Plant Archives Vol. 25, Supplement 1, 2025 pp. 809-815 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.107

ANTINUTRITIONAL FACTORS IN MILLETS: HEALTH BENEFITS AND ADVERSE EFFECTS IN HUMAN HEALTH

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(Date of Receiving : 07-08-2024; Date of Acceptance : 11-10-2024)

ABSTRACT

Millet grains are well known for their nutritional benefits but availability of antinutritional factors in these grains impair nutrient absorption and utilization. This review explores various antinutritional factors present in millets, such as tannins, phytic acid, protease inhibitors, and trypsin inhibitors, and their impact on human health. Additionally, the study investigates different processing techniques aimed at reducing these antinutritional factors, including traditional methods like cooking, fermentation, and sprouting, as well as industrial processes such as milling, extrusion, and enzymatic treatments. The effectiveness of each method in justifying antinutritional factors is assessed based on available research findings. Understanding and applying appropriate processing techniques can enhance the nutritional quality and bioavailability of millet-based foods, thereby promoting their consumption as part of a balanced diet. Further research and studies is necessary to optimize these processing methods and evaluate their impact on overall nutrient retention and bioavailability in millets.
Keywords **:** Millets, Antinutritional factors, Health, Nutrition

Introduction

Millets are small seeded grasses which grow in arid and semi-arid conditions. These are favoured because of its productivity and short growing season in hot, dry climates and resist extreme weather and scarcity of water. Millets are staple food in areas of Asia and Africa with low rainfall and are taken as bread, porridge, fermented and beverages etc. “India is the world’s largest producer and consumer of millets”. These are divided as major millets and minor millets. Major millets are Pearl millet, finger millet and Sorghum whereas kodo millets, little millets, foxtail millets, barnyard millets and prosomillets are minor millets. In India, 95% of the total millet growing area is covered by major millets and remaining 5% is covered by the little millets. (Jyoti *et al.,* 2023)They possess 3 to 5 times higher nutritional value than widely used wheat and rice due to unique nutritional characteristics. They are rich in phytochemicals, dietary fiber, phenolic compounds and have complex carbohydrates, with medicinal properties. The important nutrients present in millets include resistant starch, oligosaccharides, lipids, antioxidants such as phenolic acids, avenanthramides, flavonoids, lignans and phytosterols which are believed to be responsible for many health benefits (Miller 2001; Edge *et al.,* 2005). Polyphenols are considered the most important phytochemicals in millets which have numerous health benefits. It is found in the millet-fed groups of diabetic animals that level ofenzymatic (glutathione, vitamin E and C),lipid peroxides and non-enzymatic antioxidants (superoxide dismutase, glutathione peroxidase, glutathione reductase and catalase) were reduced and restored to normal levels (Hegde *et al*., 2005). Despite of therapeutic properties and agro-economic potential of millets, these are underutilized or forgotten crops because of their coarse character and minimum usage in convenience foods along with poor research and novel techniques for the development of food products (Pradeep *et al.*, 2015; Sharma *et al.,* 2021). Millet foods are also characterized to be potential prebiotic

