Journal of Advanced Zoology

ISSN: 0253-7214

*Volume **44** Issue **S-6 Year 2023** Page **2012:2025***

INDIAN MILLETS (FINGER MILLET, KODO, SORGHUM AND PEARL MILLET): POTENT FUNCTIONAL FOODS AND PROCESSING SCOPES

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Article History

Received: 28 September 2023
Revised: 21 October 2023
Accepted: 02 November 2023

Abstract:

Millets, a group of small-seeded grasses, are emerging as functional foods with numerous health benefits. With the world facing challenges in agriculture and nutrition, millets offer a promising solution due to their resilience in marginal growing conditions and high nutritional value. Millets are an abundant source of essential macronutrients and micronutrients, branched-chain amino acids (BCAAs) that are essential for muscle growth and repair. The phytochemicals present in millets, such as phytosterols, polyphenols, and phytoestrogens, act as antioxidants, immunomodulators, and detoxifying agents, potentially preventing age-related diseases like cardiovascular conditions, type-2 diabetes, and cancer. Different millets contain diverse phenolic groups with potent antioxidant capacity. The nutritional characteristics and processing techniques of four common Indian millets - Finger millet, Kodo, Sorghum and Pearl millets are discussed in view of their potential as functional foods for promoting good health. Millets contain resistant starch, that acts as prebiotic, promoting the growth of beneficial bacteria in the gut and reducing inflammation, helps in the production of desirable metabolites such as short-chain fatty acids in the colon, especially butyrate, which helps to stabilize colonic cell proliferation and thus contributing to overall health. Although millets contain higher levels of antinutrients, some of these compounds also offer antioxidant properties. The use of processing techniques like debranning, soaking, germination, fermentation, and autoclaving can reduce antinutrient content and enhance the bioavailability of essential nutrients and proteins. Future research in the realm of Indian millets could focus on optimizing processing techniques, exploring health impacts, and transforming antinutrients for potential benefits in combating malnutrition and food security.

Keywords: Indian Millets, Phytochemicals, Micronutrients, Functional food, Food security

Introduction:

Millets are among the oldest known foods to humans and could be the earliest cereal grain used for domestic purposes. They have been staple foods for people living in semi-arid regions of Asia and Africa for centuries, where other crops do not thrive. Millets have also been consumed widely in Asia and India since ancient times **(Karuppasamy, 2015)**. These small-grained cereal crops are highly nutritious and can be grown under marginal or low-fertility soils with minimal use of fertilizers and pesticides **(B Venkatesh et.al, 2018)**. Millets are classified into three types based on their grain size: major millets (Sorghum, Pearl, Finger millet), minor millets (Foxtail, Kodo, Barnyard, Little, and Proso millet), and pseudo-millets (Amaranth, Buckwheat millet) **(Sanjay et. al, 2022).** Although millets are used for human consumption in most developing countries, they have mainly been limited to animal feed in developed countries. **(Karuppasamy, 2015)**

Millets are often referred to as "Nutri-Cereals" because they are highly nutritious compared to commonly grown cereals like wheat, rice, or corn. They contribute to human and animal health, including that of mothers and their young **(FAO, 2022)**. Millets were declared nutri-cereals by the Indian government in April 2018 **(Sanjay et. al, 2022)**.Millets are a rich source of fiber, minerals, and B-complex vitamins. Their high fiber content and presence of anti-nutritional factors like phytates and tannins affect mineral bioavailability. Millets act as prebiotics, feeding the micro-flora in our inner ecosystem. Millets are also rich in health-promoting phytochemicals like polyphenols, lignans, phytosterols, phyto-estrogens, and phytocyanin. These function as antioxidants, immune modulators, detoxifying agents, etc., and hence protect against age-related degenerative diseases like cardiovascular diseases (CVD), diabetes, cancer, etc **(Dayakar Rao et. al, 2017; B Venkatesh et.al, 2018).** They have resistance to pests and diseases, a short growing season, and productivity under drought conditions **(Saleh et. al 2013)** However, despite these extraordinary qualities and capacities of millet farming systems, the area under millet production has been decreasing over the last five decades and rapidly after the green revolution period. **(Karuppasamy, 2015)**. The decline in demand has led to a considerable reduction in millet production in India **(Dayakar Rao et. al, 2017).** With diabetes, hypertension, and cardiovascular disease becoming more prevalent, millets have returned as a viable option for a healthy lifestyle and can reduce the incidence of these lifestyle diseases **(B Venkatesh et.al, 2018).** With respect to the rise in global warming, millets could become valuable crops in the long run owing to their adaptation to a wide range of climatic and ecological conditions, where major crops like rice and wheat could not survive **(Pragyani et. al, 2019).** In light of the challenges of global food and nutrition security, the United Nations General Assembly declared 2023 the International Year of Millets (IYM) at its 75th session in March 2021. **(FAO, 2021)**

Millets as functional food:

The world is grappling with agricultural and nutritional challenges, with over 800 million individuals undernourished and more than 2 billion experiencing chronic deficiencies in essential nutrients. While addressing these issues through food-based solutions is a significant challenge, it offers a potentially sustainable, cost-effective, and feasible approach to combating malnutrition. **(Kumar et al., 2018; Kumar et al., 2021).** Functional foods refer to dietary items that not only provide energy and nutrients but also modulate specific bodily functions and reduce the risk of disease**(Donato-Capel et al.,2014).** Millets, like wheat and rice, boast high nutritional quality and serve as excellent functional foods with multiple health benefits. **(Pragyani et. al, 2019)**. In this article, we will delve into the functional components of millets in greater detail.

Functional components of millets:

Carbohydrates

Millet grains, comprising about 65% carbohydrates, notably non-starchy polysaccharides and dietary fiber, help prevent constipation, lower cholesterol, and regulate glucose release during digestion. Regular millet consumption is linked to reduced cardiovascular disease, duodenal ulcers, and diabetes risk. **(Rao. Et al., 2017)**

Dietary fibre: Millet's fiber content prevents constipation and lowers the risk of bowel disorders like colon cancer. Its swelling properties reduce glucose absorption in the small intestine, aiding in managing non-insulin-dependent diabetes mellitus. Additionally, it binds bile salts, promoting cholesterol excretion and reducing food toxin toxicity in the gut. **(B Venkatesh et.al, 2018; Rao. Et al., 2017)**

Resistant Starch: Resistant starch (RS) is starch that resists digestion as it passes through the gut. (**Nugent, 2005**). Resistant starch boosts colon-friendly bacteria, bolstering gut health and lowering the risk of conditions like inflammatory bowel disease and colon cancer. (**Topping et al., 2001**). Resistant starch fermentation yields short-chain fatty acids with anti-inflammatory properties, curbing body-wide inflammation. Additionally, it can lower the glycemic index of foods, aiding in blood sugar regulation, especially valuable for those with diabetes or at risk of the condition. (**Higgins et al., 2004, Hamer et al., 2008**).

