Efficacy of Kodo Millets *Paspalum scrobiculatum*: A Systematic Review

Shikha Yadav, Gurminder Kaur* and Siddharth Vats

[1]Faculty of Biosciences, Institute of Bio-Sciences and Technology, Shri Ramswaroop Memorial University, Barabanki, Uttar Pradesh, India

ABSTRACT

In recent times, when the COVID pandemic has hit the world badly, there has been a marked shortage of food, water, and other essentialities, an increase in food pricing which together with other socioeconomic impacts have eventually posed threats to agriculture, food supplies, and nutritional security all over the world. Researchers worldwide are looking for potential solutions to combat poverty and hunger issues. This review focuses on the various medicinal properties of Kodo, its uses in various fields, and prospects where it could be utilized thereafter. The findings of the present rerview revealed that the Kodo millets, *Paspalum scrobiculatum*: are nutritionally dense when compared to the number of grains consumed. They have a greater mineral content when compared to rice and wheat. Some of them weigh fifty times as much as rice. Finger millet contains thirty times the calcium content of rice, whereas every other millet has at least half the calcium content.

KEY WORDS: KODO MILLET, PASPALUM SCROBICULATUM, CARDIOVASCULAR DISEASES, OBESITY, FOOD.

INTRODUCTION

Drought-resistant plants such as Kodo millet are rare, they are made up of coarse grain. Rice grass, cow grass, and millet are some of the alternate names for Kodo millet. *Paspalum scrobiculate* is a tropical African plant that was first cultivated 3000 years ago in India. The grain is encased in a testa that must be removed before preparation (Krishnan et al. 2012; Baghele et al. 2021).

Grain has 98.3 percent protein, 1.4 percent fat, 65.6 percent carbs, and 2% ash. Fiber The overall fiber level of the grain is fairly high throughout. Kodo-millet has a lower Phosphorus (P) concentration than other millets, and it has a significantly higher antioxidant capacity than virtually other millets and common cereals (Ratnavathi 2017). The grain is recommended as a rice supplement for those with diabetes (Bhat 2018). India's Uttar Pradesh, Rajasthan, Bengal West, Tamil Nadu, Andhra Pradesh, and Madhya Pradesh grow this crop (Bhat 2018; Baghele et al. 2021). Throughout the year, Kodo millet is produced on 1.97 lakh hectares over a vast region, with a total gross output of about 0.84 lakh tonnes and a yield of 429 kg per hectare (Pradesh 2011). Kodo millet is mostly grown in hot and temperate regions. That is drought resistant and, as a result, may be grown in areas where rainfall is scarce and erratic. It's wonderful to thrive in areas where yearly precipitation is just 40 to 50 cm (Tadele 2016). Because of the nutritional and physiological benefits they provide to customers, v. millets have become a popular food raw material alternative for major cereals in recent years (Baghele et al. 2021).

The coarse grains Kodo millet (*Paspalum scrobiculatum* L.) and small millet (*Panicum miliare* L.) are mostly grown in India, China, the Soviet Union, Japan, and Africa (Kumar et al. 2016). In 1998, coarse grain output totaled 902 million tonnes, accounting for roughly 44% of total world cereal production. India produces 3 I million tonnes of coarse grains, ranking third in the world behind the United States and China, with a share of 3.4 percent. In 1950-5, the area under coarse cereals was 37.6 million hectares, rising to a peak of 47.34 million hectares in 967-68 before steadily declining to 30.00 million hectares in 2000-0, of which just 2% is irrigated (Kulkarni et al. 2006; Kumar et al. 2016; Baghele et al. 2021). In Madhya Pradesh, India's tribal area, Kodo is a staple meal (Sharma and Mandhyan 1992). The bran layer on the surface of the Kodo kernel makes it tough to digest. The final product is more pleasant and digestible if Kodo is dehusked and then polished to remove the bran layer. Millets are also acceptable for diabetic diets, although their distinctive flavor and difficulties in the processing are limits to their use in diets (Baghele et al. 2021).