and can enhance the viability of probiotics with potential health benefits. In the colon, millets have been shown to encourage probiotic such as Bifidobacterium and Lactobacillus, whereas reducing the growth of pathogenic bacteria such as *Escherichia coli, Enterococcus* and Bacteroides in mice models (Chen *et al.,* 2022). It indicates that millets could also have a prebiotic effect on the gut. Plants produce antinutritional factors for their defence mechanism and many of them come under the category of "secondary metabolites". The antinutritional factors present in millets are harmful as well as helpful for us. They can be harmful to animals if consumed in large quantities and may exhibit positive effects when taken in low concentrations. For example, they can reduce cholesterol and blood glucose levels which helps to protect beta cells of the pancreas, reduce inflammation and oxidative stress, show activity against pathogenic bacteria and microbial biofilms (microbial structures resistant to antibiotics), delay tumor formation, and play a role against degenerative diseases, etc. (Rather *et al.*2021a and 2021b; Rather *et al.,* 2022; Rather *et al.,* 2023). According to the review literature, variety of anti-nutritional components of plants are beneficial in small doses otherwise create varieddangers to human health. Therefore, anti-nutrients may not always be harmful despite lack of nutritional value (Popova 2019). Absorption of micro nutrient and Vitamin are hindered by anti-nutritional compounds in diet which can cause organ failure. The foods with high in tannin's, lectins, alkaloids cyanogenic glycosides, enzyme inhibitors, and saponins might harm people if consumed in large quantities and breakdown products may also have negative consequences (Soetan2008; Awoyinka 2016). Therefore, traditional processing techniques such as roasting, decorticating, malting, fermentation, flaking, and grinding should be used before consumption of millet grains to reduce antinutritional factors and to improve their edible, nutritional, and sensory properties (Ahmed *et al.*, 2013).

Production and availability

Millets are the 6th most significant cereals with reference to production after rice, wheat, sorghum, corn and barley. It was observed that 80 countries produce millets out of which 90% production happen in only 13 countries, where India globally tops by producing 41% of pearl and finger millet, that is three and half times higher than Nigeria on an average of just 25% of land. The improved and hybrid varieties of the millets have largely led to this increased production in India (Taylor and Awika, 2017)**.** Globally, 27.8 million tons millet production is assessed and India is the major producer of millet at the global level with 41.04% share in the worldwide market (Global Millets Market Report, 2019-2024). Rajasthan is the highest producer of millet with 32% millet yield in India as shown in Figure 1 (APEDA, 2024).

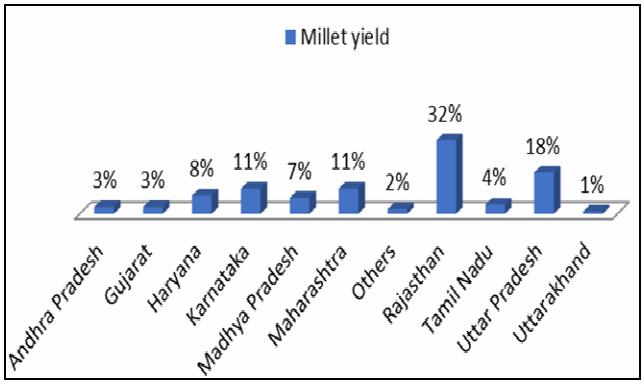

Fig. 1 : State wise Millet Production during 2023-2024

Nutritional Quality of Millets

Millets has very good nutritional content. They comprisenumerous health-promoting components such as good protein, dietary fibre, fat, carbohydrate, vitamins and minerals along with antioxidant and phytochemicals. Millets can be a good substitute of rice, wheat and cereals (Hegde *et al.*2005; Amadou *et al.,*2013). Millets phenolic compounds and phytochemicals boost antioxidant properties and are nutritionally superior to other grains. They have bioactive phytonutrients such as polyphenols, flavonoids, phytoestrogens, isoflavonoids, terpenoids, carotenoids, limonoids, glucosinolates, phytosterols, anthocyanins, resveratrol, omega-3 fatty acids, and probiotics. They possess anti-microbial, anti-allergic, anti-aging, anti-oxidants, anti-inflammatory and anti-cancer properties (Benincasa *et al.,* 2019; Chalorcharoenying *et al.,* 2017). Millets have non-acidic properties, which makes them easier to digest. It is widely acknowledged that people who rely on these grains as a staple food tend to experience lower rates of diabetes mellitus and gastrointestinal disorders (Kimeera and Sucharitha, 2019).Phenolic acids, flavonols and athocyaninsin millets have antioxidant properties and act as nutraceutical and functional food.Millets are a good source of proteinand sulphur-containing amino acids (methionine and cysteine)and have a better fatty acid profile in comparison to wheat and rice (Nithiyanantham *et al.,*2019; Anitha *et al.,* 2020). Now a days different products are made using millets. It is observed that fermented millet products act as natural probiotic and can be used for the treatment of diarrhoea in young children (Lei *et al.*, 2006).