Millet	Total Fibre (g)	Insoluble Fibre(g)	Soluble Fibre (g)	Total starch(g)
Pearl/Bajra/Kamboo (*Pennisetum typhoideum*)	11.49±0.62	9.14±0.58	2.34±0.42	55.21± 2.57
Sorghum/Jowar/Juar/Cholam (*Sorghum bicolor)*	10.22± 0.49	8.49 ± 0.40	1.73 ± 0.40	59.70 ± 1.70
Kodo/Kodon/Varagu (*Paspalum scrobiculatum)*	6.39±0.60	4.29±0.82	2.11±0.34	64.96 ± 2.93
Finger/Ragi/Mandua/Kelvaragu (*Eleusine coracana*)	11.18±1.14	9.51±0.65	1.67±0.55	62.13 ± 1.13
Rice, raw, milled(*Oryza sativa*)	2.81±0.42	1.99±0.39	0.82±0.22	75.70± 2.70
Wheat, whole(*Triticum aestivum*)	11.23±0.77	9.63±0.19	1.60±0.75	56.82 ± 2.69
Maize, dry (*Zea mays*)	12.24 ± 0.93	11.29 ± 0.85	0.94 ± 0.18	59.35 ± 0.83

Table 1: Fibre and Starch content of millets and cereals **(Longvah et al., 2017)**

Proteins

Protein, a vital macronutrient in our diet, serves multiple structural and functional purposes within the body. Furthermore, protein-based ingredients play diverse technological roles in processed foods, influencing properties such as texture, color, and flavor. Food-derived proteins also provide essential amino acids while contributing to the technological aspects of food production, as highlighted by **Loveday, S. M**. in 2019.

Amino Acid (mg/100g)	Pearl Millet	Finger Millet	Sorghum	Kodo	Rice, raw, milled	Wheat, whole	Maize, dry
Histidine (HIS)	2.15±0.37	2.37±0.46	2.07±0.20	2.14±0.07	2.45±0.30	2.65±0.31	2.70±0.21
Isoleucine (ILE)	3.45±0.74	3.70±0.44	3.45±0.63	4.55±0.22	4.29±0.23	3.83±0.20	3.67±0.22
Leucine (LEU)	8.52±0.86	8.86±0.54	12.03±1.51	11.96±1.65	8.09±0.40	6.81±0.33	12.24±0.57
Lysine (LYS)	3.19±0.49	2.83±0.34	2.31±0.40	1.42±0.17	3.70±0.39	3.13±0.26	2.64±0.18
Methionine (MET)	2.11±0.50	2.74±0.27	1.52±0.50	2.69±0.16	2.60±0.34	1.75±0.21	2.10±0.17
Phenylalanine (PHE)	4.82±1.18	5.70±1.27	5.10±0.50	6.27±0.34	5.36±0.43	4.75±0.38	5.14±0.29
Threonine (THR)	4.82±1.18	3.84±0.45	2.96±0.17	3.89±0.16	3.28±0.27	3.01±0.17	3.23±0.29
Tryptophan (TRP)	1.33±0.30	0.91±0.30	1.03±0.21	1.32±0.19	1.27±0.14	1.40±0.10	0.57±0.12
Valine (VAL)	4.79±1.04	5.65±0.44	4.51±0.71	5.49±0.23	6.06±0.02	5.11±0.05	5.41±0.71
Arginine (ARG)	4.54±0.62	4.33±0.48	3.96±0.43	3.18±0.19	7.72±0.55	5.13±0.33	4.20±0.24

Table 2: Composition of amino acids of millets compared to other traditional cereal crops. (All values are expressed as mg/100g edible portion) **(Longvah et al., 2017)**

Source of Quality Proteins: Branched Chain Amino Acids – BCAAs

Millets, including finger millet, pearl millet, sorghum, and kodo millet, are excellent sources of branched-chain amino acids (BCAAs), with leucine being the most abundant in all of them(**Gowda et al., 2022**). Branched chain amino acids (BCAAs) like leucine, isoleucine, and valine are unique for their muscle-focused metabolism, distinct from other amino acids processed in the liver. They play key roles in regulating protein synthesis, insulin secretion, and brain metabolism **(Seugnet, 2022).** Isoleucine, an essential BCAA, supports immune system function, growth, protein and fatty acid metabolism, and glucose transport. It enhances immune responses by activating host defense peptides, aiding in immune defense against pathogens **(Gu et al., 2019).** Leucine supplementation, within a specific dosage range, has been found to counteract muscle loss in sarcopenia, particularly when combined with adequate vitamin-D intake **(Martínez-Arnau et al., 2019).**

Fats

Pearl millet grains have a relatively higher fat content (1.5% to 6.8%) compared to other millets. The dominant fatty acids in pearl millet include palmitic acid, stearic acid, and linolenic acid, with lower amounts of oleic and linoleic acids. About 75% of the fatty acids in pearl millet are unsaturated, with linoleic acid being notably high at 46.3%. (**Patni, D., & Agrawal, M., 2017**). In contrast to other minor cereals like pearl millet, barnyard millet, and foxtail millet, finger millet has a lower fat content, ranging from 1.3% to 2%. The primary fatty acids in finger millet are oleic acid, palmitic acid, and linoleic acid, with a small amount of linolenic acid. Saturated and unsaturated fatty acids make up 25.6% and 74.4% of total fatty acids, respectively. Finger millet seeds are particularly rich in linoleic and α-linolenic acids, essential for proper central nervous system function. (**Abioye, V. F. et al., 2022**). Sorghum and Kodo millets have relatively low-fat content, with an average lipid content ranging from 3% to 6%. The predominant fatty acids in sorghum are unsaturated fatty acids, including oleic acid, linoleic acid, and palmitoleic acid, with small amounts of saturated fatty acids such as palmitic acid and stearic acid. (**Girard, A. L., & Awika, J. M., 2018; Sridhar, R., & Lakshminarayana, G., 1992**)

Vitamins

Finger millet, kodo millet, and pearl millet are nutrient-rich grains with vital water-soluble vitamins, including niacin (B3), riboflavin (B2), and folic acid. These vitamins are essential for various bodily functions and must be obtained from external sources since the body cannot store them. **(Ramashia et al., 2019; Uebanso et al., 2020; Patni & Agrawal, 2017**). Finger millet stands out for its high content of both fat-soluble and water-soluble vitamins, including vitamin A and B complex, whereas pearl millet is particularly rich in thiamine, niacin, and riboflavin **(Patni & Agrawal, 2017).** Sorghum, is a notable source of essential B-vitamins like niacin and vitamin B6, vital for energy metabolism and cellular functions. It also provides folates, vitamin K1, and carotenoids, playing key roles in DNA synthesis, blood clotting, and immune function. **(Vitamin K, 2020).** Millets are notable sources of several essential B-vitamins. Thiamine (B1) supports nerve and muscle function and carbohydrate metabolism **(Uebanso et al., 2020).** Riboflavin (B2) plays a critical role in maintaining healthy skin, eyes, and the nervous system while aiding in various cellular processes**.** Niacin (B3) is vital for digestive system, skin, and nerve function, and it participates in numerous enzymatic reactions in the body **(Ramashia et al., 2019).** Millets also provide vitamin B6, essential for red blood cell production and brain function, and folate (B9), crucial for fetal development and various metabolic processes **(Uebanso et al., 2020).** Furthermore, millets contain vitamin E, serving as antioxidants to protect cells, and sorghum stands out with its high vitamin K content. These diverse millet grains offer a spectrum of water-soluble vitamins essential for overall health.

