, which are well-known for their anti-cancer, anti-diabetic, anti-inflammatory, antioxidant, and anti-oxidative properties. Flaxseeds have three types of phenolic compounds, including phenolic acids, flavonoids, and lignan.

### Phenols

The main phenolic acids in this two millet and flaxseed include chlorogenic acid, ferulic acid, gallic acid, protocatechuic acid (Xiang *et al.*, 2019) [99]. According to (Leitzmann *et al.*, 2016) [49] this phenolic acid contains antidiabetic, anti-obesity, antioxidant, anti-inflammatory, antihypertension, antimicrobial, neuroprotection, and anticancer properties.

Chlorogenic acid has been shown to possess anti-inflammatory, anti-diabetic, anti-cancer and anti-virus supported by considerable evidence (Naveed *et al.*, 2018) [61]. It exhibits anti diabetic properties studies shown that Chlorogenic acid administered by gavage reduces fasting blood glucose and increases muscle glycogen levels. CGA inhibits  $\alpha$ -glucosidase and  $\alpha$ -amylase in a dose-dependent manner, potentially reducing postprandial hyperglycemia by limiting the activity of salivary and pancreatic  $\alpha$ -amylase and delaying glucose absorption through inhibition of intestinal brush border enzyme  $\alpha$ -glucosidase. (Liang & Kitts, 2015) [51] a study conducted on murine RAW 264.7 macrophages revealed that CGA has anti-inflammatory properties. This is carried out by reducing the production of COX-2 that is triggered by LPS and the activation of the NF- $\kappa$ B and JNK/AP-1 signaling pathways. It also has a potential to exhibit anti-cancer studies show that chlorogenic acid can induce the expression of caspases and mitochondria-dependent signaling pathways, resulting in promotion of apoptotic cell death and inhibition of cell proliferation in human U937- leukemia cells. CGA has certain therapeutic effects on influenza virus, respiratory syncytial virus, viral myocarditis, herpes virus, and adenovirus. CGA's mechanism of action may effectively act as an antiviral by downregulating interferon (IFN)- $\beta$  and regulating the TLR3 signaling pathway through key signaling molecules such as TLR3, TBK1, and IRF3 (Miao & Xiang, 2020) [56].

Ferulic acid has been known to possess anticancer, antiplatelet, antimicrobial and anti-diabetic properties. (Gao *et al.*, 2018) [3] investigated that ferulic acid suppressed the invasion of cells by inhibiting the expression of MMP-9 mRNA. HeLa and caski cells also induced apoptosis and caused to stop in the G0/G1 phase due to induction of specific protein related to cell cycle such as p53 and p21 and reduced the levels of cyclin D1 and cyclin E. Additionally it also suppress breast cancer cell line MDA-MB-231 cell growth in a dose - dependent way and result in apoptosis (Zhang *et al.*, 2016). A study investigated the protective effects of ferulic acid (FA) and ethyl ferulate (EF) on TNF-induced HIV activation in a chronically infected cell line. Results showed that at 5  $\mu$ M, both Ferulic acid and ethyl ferulate significantly decreased HIV p24 release, with Eethyl ferulate demonstrating greater inhibition of HIV than Ferulic acid after pretreatment (Oliveira *et al.*, 2017) [24].

Ferulic acid can reduce platelet activation, aggregation, and

contractile activity of blood clots. It inhibits the secretion of serotonin and reduces the expression of P-selectin, resulting in the inhibition of collagen-induced platelet aggregation. According to (M. A. Alam, 2019) [5] ferulic acid has been shown to potentially increase insulin secretion from cultured beta cells and adiponectin secretion from adipocytes. This improvement in glucose metabolism may contribute to better vascular function.

Gallic acid It possesses Anti-inflammatory, anti-microbial, anti-diabetic and many other potential health properties (Bai *et al.*, 2021) [14] study revealed that GA has the potential to inhibit p38 MAPK, JNK, and NF- $\kappa$ B in IL-33-induced KU812 cells, leading to a reduction in the release of inflammatory factors, chemokines, and intercellular adhesion molecule (ICAM-1). This indicates that GA may effectively alleviate the symptoms of atopic dermatitis, and this effect could be partly attributed to its regulation of the MAPK and NF- $\kappa$ B pathways.