Antinutritional Factors

Antinutritional factors are compounds naturally occurring in foods or feeds. These substances can hinder nutrition by reducing digestibility and inactivating specific nutrients (Samtiya 2020; Si 2016; Popova, 2019). These factors in the cereals are harmful as well as beneficial to humans. Millets have different type of antinutrients. These antinutrients are such as phenols, phytates, tannins, trypsin inhibitory factors, and dietary fiber which chelates metals and obstructs enzymes (Sruthi and Rao 2021).

Tannin

Tannins are important antioxidant polyphenols, following lignin, cellulose and hemicelluloses they rank as the 4thmost prevalent plant constituent. Tannins are bitter and astringent polyphenolic molecules in plants which have an affinity for binding or precipitating proteins, amino acids, and alkaloids (Gemede and Ratta, 2014; Muhayyidin *et al.,* 2018). Excessive levels of tannins in food can harm microbial enzyme activities like intestinal digestion and cellulose breakdown. Moreover, tannins can create insoluble complexes with proteins, potentially leading to the anti-nutritional effects associated with diets higher in tannin content (Maisetta *et al.,* 2019; Ramakrishnan and Krishnan, 1994). The impact on human health by food tannins is a frequent concern. Goudar *et al.*, 2023 observed the tannin content in millet varies considerably, ranging from 15.7 to 48.1 mg per 100 g. The highest tannin content was found in kodo millet, while the lowest was observed in little millet. The tannin content (mg/100 g) amid other millets was observed in the sequence of finger millet (42.1) > barnyard millet (35.5) > foxtail millet (28.7) > pearl millet (23.9) > proso millet (21.8) (Figure 2).

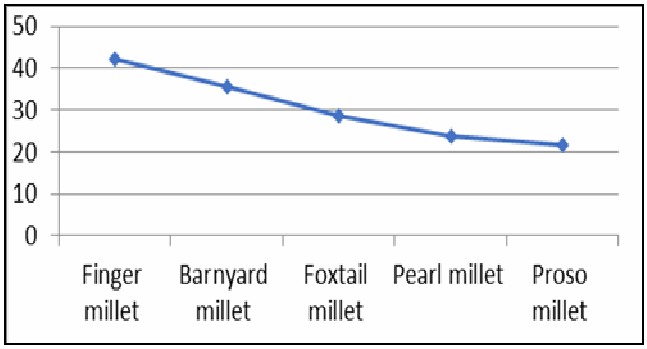

Fig. 2 : Tannin Content

Phytate

Phytic acid, is known as phytate. It is myoinositol 1,2,3,4,5,6-hexakis dihydrogen phosphate. Availability of Phytate content is higher in millets than in refined grains. It serves as a significant factor influencing mineral bioavailability in these grains and affecting its nutritional value. Itminimizes the bioavailability of calcium, and the molar ratio of Ca2+: phytate has been recommended as a marker of Ca2+ bioavailability. The critical molar ratio of Ca2+: phytate is specified to be 6:1(Oladimeji, 2000).

Saponin

Plant saponins are glycosides and known as "natural detergents." due to their foamy characteristics. They are non-volatile, surface-active compounds commonly present in various plant species as secondary metabolites**.** They can be either beneficial or harmful depending on their concentration. Studies have revealed that saponins can have positive impacts such as immune modulation, anticarcinogenic properties, and regulation of cell proliferation. They also provide health benefits like lowering cholesterol levels and inhibiting cancer cell growth (Jimoh and Oladiji, 2005). On the contrary, saponins have been linked to detrimental effects such as inhibiting enzymes, damaging red blood cellsand disrupting thyroid function (A.P. Briggs, 1922). These are also known as anti-HIV, Anti-inflammatory, anti-diabetic, anti-atherosclerotic and gastro-protective, anti-ulcer activities, anti-diabetic, immune stimulatory effects, antimicrobial activity, management of arthrosclerosis, hepatoprotective and hypo-lipidemic, lowering blood cholesterol, preventing peptic ulcer, and osteoporosis as well as platelet agglutination (Khanbabaee, 2001; Yu-Pu, 2020).