Vitamins	Pearl Millet	Finger Millet	Sorghum	Kodo	Rice, raw, milled	Wheat, whole	Maize, dry
Thiamine (mg)	0.25±0.044	0.37±0.041	0.35±0.039	0.29±0.054	0.05±0.019	0.46±0.067	0.33±0.032
Riboflavin (mg)	0.20±0.038	0.17±0.008	0.14±0.014	0.20±0.018	0.05±0.006	0.15±0.041	0.09±0.009
Niacin (mg)	0.86±0.10	1.34±0.02	2.10±0.09	1.49±0.08	1.69±0.13	2.68±0.19	2.69±0.06
Pantothenic Acid (mg)	0.50±0.05	0.29±0.19	0.27±0.02	0.63±0.07	0.57±0.05	1.08±0.21	0.34±0.03
Total B6 (mg)	0.27±0.009	0.05±0.007	0.28±0.023	0.07±0.017	0.12±0.012	0.26±0.036	0.34±0.017
Biotin (µg)	0.64±0.05	0.88±0.05	0.70±0.06	1.49±0.18	0.60±0.12	1.03±0.58	0.49±0.05
Total Folates (µg)	36.11±5.05	34.66±4.97	39.42±3.13	39.49±4.52	9.32±1.93	30.09±3.79	25.81±1.44
Vit E (mg)	0.24±0.02	0.16±0.01	0.06±0.01	0.07±0.02	0.06±0.03	0.77±0.35	0.36±0.03
Vit K1 (µg)	2.85±0.63	3.00±0.44	43.82±4.84	3.75±0.63	1.50±0.40	1.75±0.26	2.50±0.76
Total Carotenoids (µg)	293±55.7	154±25.6	212±48.9	272±25.1	16.87±5.61	287±40.5	893±154

Table 3: Vitamins Composition of millets and cereals (All values are expressed per 100g edible portion) **(Longvah et al., 2017)**

Minerals

Millets are rich source of macro as well as micro minerals. Calcium, a vital mineral for bone health, muscle function, and nerves, can reduce colorectal cancer risk (>1000mg/day diet). It may also lower pregnancy-related hypertensive disorders **(Theobald, 2005; Kana Wu et al., 2002; Hofmeyr et al., 2018).** Magnesium, involved in 600+ enzymatic reactions, is crucial for bone health, insulin sensitivity, and heart health. It fights inflammation, reducing heart disease and cancer risk. Additionally, it eases anxiety and depression symptoms **(Nielsen, 2018; Veronese et al., 2014; Rosanoff et al., 2016; Gobbo et al., 2013; Boyle et al., 2017).** Phosphorus is vital for energy metabolism, bone health, and cell signaling. It's essential for hormonal activation, maintaining bone density, and cardiovascular health **(Takeda et al., 2012; Tucker et al., 1999; Kestenbaum et al., 2005).** Potassium maintains fluid balance, muscle and nerve function, and regulates blood pressure, reducing cardiovascular risks and promoting bone health **(Whelton et al., 1997; He et al., 2008; Weaver, 2013)**

Iron is crucial for oxygen transport, energy production, brain function, immune support, and pregnancy **(Moustarah et al., 2019; Zimmermann et al., 2007; Beard, 2001; Lozoff, 2007).** Manganese supports connective tissue, metabolic processes, brain function, and immunity **(Al-Fartusie et al., 2017; Keen et al., 2000; Irani et al., 2018; Wu et al., 2021).** Selenium, an antioxidant, aids thyroid function, enhances immunity, reduces inflammation, and may protect against certain cancers and cardiovascular disease **(Rayman, 2012; Beck et al., 2003; Kryscio et al., 2017).** Zinc, crucial for DNA synthesis, immune function, wound healing, and mood regulation, prevents infections, aids fertility, and supports mental health

Millet	Calcium (mg)	Iron (mg)	Magnesium (mg)	Manganes e (mg)	Phospho rus (mg)	Potassiu m (mg)	Selenium (µg)	Zinc (mg)
Pearl (Bajra) (*Pennisetum typhoideum*)	27.35±2.16	6.42±1.04	124±19.5	1.12±0.17	289±25.3	365±18.0	30.40±5.22	2.76±0.36
Sorghum (*Sorghum bicolor*)	27.60±3.71	3.95±0.94	133±14.8	1.19±0.11	274±35.7	328±25.1	26.29±11.08	1.96±0.31
Finger (Ragi) (*Eleusine coracana*)	**364±58.0**	4.62±0.36	146±10.7	3.19±0.88	210±58.4	443±59.6	15.30±6.23	2.53±0.51
Kodo (*Paspalum scrobiculatum*)	15.27±1.28	2.34±0.46	122±5.9	0.33±0.05	101±5.2	94±10.7	14.12±2.26	1.65±0.18
Rice, raw, milled (*Oryza sativa*)	7.49±1.26	0.65±0.11	19.30±6.99	0.73±0.21	96±16.30	108±10.9	1.01±0.13	1.21±0.17
Wheat, whole (*Triticum aestivum*)	39.36±5.65	3.97±0.78	125±14.8	3.19±0.59	315±41.8	366±59.6	47.76±5.96	2.85±0.65
Maize, dry	8.91±0.61	2.49±0.32	145±12.4	0.71±0.08	279±35.3	291±27.7	8.69±1.81	2.27±0.23

(Prasad, 2008; Maret et al., 2006; Wessels et al., 2017).