Gallic acid has been shown to inhibit the motility, adherence, and biofilm formation of various bacteria, including *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Streptococcus mutans*, *Chromobacterium violaceum*, and *Listeria monocytogenes* (Kahkeshani *et al.*, 2019) [43]. Additionally, gallic acid can alter the charge, hydrophobicity, and permeability of both Gram-positive and Gram-negative bacterial cell membranes, ultimately disrupting their integrity (Teodoro *et al.*, 2015) [89].

Protocatechuic acid is inhibition of free radical generation and the influence on phases 1 and 2 metabolism of specific carcinogens result in the direct blocking of carcinogen binding sites with DNA molecules (Muthukumaran *et al.*, 2013) [58]. protocatechuic acid also possess anti hyperglycemic activity where it lowers blood glucose levels in diabetes-induced by Streptozotocin (STZ) through restoration of carbohydrate metabolic enzyme activity, increased plasma insulin level, and normalization of pancreatic islet activity (Semaming *et al.*, 2015) [79].

(Song *et al.*, 2020) [86] demonstrated that it reduces the production of inflammatory mediators in BV2 microglia and keratinocytes induced by lipopolysaccharide (LPS) as well as inflammatory cytokines produced by THP-1 monocytes and macrophages. The mechanism of such effects could be the reduction of toll-like receptor 4-dependent activation of Akt, mTOR, and NF- $\kappa$ B pathways, as well as the activation of JNK and p38 MAPK. It also has Anti-osteoporotic property, studies showed that protocatechuic acid resulted in a decrease in the serum RANKL level and an increase in OPG content, and the expression of TNF receptor-associated factor 6 (TRAF6) and nuclear factor of activated T cells c1 (NFATc1) was inhibited.

### Flavonoids

Kaempferol and quercetin are the major flavonoid compounds present in finger millet, pearl millet and flaxseed (Hassan *et al.*, 2020; Ruiz *et al.*, 2021) [36, 75]. These two compound posses potential health properties such as Anti-inflammatory, anti-diabetic. The study conducted by (Alam *et al.*, 2020) [6] demonstrated that *In vivo* effectiveness of reduction in the levels of cholesterol and arteriolar lesions. kaempferol has the potential to prevent vascular inflammation and was identified as a possible anti-atherogenic agent. Another study done by (Imran *et al.*, 2019) [36] conducted *In vivo* on diabetic rat improved insulin and blood lipid levels and decreased insulin