Oxalate

Oxalate is found widely distributed in plants. It is a salt derived from oxalic acid, such as calcium oxalate and forms strong bonds with various minerals, including calcium, sodium, magnesium, and potassium (Diouf *et al.,* 2019). It acts as an anti-nutrient by binding with calcium and other mineral ions and rendering them unavailable for nutritional use and absorption (Kennefick 2000; Sotelo *et al*., 2010). These have negative effect on human nutrition and health due to their potential to chelate minerals. Therefore, mineral bioavailability declines (Natesh *et al.*, 2017). Several antinutrients, such as oxalate or cyanogenic acid, may be risky above a certain level and effects absorption of nutrient. Thus, it is significant to remove these factors (Novak and Haslberger, 2000). Oxalic acid possesses strong taste and it poses risk for kidney injury (Campos-Vega *et al*., 2010). If Oxalic acid is consumed with high fiber diet, it may cause more decreases in mineral availability temporarily. Males who are consuming diet containing fibre and

oxalates show undesirable magnesium, calcium, zinc and copper balances (Kelsay JL *et al,* 1979).

Enzyme Inhibitor

Polyphenol antinutrient acts as inhibitors that deter the activity of digestive enzymes like lipases, amylase, glucosidase, pepsin, and trypsin (Rohn *et al.,* 2002). Dietary polyphenolsalter drug activity through interactions that affect enzymes or drug carriers involved in the reaction, reduce the transport of folic acid and thiamine at intervals, increase inhibition and bioavailability. Polyphenols show a repressive effect on iron absorption, resulting poor iron status (Cory *et al.* 2018; Zhang Hua and Rong Tsao, 2016). Millet's polyphenol content exhibit antifungal and antibacterial activity (Xu W *et al*., 2011). Polyphenols in millet consist of a varied blend of cinnamic acid derivatives and benzoic acid, which exhibit activities such as enzyme inhibition and prevention of cataracts (Devi *et al.*, 2014).

Protease inhibitor

Protease inhibitors are prevailing anti-nutritional factors found in plants. They act by obstructing the action of proteolytic enzymes within the gastrointestinal tract of animals (NitinVikram *et al.*, 2020). Protease inhibitors such as trypsin inhibitors induce pancreatic hyperplasia, reducing protein digestibility and disrupting sulfur metabolism by impairing the efficient utilization of amino acids (Sharma *et al*., 2021; Popova Aneta and Dasha Mihaylova, 2019). By changing protease activity, protease inhibitors disrupt several biological processes in mammals, including inflammation, blood clotting, apoptosis, fibrinolysis, and hormonal pathways. Therefore, there is a demand to eliminate or decrease protease inhibitor levels in foods. These inhibitors also exhibit biotechnological promise as insecticides, anticancer agents, and antibacterial compounds (Paiva Patrícia *et al.,* 2013; Mehrabadi *et al*., 2012).

Alkaloids

Alkaloids are a diverse group of naturally occurring compounds that are often found in plants, including some types of millets. Alkaloids have diverse effects ranging from pharmacological to toxic are harmful to humans. Specific plant alkaloids are frequently mutagenic and can cause severe intoxication in humans and animals (Ahmed *et al*., 2006; Aletor and Adeogun 1995). Alkaloids are utilized in medicine because of their ability to quickly target specific areas of the nervous system (Owheruo *et al.,* 2018).