Table 4: Mineral content of Cereals and millets. (**Longvah et al., 2017**)

Polyphenols/Phenolic compounds

Plants produce phenolic compounds as secondary metabolites, vital for biological functions and defense against environmental stress. These compounds offer numerous health benefits, including antioxidants, antiallergic, antiviral, anti-inflammatory, and antimutagenic properties. Millets contain both free and conjugated forms of phenolic acids derived from hydroxybenzoic and hydroxycinnamic acids. Additionally, millets include various flavonoids like anthocyanidins, flavanols, flavones, flavanones, chalcones, and aminophenolic compounds. The content and composition of these compounds vary among different grain parts and millet types. (**Czajkowska-González et al. 2021**; **Shahidi et al. 2013**). Gallic, proto-catechuic, p-hydroxybenzoic, gentisic, vanillic, and syringic are some of the hydroxybenzoic acids that have been found in whole millet grains. There have been reports of chlorogenic, caffeic, trans-cinnamic, p-coumaric, sinapic, trans-ferulic, and cis-ferulic acids in millet grains. (**Shahidi et al., 2013**). Phenolic acids are present in the endosperm, pericarp, testa, and aleurone layer of all sorghums and millets. The phenolic acids found in sorghum and millets are (i) hydroxybenzoic acids, including gallic, protocatechuic, p-hydroxybenzoic, gentisic, vanillic, and syringic; and (ii) hydroxycinnamic acids, including ferulic, caffeic, p-coumaric, cinnamic, and sinapic. (**Dykes & Rooney, 2006**)

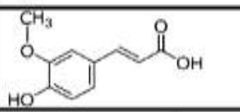
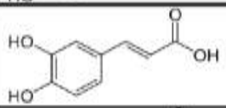
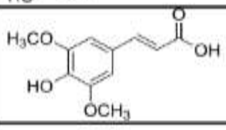
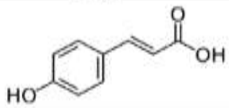
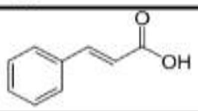
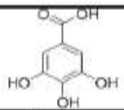
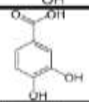
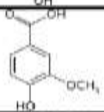
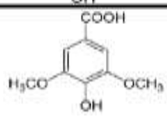
Phenolic acid	Structure	Sorghum (mcg/g)	Kodo (mcg/g)	Finger (mcg/g)	Pearl (mcg/g)
II) Cinnamic acids					
Ferulic acid		120.5 to 173.5	Trans-ferulic – 2209.5	Trans-ferulic – 358.4	Trans-ferulic – 812.3
Caffeic acid		13.6 to 20.8	324.4	15.9	30.4
Sinapic acid		50 to 140	53.2	0.8	12.8
p-Coumaric acid		41.9 to 71.9	802.0	41.4	91.9
Cinnamic acid		9.8 to 15.0	37.4	na	na
I) Benzoic acids					
Gallic acid		14.8 to 21.5	1.8	5.0	5.4
Protocatecuic acid		150.3 to 178.2	70.5	119.8	1.6
Vanillic acid		15.4 to 23.4	98.1	na	16.0
p-Hydroxybenzoic acid		6.1 to 16.4	31.2	6.3	47.9
Syringic acid		15.7 to 17.5	141.4	25.1	6.3

Table 5: Total content of phenolic acids (mcg/g) of sorghum, kodo, finger and pearl millet. Adapted from (**Xiong et al., 2019) and (Shahidi and Chandrasekara, 2013**)

Health Benefits of Millets:

Millets have several health benefits and can be a suitable option for individuals with certain health conditions and deficiencies. Millets are a gluten-free choice for people with coeliac disease or gluten intolerance, as they naturally lack gluten, a protein commonly found in grains. (**Jnawali, P et al., 2016**). Their high protein content can combat protein-energy malnutrition (PEM) by delivering essential amino acids, enhancing overall nutrition and health, particularly in vulnerable populations. (**Saleh, A. S et al., 2013**). Millets are packed with essential micronutrients like iron, iodine, zinc, calcium, and magnesium. They can play a role in fortifying staple cereals with these vital nutrients, making them a valuable addition to a nutritious diet. **(Shashi, B. K et al., 2007; Shobana, S et al., 2009**). Their low energy density (low glycemic index), reduced palatability, and high volume can promote a feeling of fullness, aiding in weight management. This is crucial because obesity is a significant risk factor for various diseases, including type 2 diabetes, cardiovascular issues, and cancer. (**Santaliestra et al., 2016**). Millets are rich in viscous soluble fiber, which enhances intraluminal viscosity, slows down gastric emptying time, and increases nutrient absorption in the small intestine (**Tieri et al., 2020**). Studies have also shown that the consumption of millets is inversely related to obesity. The effect of soluble fiber – β glucan present in millets such as sorghum and pearl decreases serum have been shown to reduce plasma triglycerides, LDL cholesterol, and C-reactive protein, markers of inflammation and predictors of cardiovascular events **(Rasaneet al., 2015**). Other compounds like antioxidants, lectins, saponins, phytic acid, phenolics and amylase inhibitors all have been shown to alter the risk of CVD. Millets, with their dietary fiber, can slow glucose release into the bloodstream, reducing glycemic load and benefiting those with diabetes. Furthermore, millets' protein concentrates, rich in antioxidants, may enhance insulin sensitivity, providing additional advantages for individuals managing diabetes. (**Shobana, S et al., 2009; Jenkins, D. J. A et al., 1986).** Phenolic extracts from various millet varieties have demonstrated anti-cancer properties, including inhibiting lipid peroxidation, DNA damage, and suppressing colon cancer cell growth. These attributes may contribute to millets' potential cancer-fighting bene (**Chandrasekara, A., & Shahidi, F. 2011; Shan, S et al., 2014**). Methanolic extract of finger millet has been shown to inhibit glycation and cross-linking of collagen, and scavenge free radicals, which may have potential anti-aging effects (**Hegde, P. S et al., 2002).** Protein extracts and polyphenols from millets have exhibited anti-fungal and antibacterial activity against microorganisms such as Bacillus cereus and Aspergillus niger, indicating potential anti-microbial properties of millets (**Viswanath, V et al., 2009).** Polyphenols and flavonoids in finger millet scavenge reactive oxygen species, inhibit nitric oxide production, and prevent sorbitol accumulation. These actions may lower the risk of ocular diseases, including diabetes-induced cataracts. (**Chethan, S. 2008; Shobana, S et al., 2010**).