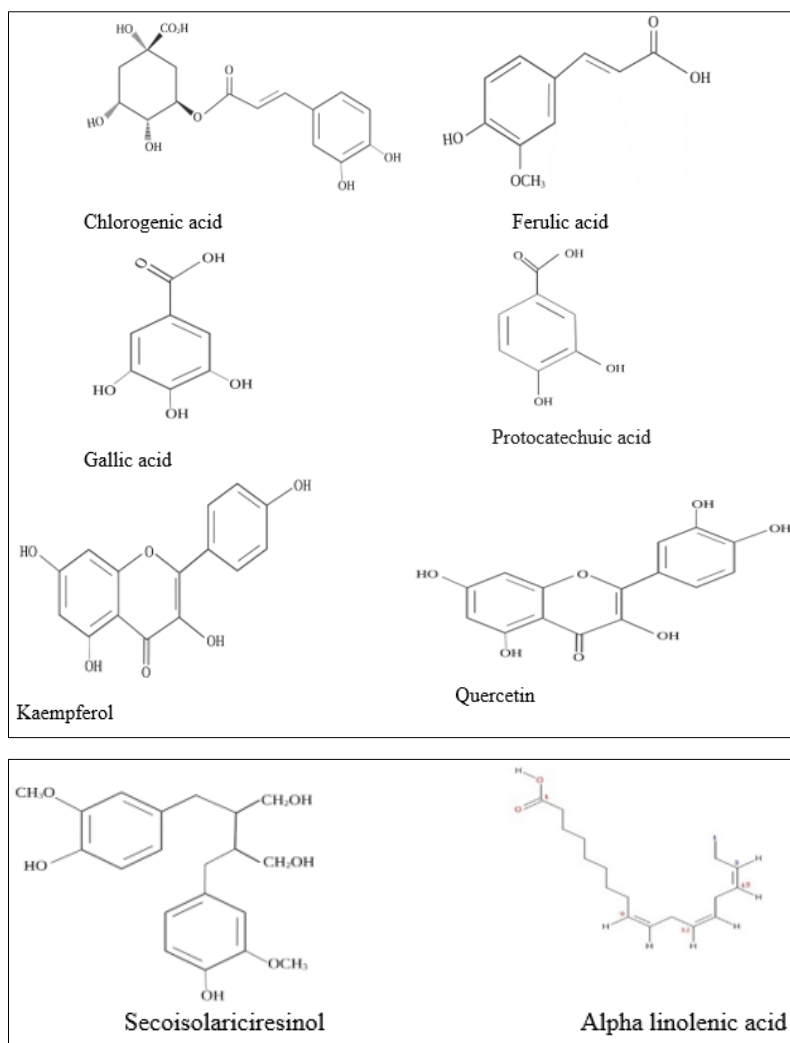
receptor substrate 1 (IRS1), I $\kappa$ B kinase (IKK), and I $\kappa$ B kinase (IKK) activation by stimulating the hepatic IKK/NF- $\kappa$ B signalling pathway. (Rauf *et al.*, 2018) [73] demonstrated that Quercetin causes cells to terminate in the G1 phase, induces apoptosis, lowers Bax expression, and increases Caspase-3 and Bcl-2 expression. It can also reverse multidrug resistance (MDR), which is caused by the gene-encoded P-glycoprotein. Another experimental study was conducted by (Azeem *et al.*, 2023) [12]. Found that the growth of *Staphylococcus aureus* was completely inhibited by the activity of a methanolic extract containing 20 mg/ml of quercetin. Additionally, in silico analysis suggested that quercetin acted as an auxiliary metabolite that blocked three proteins in *S. aureus*.

Flaxseed lipids and lignans have been discovered to have anti-inflammatory, anti-cholesterolemic, hypolipidemic effects, anti-atherogenic, anti-postprandial glycaemic and insulinemic responses (Dzuvor *et al.*, 2018) [29]. Recent research has indicated that omega-3 fatty acids may possess anti-inflammatory properties that can benefit individuals with chronic metabolic disorders. Studies have shown that flaxseed oil (FO), which is a plant-based source of -3 polyunsaturated fatty acids (PUFAs) high in alpha-linolenic acid (ALA), also has anti-inflammatory effects (Zhu *et al.*, 2020) [97]. Studies show that chronic exercise and  $\omega$ 3 enhance metabolic and molecular characteristics in obese mice by interfering with the recently deorphanized GPR120 (G Protein Coupled Receptor 120) liver levels and anti-inflammatory signals. Study

conducted by Ghaseminasab-Parizi *et al.*, (2022) [33] revealed encouraging outcomes when flaxseed was used as an adjuvant treatment for rheumatoid arthritis patients. Clinically, pain reduction is crucial since it can reduce the need for non-steroidal anti-inflammatory drug use. The anti-inflammatory drugs work by inhibiting the inflammatory mediators are produced (including NO, iNOS, PGE2, COX-2, TNF-, and IL-6) at the cellular level, systemic mediators at levels of systemic mediators, and transcription factors at the molecular level (like NF- $\kappa$ B) (Chera *et al.*, 2022) [19].

(El Tanbouly *et al.* 2017) [30] conducted a study which showed that the G9 and G10 varieties of flaxseed oil from Egypt were effective in reducing symptoms of anxiety and depression, as well as biochemical changes, in female rats induced with postpartum depression.

The presence of reactive oxygen species (ROS) can cause oxidative stress, which is linked to the onset of diabetes. Flaxseeds contain Secoisolariciresinol diglucoside (SDG), which can scavenge ROS and prevent liver damage, thus slowing down the progression of diabetes and its complications. Flaxseeds are also rich in soluble fiber and other bioactive components that can help regulate plasma glucose levels and reduce the risk of diabetes by affecting insulin secretion and action, according to (Rehman *et al.*, 2021) [74]. In the figure 3 shows that chemical structure of the phytochemical compounds mentioned below.