Antinutrients and Human Health

Millets are very good source of antinutrients such as phenolic compounds, polyphenols which may have health benefits. Polyphenols has been known to impart anti-diabetic, antimicrobial, antimutagenic properties. The phytates, tannins and polyphenols present in millet contribute to antioxidant activity, which provide important role in addressing aging, promoting health, and managing metabolic diseases (Bravo 1998). Scientific evidence supports that consuming adequate amounts of certain anti-nutrients can lower the risk of specific diseases like coronary heart disease, inflammation and breast cancer (López*et al.*, 2013; Patterson *et al.,* 2016). Certain tannins are known for their potential anti- mutagenic, anti- carcinogenic propertiescardiovascular protection and anti-inflammatory due to their antioxidant properties (Ojo, 2022).

Techniques to remove antinutritional factors

We can remove or decrease the antinutritional factors of the millets by adapting processing techniques. Many researchers observed that different processing techniques are helpful to reduce the antinutritional factors and enhance the nutritive value of millets. Indian cooking styles such as pressure cooking, prolonged boiling, and steaming, are traditional methods known to significantly decrease phytic acid levels in cereals and millets compared to methods used in other countries (Agte *et al.,* 2019). Soaking is a process which involves immersing millets in water for a period of time before cooking or further processing which help to eliminate the antinutritional content of millets. The bioavailability of minerals like zincincreases due to reduction of antinutritional compounds such as phytic acid by soaking(Saleh*et al.,* 2013).Decortication or dehulling is removing the outer covering (pericarp) of grains. It decreases crude fiber content, phytochemicals, minerals, antioxidant activity, and antinutrients in millets (Babiker *et al.,* 2018). Fermentation technique is widely recognized as a convenient and popular method for reducing anti-nutrients found in millets such as trypsin inhibitors, phytic acid, tannins and others. This process also improves the overall nutritional value of millets (Mrinal *et al.,* 2020). Germination helps to initiate enzymatic activity and the breakdown of antinutritional factors. It is an efficient way for reducing anti-nutritional components like phytate in grains (Schlemmer *et al.,* 2009, Mahdavi *et al.,* 2020). Puffing of millets is a famous method of processing. It is usually carried out by conditioning of grains to higher moisture content and roasting in hot sand.This processing method also increases the dietary fibre of

the final products and reduces antinutritional factors (Choudhury *et al.,* 2011; Sarkar *et al.,* 2015). Puffing millet grains at a commercial scale facilitates their use as a convenient, ready-to-eat food, thereby promoting their widespread consumption (Saleh *et al.,* 2013).Heat treatment is employed to remove protein-based antinutrients, although it can potentially degrade certain vitamins and amino acids. Industrial methods like canning, fractionation, toasting, and isolating protein concentrates have also proven effective in reducing antinutritional factors (Blainski *et al.,* 2013; Briggs, 1922).

Conclusion

Millet has varied range of nutrients, anti-nutrients and antioxidants which makes them beneficial components of dietary and nutritional balance in foods. This comprehensive review explores the millets production, nutritional aspects, antinutritional factors, their impact on our health and processing techniques to reduce antinutritional factors. These help in contributing health benefits like blood pressure regulation, reduction in blood sugar level, thyroid, cardiovascular diseases. Despite of the various health benefits, millets consumption has significantly declined due to lack of awareness of nutritional merits, lack of processing technologies and inconvenience in food preparation. Presently people are conscious for their healthy living practices to get over metabolic disorders and lifestyle diseases. Therefore, the aim of this study is to concern and developing specific agenda for millets to create awareness on nutritional aspects of millets and make them recognized as an important nutritious food andfulfilment of the nutritional need of global population as part of everyone's diet.

Acknowledgement

The OA facility rendered by Maharishi Markandeshwar Deemed to be University, Mullana-133207, Ambala, Haryana, India is gratefully acknowledged.

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