Extraction:

Processing methods significantly impact the nutritional properties of millets, including Kodo millets. These grains contain anti-nutrients like polyphenols, tannins, phosphorus, and phytic acids, which can hinder the absorption of important micronutrients like iron, calcium, and zinc **(Balasubramanian, 2013).** Germinating millet grains through malting can increase nutrient bioaccessibility. It boosts iron bioaccessibility by 300% and manganese by 17% by reducing phytic acid content through phytase activity **(Platel et al., 2010).** Soaking and sprouting decrease anti-nutrient levels, especially phytic acid and tannins. Longer germination further reduces anti-nutrients due to enzyme activity **(Handa et al., 2017; Hussain et al., 2011).** Boiling and Pressure Cooking effectively reduce anti-nutrients, particularly tannins. High-temperature short-time processing and extrusion cooking also lower phytates and tannins while enhancing mineral bioavailability **(Pushparaj & Urooj, 2011).** Fermentation lowers anti-nutrient levels and enhances protein digestibility by reducing phytic acid, tannins, and polyphenols **(Budhwar et al., 2020).** Irradiation inhibits anti-nutrients, leading to improved protein digestibility **(Sharma & Niranjan, 2018).** Some processing methods, like debranning, may lead to the loss of germ, bran, and antioxidants, affecting millet's nutritional value **(Deshpande et al., 2015).** Dehulling, heat treatments, and fractionation can alter antioxidant activity and phytate content **(Saleh et al., 2013).**

Conclusion:

Millets, ancient grains with global agricultural and dietary significance, offer a multitude of nutritional and environmental advantages. Packed with fiber, vitamins, minerals, and antioxidants, they cater to diverse dietary needs, being gluten-free with a low glycemic index. Consumption can aid weight management, enhance digestion, and reduce diabetes and heart disease risk. Millets require less water than major grains like wheat and rice and thrive in various ecological zones. This resilience makes them an eco-friendly choice for sustainable agriculture, especially in regions grappling with water scarcity and climate change. Millets hold promise in addressing today's challenges, from improving nutrition and health to ensuring food security and combating climate change. Continued research and support for millet cultivation and utilization are essential for a sustainable and nutritious food source for a growing global population.

References:

- Abioye, V. F., Babarinde, G. O., Ogunlakin, G. O., Adejuyitan, J. A., Olatunde, S. J., & Abioye, A. O. (2022). Varietal and processing influence on nutritional and phytochemical properties of finger millet: A review. Heliyon, 8(12), e12310. https://doi.org/10.1016/j.heliyon.2022.e12310
- Al-Fartusie, F. S., & Mohssan, S. N. (2017). Essential trace elements and their vital roles in human body. Indian Journal of Advances in Chemical Science, 5(3), 127–136.
- Beard, J. L. (2001). Iron biology in immune function, muscle metabolism and neuronal functioning. Journal of Nutrition, 131(2S–2), 568S–579S; discussion 580S. https://doi.org/10.1093/jn/131.2.568S
- Beck, M. A., Levander, O. A., & Handy, J. (2003). Selenium deficiency and viral infection. Journal of Nutrition, 133(5), Suppl. 1, 1463S–1467S. https://doi.org/10.1093/jn/133.5.1463S
- Bora, P., Ragaee, S., & Marcone, M. (2019). Characterisation of several types of millets as functional food ingredients. International Journal of Food Sciences and Nutrition, 70(6), 714–724. https://doi.org/10.1080/09637486.2019.1570086
- Boyle, N. B., Lawton, C., & Dye, L. (2017). The effects of magnesium supplementation on subjective anxiety and stress—A systematic review. Nutrients, 9(5), 429. https://doi.org/10.3390/nu9050429
- Budhwar, S., Sethi, K., & Chakraborty, M. (2020). Efficacy of germination and probiotic fermentation on underutilized cereal and millet grains. Food Production, Processing and Nutrition, 2(1), 1–17. https://doi.org/10.1186/s43014-020-00026-w
- Chandrasekara, A., & Shahidi, F. (2011). Determination of antioxidant activity in free and hydrolyzed fractions of millet grains and characterization of their phenolic profiles by HPLC-DAD-ESI-MSn. Journal of Functional Foods, 3(3), 144–158. https://doi.org/10.1016/j.jff.2011.03.007
- Chethan, S. (2008). Finger millet (Eleusine coracana) polyphenols and their nutraceutical potential ([Doctoral Dissertation]. University of Mysore).
- Czajkowska-González, Y. A., Alvarez-Parrilla, E., del Rocío Martínez-Ruiz, N., Vázquez-Flores, A. A., Gaytán-Martínez, M., & de la Rosa, L. A. (2021). Addition of phenolic compounds to bread: Antioxidant benefits and impact on food structure and sensory characteristics. Food Production, Processing and Nutrition, 3(1), 1–12.
- Dayakar Rao, B., Bhaskarachary, K., Arlene Christina, G. D., Sudha Devi, G., & Vilas, A. (2017), Nutritional and Health benefits of Millets. Tonapi p. 112. Indian Council of Agricultural Research_Indian Institute of Millets Research (IIMR) Rajendranagar. Hyderabad.
- Del Gobbo, L. C., Imamura, F., Wu, J. H., de Oliveira Otto, M. C., Chiuve, S. E., & Mozaffarian, D. (2013). Circulating and dietary magnesium and risk of cardiovascular disease: A systematic review and meta-analysis of prospective studies. American Journal of Clinical Nutrition, 98(1), 160–173. https://doi.org/10.3945/ajcn.112.053132
- Deshpande, S. S., Mohapatra, D., Tripathi, M. K., & Sadvatha, R. H. (2015). Kodo millet-nutritional value and utilization in Indian foods. Journal of Grain Processing and Storage, 2(2), 16–23.
- Donato-Capel, L., Garcia-Rodenas, C. L., Pouteau, E., Lehmann, U., Srichuwong, S., Erkner, A., Kolodziejczyk, E., Hughes, E., Wooster, T. J., & Sagalowicz, L. (2014), Chapter 14. Technological means to modulate food digestion and physiological response. In M. Boland, M. Golding & H. Singh (Eds.), Food structures, digestion and health (pp. 389–422). Academic Press, ISBN 9780124046108. https://doi.org/10.1016/B978-0-12-404610-8.00014-1