**Fig 1:** Chemical structure of the bioactive compounds

#### 4. Utilization of flaxseed, finger millet and pearl millet in Industry

There are many applications of finger millet, pearl millet and flaxseed both nutritionally and industrially. Each form of these has its own properties, Various industrial applications are known so far.

##### Flaxseed

Paper production is one of the most important industrial uses of flaxseed. Due to their strength, durability, and absorbency, flax fibers make an excellent choice for producing high-quality paper. According to (Crini *et al.*, 2020) [221], flax fibers are commonly utilized in the paper industry for producing specialty papers like cigarette papers and tea bag papers. Flax fibers are commonly used to manufacture currency because of their durability, strength, and high-density, which also give them superior anti-counterfeiting capabilities, as per Mbakop *et al.* (2018) [54]. Additionally, flax fibers are biodegradable, which means that they can be disposed of without harming the environment, according to (Elgat *et al.*, 2020) [102].

The transesterification process of 50 g of flaxseed oil using a methanol-to-oil ratio of 5.9:1, a reaction temperature of 59.2 °C, a reaction time of 33 minutes, and a catalyst of potassium hydroxide with a weight of 0.51% resulted in a high biodiesel yield of 98.6% (Danish *et al.*, 2020) [22]. According to Azhar *et al.*, (2020) [13], flaxseed oil undergoes a process called polymerization upon exposure to air, leading to the formation of a tough, protective layer that provides endurance and protection to the painted surface. One of the advantages of using flaxseed oil for making paint is its low toxicity, as highlighted by Gupta *et al.*, (2022) [34]. The exceptional penetration capabilities of flaxseed oil-based varnishes allow them to offer great protection by penetrating deeply into the wood grain (Qamar *et al.*, 2019) [69]. Finishes made with flaxseed oil are renowned for their longevity and ability to endure adverse weather conditions (Debnath, 2021) [26].

Millet grains possess favorable qualities for processing, and there are several ways to process them for various purposes. The primary methods include wetting, dehulling, and milling, while the secondary methods consist of fermentation, malting, extrusion, flaking, popping, and roasting (Trotter & Belton, 2002) [90]. In Africa, making malt from millet is a customary activity, which involves using the malt to make fermented drinks containing lactic acid or alcohol, as well as in producing infant food (Adekunle *et al.*, 2012) [4].

Although there is vast potential in the weaning food industry, advancements have been sluggish due to the restricted capacity for industrial malting (Amadou *et al.*, 2013) [7]. The growing desire for gluten-free products that are high in fiber has prompted many interested groups to prioritize food commodities based on millet. Resistant starch has become more popular than dietary fiber because it offers sensory benefits when creating high-fiber formulations (Ashwar *et al.*, 2016) [11].

Waffles are a type of baked goods that are made by cooking raised wheat batter between two heated plates. However, because they lack fiber and polyphenols, some researchers have looked into adding millets to the batter in order to create a waffle that is more nutritious (Chaitra *et al.*, 2020) [17]. studied that how the quality and nutritional properties of Belgium waffles were affected by the addition of finger and pearl millet to the batter. They examined three different flour mixtures that contained varying amounts of wheat, finger millet, and pearl millet.

In the innovation of edible films, pearl millet starch (PMS) was used in its original form as well as in modified forms that had been acetylated or hydroxy propylated. Consequently, hydroxy propylated starch-based films could be utilized for packaging freshly prepared, ready-to-eat vegetables. Additionally, the inclusion of acetylated Pearl millet starch (PMS) in the recipe resulted in films that possess outstanding moisture-barrier characteristics (Shaikh *et al.*, 2019) [80].

Millets in India are mainly consumed as a staple food and not commonly used in convenient and ready-to-use food products due to the lack of appropriate milling technology. The challenges hindering the extensive use of millet are their tough fibrous seed coat, pigments that give them color, their astringent taste, and the limited shelf life of processed products (Jaybhaye *et al.*, 2014) [41].