- Doosti-Irani, A., Ostadmohammadi, V., Mirhosseini, N., Mansournia, M. A., Reiter, R. J., Kashanian, M., Rahimi, M., Razavi, M., & Asemi, Z. (2018). The effects of melatonin supplementation on glycemic control: A systematic review and meta-analysis of randomized controlled trials. Hormone and Metabolic Research, 50(11), 783–790. https://doi.org/10.1055/a-0752-8462
- Duntas, L. H., & Benvenga, S. (2015). Selenium: An element for life. Endocrine, 48(3), 756–775. https://doi.org/10.1007/s12020-014-0477-6
- Dykes, L., & Rooney, L. W. (2006). Sorghum and millet phenols and antioxidants. Journal of Cereal Science, 44(3), 236–251. https://doi.org/10.1016/j.jcs.2006.06.007
- Food and Agriculture Organization. (2018). Sorghum polyphenols and other bioactive components as functional and health promoting food ingredients. International Year of Millets 2023 Communication handbook and toolkit, 2022 https://www.fao.org/documents/card/en/c/cc3253en · Girard, A.L., and Awika, J. M. Journal of Cereal Science, 84, 112–124.
- Gu, C., Mao, X., Chen, D., Yu, B., & Yang, Q. (2019). Isoleucine plays an important role for maintaining immune function. Current Protein and Peptide Science, 20(7), 644–651. https://doi.org/10.2174/1389203720666190305163135
- Gupta, M., Mahajan, V. K., Mehta, K. S., & Chauhan, P. S. (2014). Zinc therapy in dermatology: A review. Dermatology Research and Practice, 2014, 709152. https://doi.org/10.1155/2014/709152
- Hamer, H. M., Jonkers, D. M. A. E., Venema, K., Vanhoutvin, S. A. L. W., Troost, F. J., & Brummer, R. J. (2008). Review article: The role of butyrate on colonic function. Alimentary Pharmacology and Therapeutics, 27(2), 104–119. https://doi.org/10.1111/j.1365-2036.2007.03562.x
- Handa, V., Kumar, V., Panghal, A., Suri, S., & Kaur, J. (2017). Effect of soaking and germination on physicochemical and functional attributes of horsegram flour. Journal of Food Science and Technology, 54(13), 4229–4239. https://doi.org/10.1007/s13197-017-2892-1
- He, F. J., & MacGregor, G. A. (2008). Beneficial effects of potassium on human health. Physiologia Plantarum, 133(4), 725–735. https://doi.org/10.1111/j.1399-3054.2007.01033.x
- Hegde, P. S., Chandrakasan, G., & Chandra, T. S. (2002). Inhibition of collagen glycation and crosslinking in vitro by methanolic extracts of Finger millet (Eleusine coracana) and Kodo millet (Paspalum scrobiculatum). Journal of Nutritional Biochemistry, 13(9), 517. https://doi.org/10.1016/s0955-2863(02)00171-7
- Higgins, J. A., Higbee, D. R., Donahoo, W. T., Brown, I. L., Bell, M. L., & Bessesen, D. H. (2004). Resistant starch consumption promotes lipid oxidation. Nutrition and Metabolism, 1(1), 8. https://doi.org/10.1186/1743-7075-1-8
- Hoffer, L. J. (2016). Human protein and amino acid requirements. JPEN. Journal of Parenteral and Enteral Nutrition, 40(4), 460–474. https://doi.org/10.1177/0148607115624084
- Hofmeyr, G. J., Lawrie, T. A., Atallah, Á. N., & Torloni, M. R. (2018). Calcium supplementation during pregnancy for preventing hypertensive disorders and related problems. Cochrane Database of Systematic Reviews, 10
- Hussain, I., Uddin, M. B., & Aziz, M. G. (2011). Optimization of antinutritional factors from germinated wheat and mungbean by Response Surface Methodology. International Food Research Journal, 18(3).
- Indian Council of Medical Research. (2020). NIN Expert group on Nutrient requirement for Indians, Recommended Dietary Allowances (RDA) and Estimated Average Requirements (EAR).
- Jenkins, D. J. A., Jenkins, M. J. A., Wolever, T. M. S., Taylor, R. H., & Ghafari, H. (1986). Slow release carbohydrate: Mechanism of action of viscous fibers. Journal of Clinical Nutrition and Gastroenterology, 1(5), 237–241.

- Jeon, S. M. (2016). Regulation and function of AMPK in physiology and diseases. Experimental and Molecular Medicine, 48(7), e245–e245. https://doi.org/10.1038/emm.2016.81
- Jnawali, P., Kumar, V., & Tanwar, B. (2016). Celiac disease: Overview and considerations for development of Gluten-Free Foods. Food Science and Human Wellness, 5(4), 169–176. https://doi.org/10.1016/j.fshw.2016.09.003
- Karuppasamy, P. (2015). Overview on Millets. Trends in Biosciences, 8(13), 3269-3273.
- Keen, C. L., Ensunsa, J. L., & Clegg, M. S. (2000). Manganese metabolism in animals and humans including the toxicity of manganese. Metal Ions in Biological Systems, 37, 89–121.
- Kestenbaum, B., Sampson, J. N., Rudser, K. D., Patterson, D. J., Seliger, S. L., Young, B., Sherrard, D. J., & Andress, D. L. (2005). Serum phosphate levels and mortality risk among people with chronic kidney disease. Journal of the American Society of Nephrology, 16(2), 520–528. https://doi.org/10.1681/ASN.2004070602
- Khaw, K. T., & Barrett-Connor, E. (1986). Dietary potassium and stroke-associated mortality-a 12 year prospective population based study. Journal of Hypertension, 4(6), 794. https://doi.org/10.1097/00004872-198612000-00024
- Kryscio, R. J., Abner, E. L., Caban-Holt, A., Lovell, M., Goodman, P., Darke, A. K., Yee, M., Crowley, J., & Schmitt, F. A. (2017). Association of antioxidant supplement use and dementia in the prevention of Alzheimer's disease by vitamin E and selenium trial (PREADViSE). JAMA Neurology, 74(5), 567–573. https://doi.org/10.1001/jamaneurol.2016.5778
- Kumar, A., Tomer, V., Kaur, A., Kumar, V., & Gupta, K. (2018). Millets: A solution to agrarian and nutritional challenges. Agriculture and Food Security, 7(1), 31. https://doi.org/10.1186/s40066-018-0183-3
- Kumar, A., Tripathi, M. K., Joshi, D., & Kumar, V. (Eds.). (2021). Millets and millet technology (p. 438). Springer.
- Lippman, S. M., Klein, E. A., Goodman, P. J., Lucia, M. S., Thompson, I. M., Ford, L. G., Parnes, H. L., Minasian, L. M., Gaziano, J. M., Hartline, J. A., Parsons, J. K., Bearden, J. D., Crawford, E. D., Goodman, G. E., Claudio, J., Winquist, E., Cook, E. D., Karp, D. D., Walther, P., . . . & Coltman, C. A. (2009). Effect of selenium and vitamin E on risk of prostate cancer and other cancers: The selenium and vitamin E Cancer Prevention Trial (SELECT). JAMA, 301(1), 39–51. https://doi.org/10.1001/jama.2008.864
- Longvah, T., Anantan, I., Bhaskarachary, K., Venkaiah, K., & Longvah, T. (2017). Indian food composition tables (pp. 2-58). Hyderabad: National Institute of Nutrition, Indian Council of Medical Research.
- Loveday, S. M. (2019). Food proteins: Technological, nutritional, and sustainability attributes of traditional and emerging proteins. Annual Review of Food Science and Technology, 10, 311–339. https://doi.org/10.1146/annurev-food-032818-121128
- Lozoff, B. (2007). Iron deficiency and child development. Food and Nutrition Bulletin, 28(4), Suppl., S560–S571. https://doi.org/10.1177/15648265070284S409
- Maret, W., & Sandstead, H. H. (2006). Zinc requirements and the risks and benefits of zinc supplementation. Journal of Trace Elements in Medicine and Biology: Organ of the Society for Minerals and Trace Elements, 20(1), 3–18. https://doi.org/10.1016/j.jtemb.2006.01.006
- Martínez-Arnau, F. M., Fonfría-Vivas, R., & Cauli, O. (2019). Beneficial effects of leucine supplementation on criteria for sarcopenia: A systematic review. Nutrients, 11(10). https://doi.org/10.3390/nu11102504
- Milman, N. (2006). Iron and pregnancy—A delicate balance. Annals of Hematology, 85(9), 559–565. https://doi.org/10.1007/s00277-006-0108-2

- Mousa, A., Naqash, A., & Lim, S. (2019). Macronutrient and micronutrient intake during pregnancy: An overview of recent evidence. Nutrients, 11(2), 443. https://doi.org/10.3390/nu11020443
- Moustarah, F., & Mohiuddin, S. S. (2019). Dietary iron.
- Navas-Acien, A., Bleys, J., & Guallar, E. (2008). Selenium intake and cardiovascular risk: What is new? Current Opinion in Lipidology, 19(1), 43–49. https://doi.org/10.1097/MOL.0b013e3282f2b261
- Nielsen, F. H. (2010). Magnesium, inflammation, and obesity in chronic disease. Nutrition Reviews, 68(6), 333–340. https://doi.org/10.1111/j.1753-4887.2010.00293.x
- Nielsen, F. H. (2018). Dietary magnesium and chronic disease. Advances in Chronic Kidney Disease, 25(3), 230–235. https://doi.org/10.1053/j.ackd.2017.11.005
- Nugent, A. P. (2005). Health properties of resistant starch. Nutrition Bulletin, 30(1), 27–54. https://doi.org/10.1111/j.1467-3010.2005.00481.x
- Patni, D., & Agrawal, M. (2017). Wonder millet–pearl millet, nutrient composition and potential health benefits-a review. Int. J. Innov. Res Rev, 5, 6–14.
- Platel, K., Eipeson, S. W., & Srinivasan, K. (2010). Bioaccessible mineral content of malted finger millet (Eleusine coracana), wheat (Triticum aestivum), and barley (Hordeum vulgare). Journal of Agricultural and Food Chemistry, 58(13), 8100–8103. https://doi.org/10.1021/jf100846e
- Prasad, A. S. (2008). Zinc in human health: Effect of zinc on immune cells. Molecular Medicine, 14(5–6), 353–357. https://doi.org/10.2119/2008-00033.Prasad
- Pushparaj, F. S., & Urooj, A. (2011). Influence of processing on dietary fiber, tannin and in vitro protein digestibility of pearl millet. Food and Nutrition Sciences, 2(08), 895–900.
- Ramashia, S. E., Anyasi, T. A., Gwata, E. T., Meddows-Taylor, S., & Jideani, A. I. O. (2019). Processing, nutritional composition and health benefits of finger millet in sub-Saharan Africa. Food Science and Technology, 39(2), 253–266. https://doi.org/10.1590/fst.25017
- Rasane, P., Jha, A., Sabikhi, L., Kumar, A., & Unnikrishnan, V. S. (2015). Nutritional advantages of oats and opportunities for its processing as value added foods-a review. Journal of Food Science and Technology, 52(2), 662–675. https://doi.org/10.1007/s13197-013-1072-1
- Rayman, M. P. (2000). The importance of selenium to human health. Lancet, 356(9225), 233–241. https://doi.org/10.1016/S0140-6736(00)02490-9
- Rayman, M. P. (2012). Selenium and human health. Lancet, 379(9822), 1256–1268. https://doi.org/10.1016/S0140-6736(11)61452-9
- Rosanoff, A., Dai, Q., & Shapses, S. A. (2016). Essential nutrient interactions: Does low or suboptimal magnesium status interact with vitamin D and/or calcium status? Advances in Nutrition, 7(1), 25–43. https://doi.org/10.3945/an.115.008631
- Saleh, A. S. M., Zhang, Q., Chen, J. M., & Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. Comprehensive Reviews in Food Science and Food Safety, 12(3), 281–295. https://doi.org/10.1111/1541-4337.12012
- Sanjay, A. N., Basarkar, G., & Buchake, V. (2022). Millets: An overview-A treatise on healthy option in daily diet. Journal of Pharmacognosy and Phytochemistry, 11(3), 177–185.
- Santaliestra-Pasías, A. M., Garcia-Lacarte, M., Rico, M. C., Aguilera, C. M., & Moreno, L. A. (2015). Effect of two bakery products on short-term food intake and gut-hormones in young adults: A pilot study. International Journal of Food Sciences and Nutrition, 67(5), 562–570. https://doi.org/10.1080/09637486.2016.1180348
- Seugnet, L. (2022). Branched chain amino acids, an “essential” link between diet, clock and sleep?
- Shahidi, F., & Chandrasekara, A. (2013). Millet grain phenolics and their role in disease risk reduction and health promotion: A review. Journal of Functional Foods, 5(2), 570–581. https://doi.org/10.1016/j.jff.2013.02.004