Research studies have indicated that the incorporation of flaxseed in foods can enhance their nutritional value, potentially reducing the risk of chronic diseases. Flaxseed is a rich source of  $\omega$ -3 fatty acids, fiber, lignans, and other bioactive compounds. These constituents are associated with reducing inflammation, lowering blood pressure, improving cholesterol levels, and promoting gut health. Furthermore, flaxseed can be used as a substitute for unhealthy ingredients in processed foods, such as salt, sugar, and saturated fat (Raghuwanshi *et al.*, 2019) [100]. Table 4 shows that finger millet, pearl millet and flaxseed-based food products

**Table 4:** Finger millet, Pearl millet and Flaxseed Based Food Products

Crop	Inclusion level	Study outcome	Reference
<b>Bread</b>			
Finger millet	10g, 20g, 30g per 100g	Bhol and Bosco investigated that bread incorporated with malted finger millet showed better sensory attributes textural properties in comparison with red kidney bean flour.	Bhol & John Don Bosco (2014) [1]
	10g, 20g, 30g per 100g	Patil showed that Breads made with extruded finger millet (BEF) have higher specific volume, loaf height exhibit favorable texture quality, high resilience, lower hardness, and chewiness.	(Patil <i>et al.</i> , 2016) [67]
		Mythrayee and Pavithra studied that blend of Finger millet and whole wheat flour fermented with lactic acid bacteria (LAB), results in a product with superior shelf-life due to lower gluten and moisture content. Fermented with Baker's yeast, exhibited a higher level of Vitamin B group (1.09% mg).	Mythrayee & Pavithra, (2017) [59]
Pearl millet	10%,15%, 20%	Ranasalva and Visvanathan showed that bread incorporated with 10,15 and 20% of cooked fermented pearl millet exhibited better physical and textural attributes with good quality.	Ranasalva & Visvanathan, (2014) [71]
		Maktouf investigated that incorporation of 5% pearl millet flour with a mix of wheat flour better rheologic properties of the dough also specific volume and texture of the bread.	Maktouf <i>et al.</i> , (2016) [52]
Flaxseed	5g,10g, 15g per 100g	Marpalle showed that addition of raw and roasted ground flaxseed flour to standardized bread resulted in an increase in water absorption, dough stickiness, crumb softness, and darkness of bread	(Marpalle <i>et al.</i> , 2014) [53]

		crust, which was positively correlated with the level of flaxseed addition.	
	5%, 10%, 15%	Wirkijowska study revealed that enriching wheat bread with flaxseed by-products, such as flaxseed flour and flaxseed marc resulted in an increase in crumb moisture content, decrease in the specific volume and porosity of the bread but nutritional value of the bread was enhanced.	Wirkijowska <i>et al.</i> , (2020) [92]
	1-5%	Sęczyk studies investigated that flaxseed hulls to wheat bread increased its phenolics content and antioxidant potential. sensory evaluation showed a slight negative impact on the bread but was still accepted by consumers. Thus, flaxseed hulls can be a beneficial food additive.	Sęczyk <i>et al.</i> , (2017) [78]
<b>Cookies</b>			
Finger millet	30%, 50%	Sinha and sharma investigated that Incorporation of 50% of finger millet flour increased total mineral, fiber, calcium, iron, phosphorous, copper, and zinc content of cookies.	Sinha & Sharma, (2017) [84]
		Abioye studies found that incorporating additional roasted African yam beans and germinated finger millet to a diet increased the nutritional value and decreased the antinutrients, which originally limited the utilization of these crops.	Abioye, (2019) [3]
earl millet	50: 50	Asna urooj Studies found that cookies prepared from pearl millet revealed that contains high protein, iron, calcium and phosphorous compared to control and has better sensory attributes in addition crispy and crumby texture.	Asna Urooj, (2014) [103]
	40:60	Kulthe studies found that Cookies made by blending wheat flour and PMF in a 40:60 ratio were found to be economically feasible and acceptable in terms of sensory parameters.	Kuthe <i>et al.</i> , (2017) [104]
Flaxseed	6%, 12% 18%	Khouryieh stuides investigated that Flaxseed flour can substitute wheat flour in cookies up to 12% without compromising their texture or taste, according to the study. The flavor attributes of flaxseed have the greatest impact on overall acceptability, but color and texture are also important factors for consumers. Therefore, adding flaxseed flour to cookies can be a viable option for increasing their nutritional value.	Khouryieh & Aramouni, (2012) [45]
	5%, 10% 20%, 25%, 30%	Ganorkar & Jain found that Flaxseed fortification in cookies improved the P/S ratio and reduced the $\omega$ -6/ $\omega$ -3 PUFA ratio below the recommended maximum level.	Ganorkar & Jain (2014) [31]
<b>Noodles</b>			
Finger millet	30% to 50%	Noodles with 30% finger millet incorporation were rated highest in sensory evaluation. nutrient analysis of the noodles revealed that the 50% finger millet incorporated noodles had the highest quantity of nutrients.	Shukla & Srivastava, (2014) [83]
Pearl millet	85:15, 75:25 and 65:35	Noodles with a 65:35 ratio of ingredients (presumably the specific ingredients were mentioned earlier in the text) were found to be the most acceptable based on sensory evaluation. Additionally, the iron, calcium, and carbohydrate content of the noodles increased significantly.	Kumari <i>et al.</i> , (2018) [48]
Flaxseed	10g, 15g, 20, 100g	Increasing the level of flaxseed in noodle samples led to a significant increase in total dietary fibre and total mineral matter content ( $P < 0.05$ ). Good source of minerals such as Na, K, P, and Mg.	(Yuksel, 2019) [95]