- Shan, S., Li, Z., Newton, I. P., Zhao, C., Li, Z., & Guo, M. (2014). A novel protein extracted from foxtail millet bran displays anti-carcinogenic effects in human colon cancer cells. Toxicology Letters, 227(2), 129–138. https://doi.org/10.1016/j.toxlet.2014.03.008
- Sharma, N., & Niranjan, K. (2018). Foxtail millet: Properties, processing, health benefits, and uses. Food Reviews International, 34(4), 329–363. https://doi.org/10.1080/87559129.2017.1290103
- Shashi, B. K., Sharan, S., Shittalamani, S., Shankar, A. G., & Nagarathna, T. K. (2007). Micronutrient composition, antinutritional factors and bioaccessibility of iron in different finger millet (Eleusine coracana) genotypes. Karnataka Journal of Agricultural Sciences, 20(3), 583–585.
- Shobana, S., Harsha, M. R., Platel, K., Srinivasan, K., & Malleshi, N. G. (2010). Amelioration of hyperglycaemia and its associated complications by finger millet (Eleusine coracana L.) seed coat matter in streptozotocin-induced diabetic rats. British Journal of Nutrition, 104(12), 1787–1795. https://doi.org/10.1017/S0007114510002977
- Shobana, S., Sreerama, Y. N., & Malleshi, N. G. (2009). Composition and enzyme inhibitory properties of finger millet (Eleusine coracana L.) seed coat phenolics: Mode of inhibition of α-glucosidase and pancreatic amylase. Food Chemistry, 115(4), 1268–1273. https://doi.org/10.1016/j.foodchem.2009.01.042
- Sridhar, R., & Lakshminarayana, G. (1992). Lipid class contents and fatty acid composition of small millets: Little (Panicum sumatrense), kodo (Paspalum scrobiculatum), and barnyard (Echinochloa colona). Journal of Agricultural and Food Chemistry, 40(11), 2131–2134. https://doi.org/10.1021/jf00023a018
- Stranges, S., Marshall, J. R., Natarajan, R., Donahue, R. P., Trevisan, M., Combs, G. F., Cappuccio, F. P., Ceriello, A., & Reid, M. E. (2007). Effects of long-term selenium supplementation on the incidence of type 2 diabetes: A randomized trial. Annals of Internal Medicine, 147(4), 217–223. https://doi.org/10.7326/0003-4819-147-4-200708210-00175
- Swardfager, W., Herrmann, N., Mazereeuw, G., Goldberger, K., Harimoto, T., & Lanctôt, K. L. (2013). Zinc in depression: A meta-analysis. Biological Psychiatry, 74(12), 872–878. https://doi.org/10.1016/j.biopsych.2013.05.008
- Takeda, E., Yamamoto, H., Yamanaka-Okumura, H., & Taketani, Y. (2012). Dietary phosphorus in bone health and quality of life. Nutrition Reviews, 70(6), 311–321. https://doi.org/10.1111/j.1753-4887.2012.00473.x
- Theobald, H. E. (2005). Dietary calcium and health. Nutrition Bulletin, 30(3), 237–277. https://doi.org/10.1111/j.1467-3010.2005.00514.x
- Tieri, M., Ghelfi, F., Vitale, M., Vetrani, C., Marventano, S., Lafranconi, A., Godos, J., Titta, L., Gambera, A., Alonzo, E., Sciacca, S., Riccardi, G., Buscemi, S., Del Rio, D., Ray, S., Galvano, F., Beck, E., & Grosso, G. (2020). Whole grain consumption and human health: An umbrella review of observational studies. International Journal of Food Sciences and Nutrition, 71(6), 668–677. https://doi.org/10.1080/09637486.2020.1715354
- Tonelli, M., Sacks, F., Pfeffer, M., Gao, Z., Curhan, G., & Cholesterol And Recurrent Events Trial Investigators. (2005). Relation between serum phosphate level and cardiovascular event rate in people with coronary disease. Circulation, 112(17), 2627–2633. https://doi.org/10.1161/CIRCULATIONAHA.105.553198
- Topping, D. L., & Clifton, P. M. (2001). Short-chain fatty acids and human colonic function: Roles of resistant starch and nonstarch polysaccharides. Physiological Reviews, 81(3), 1031–1064. https://doi.org/10.1152/physrev.2001.81.3.1031
- Tucker, K. L., Hannan, M. T., Chen, H., Cupples, L. A., Wilson, P. W., & Kiel, D. P. (1999). Potassium, magnesium, and fruit and vegetable intakes are associated with greater bone mineral

density in elderly men and women. American Journal of Clinical Nutrition, 69(4), 727–736. https://doi.org/10.1093/ajcn/69.4.727

- Uebanso, T., Shimohata, T., Mawatari, K., & Takahashi, A. (2020). Functional roles of B- vitamins in the gut and gut microbiome. Molecular Nutrition and Food Research, 64(18), e2000426. https://doi.org/10.1002/mnfr.202000426
- Venkatesh Bhat, B., Dayakar Rao, B., & Tonapi, V. A. (2018). The story of millets Karnataka State department of agriculture. India with Icar-Indian Institute of Millets Research. Hyderabad, India.
- Veronese, N., Berton, L., Carraro, S., Bolzetta, F., De Rui, M., Perissinotto, E., Toffanello, E. D., Bano, G., Pizzato, S., Miotto, F., Coin, A., Manzato, E., & Sergi, G. (2014). Effect of oral magnesium supplementation on physical performance in healthy elderly women involved in a weekly exercise program: A randomized controlled trial. American Journal of Clinical Nutrition, 100(3), 974–981. https://doi.org/10.3945/ajcn.113.080168
- Viswanath, V., Urooj, A., & Malleshi, N. G. (2009). Evaluation of antioxidant and antimicrobial properties of finger millet polyphenols (Eleusine coracana). Food Chemistry, 114(1), 340–346. https://doi.org/10.1016/j.foodchem.2008.09.053
- Vitamin, K. (2020). The nutrition source.
- Weaver, C. M. (2013). Potassium and health. Advances in Nutrition, 4(3), 368S–377S. https://doi.org/10.3945/an.112.003533
- Wessels, I., Maywald, M., & Rink, L. (2017). Zinc as a gatekeeper of immune function. Nutrients, 9(12), 1286. https://doi.org/10.3390/nu9121286
- Whelton, P. K., He, J., Cutler, J. A., Brancati, F. L., Appel, L. J., Follmann, D., & Klag, M. J. (1997). Effects of oral potassium on blood pressure: Meta-analysis of randomized controlled clinical trials. JAMA, 277(20), 1624–1632. https://doi.org/10.1001/jama.1997.03540440058033
- Wong, W. Y., Flik, G., Groenen, P. M., Swinkels, D. W., Thomas, C. M., Copius-Peereboom, J. H., Merkus, H. M., & Steegers-Theunissen, R. P. (2001). The impact of calcium, magnesium, zinc, and copper in blood and seminal plasma on semen parameters in men. Reproductive Toxicology, 15(2), 131–136. https://doi.org/10.1016/s0890-6238(01)00113-7
- Wu, K., Willett, W. C., Fuchs, C. S., Colditz, G. A., & Giovannucci, E. L. (2002). Calcium intake and risk of colon cancer in women and men. Journal of the National Cancer Institute, 94(6), 437–446. https://doi.org/10.1093/jnci/94.6.437
- Wu, Q., Mu, Q., Xia, Z., Min, J., & Wang, F. (2021, July). Manganese homeostasis at the host–pathogen interface and in the host immune system. In Seminars in Cell and Developmental Biology. Academic Press, 115. https://doi.org/10.1016/j.semcdb.2020.12.006
- Xiong, Y., Zhang, P., Warner, R. D., & Fang, Z. (2019). Sorghum grain: From genotype, nutrition, and phenolic profile to its health benefits and food applications. Comprehensive Reviews in Food Science and Food Safety, 18(6), 2025–2046. https://doi.org/10.1111/1541-4337.12506
- Zimmermann, M. B., & Hurrell, R. F. (2007). Nutritional iron deficiency. Lancet, 370(9586), 511–520. https://doi.org/10.1016/S0140-6736(07)61235-5