## 5. Side effects of millets and flaxseed

Flaxseed:

Based on the data that is currently available, it appears that flaxseed is safe for consumption through oral administration and in the prescribed amount for a duration of less than 4 months in healthy individuals. However, prolonged use of flaxseed may result in minor adverse effects (Issn *et al.*, 2020) [38].

Flaxseed is not recommended as a primary source of human nutrition due to the presence of potentially harmful substances. This includes toxic cyanoglycosides, such as limarin, as well as compounds that can inhibit the absorption of vitamin B6 and other anti-nutritional factors like trypsin inhibitors, phytic acid, allergens, and goitrogens. These elements can limit the safe and beneficial consumption of flaxseed as a food source (Hall *et al.*, 2006) [35].

(Amin *et al.*, 2014) [8] reported that individuals who consumed flaxseeds in excessive amounts experienced minor yet bothersome side effects like stomach discomfort, flatulence, and diarrhea. These side effects are a result of flaxseeds' laxative properties.

### Finger millet and pearl millet

Although biofortification of millet is possible, antinutrients such as phytic acid, polyphenols, and tannins still hinder its progress. Phytic acid, also known as phytate, is a major form of stored phosphorus and minerals in plants, and it can constitute up to 75% of the total phosphorus in the millet kernel (Boncompagni *et al.*, 2018) [15]. Nutritional factors were found to contribute to the excessive incidence of goiter,

along with iodine deficiency. (de Souza dos Santos *et al.*, 2011) [25] conducted an In vitro experiment indicated that pearl millet, a commonly consumed staple food, has significant levels of apigenin and luteolin, which are potent inhibitors of thyroid follicle iodine organification. (Soetan *et al.*, 2010) [85] showed one of the effects of flavonoids in vitro is inhibition of iodide organification. This was thought to occur because of an inhibition of thyroid peroxidase.

## 6. Conclusion

The nutritional value of food is crucial for maintaining good health and wellbeing, and millet is an important cereal crop that offers various benefits. Millets are highly nutritious and contain macronutrients, micronutrients, and essential amino acids. They are also rich in phytochemicals, which have numerous health benefits. On the other hand, while flaxseed contains several bioactive plant substances that offer health benefits, it also has potentially harmful substances that can limit its safe and beneficial consumption. Therefore, it is important to be cautious while consuming flaxseed and consume it in moderate amounts. Overall, the inclusion of millets in our diet can have positive impacts on our health, and it is important to be mindful of the potential risks associated with other food sources.

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