Article Information:*Corresponding Author: gurminder.ibst@srmu.ac.in
Received 15/07/2022 Accepted after revision 18/09/2022
Published: 30th Sep 2022 Pp- 379-385

Available at: https://bbrc.in/ DOI: http://dx.doi.org/10.21786/bbrc/15.3.2

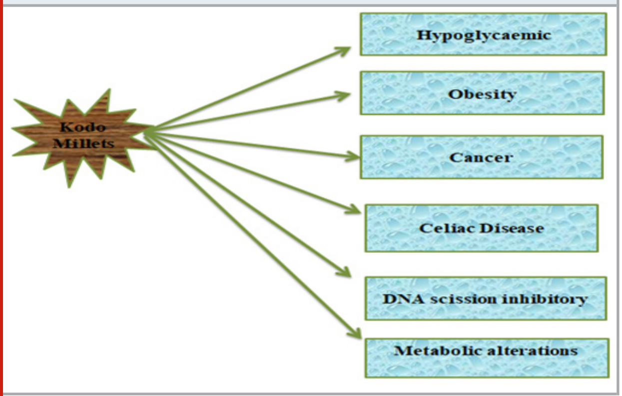
Kodo millet is nutritionally equal to other common grains, and in certain ways, such as minerals and fiber, it is even superior to rice and wheat (Gopalan et al. 2018). Hand/ foot pounding is still used in the milling of Kodo millet. The requirement of the day, however, is to make use of the possibilities of identifying processing methods and suitable machinery for Kodo millet processing (Baghele et al. 2021). Physical and technical characteristics of biological materials are critical not only for classifying them into subgroups but also for developing handling and processing equipment and procedures. Cleaning, grading, categorization, shipping, aeration, drying, and storage are all part of post-harvest processing for value addition. Knowledge of grain characteristics and qualities is required for successful post-harvest equipment design (Liu et al. 2017; Baghele et al. 2021).

Bioactive substances in Kodo millets: Some grain components have bioactivity in relation to the nutrients they offer. Phytochemical compounds abound in Kodo millet grains. Tannins, phenolics, flavonoids, alkyl resorcinol, and coumarins are phytochemicals. Phenols are responsible for the oxidative quality of plant-based foods' flavor, texture, color, and taste (Naczk and Shahidi 2004). They are usually found in Bran and have nutraceutical benefits. Millet is more than simply an interesting alternative for the more popular grains. The grain also contains phytochemicals such as phytic acid, which is considered to lower cholesterol, and phylate, which is linked to lower cancer risk (Coulibaly et al. 2011). Certain health advantages have been ascribed in part to the wide spectrum of potential medicinal substances known as phytochemicals, which may be found in foods such as millets in high concentrations of antioxidants (Izadi et al. 2015; Baghele et al. 2021).

Table 1. List of bioactive substances responsible for curing disease.

Bioactive substances	Disease cure
Saponins	Improve immune function by stimulating of production of T cell (Marciani et al. 2000)
Flavonoids	Cardiovascular, (Sharma et al. 2018)
Glycosides	Diuretic effect, (Sharma et al. 2017)
Alkaloids	Antioxidants, (Singh et al. 2016)
Triterpenoids	Diabetic complications, (Nazaruk and Kluczyk 2015)
Steroids	Reduce systemic inflammation, (Hill et al. 2020)
Tannin	Tonsillitis, Pharyngitis, (Kamal 2014)
Phenolic acids	Cancer treatment, (Abotaleb et al. 2020)

Figure 1: Role of Kodo Millets in treatment.



Hypoglycemic properties of Kodo millet: In a research published in 2013, Neelam et al. (2013) found that when Sewai upma and Idli were mixed with Kodo millet, the mean quantity of glucose and GI were reduced (60%). In the control Idli and Sewai upma, the CV percent of the inter-individual variation was determined to be 4.03 and 4.98, respectively. Similarly, the GI values in the Kodo-dependent items were low (Kodo Idli 3.98 and Kodo upma 3.53). Lesser CV percent values of average blood glucose levels indicate variations across participants, which offers useful statistics for comparing the accuracy of various variables (Farugui et al. 2013; Liu et al. 2021).

The lower CV percent number indicates that the research participants were a homogenous group. Cereals and millets are the most abundant sources of carbohydrates and a key source of human energy. Carbohydrate foods, particularly rice and wheat (60-65 percent), supply the majority of energy in the Asian Indian diet (Amadou et al. 2013). It's critical to comprehend the glycemic reaction of such common meals, especially for insulin-resistant individuals (Mohan et al. 1986; Zhang and Hamaker 2009; Farugui et al. 2013; Liu et al. 2021). According to Brand-Miller et al. (2003), the glycemic index value may be divided into three categories: a hundred (high GI food). According to studies, white rice and extruded wheat flour products have high GI values, therefore traditional Idli (control), which is generally made of rice, and Sewai upma, which is made of refined wheat flour, may be classed as high GI foods and are not advised for diabetes patients. In research conducted by Neelam et al. (2013), control Idli and Sewai upma were replaced with Kodo millet (60%) and the GI was reduced by 15% and 9%, respectively (Liu et al. 2021).

This would be especially important in Southeast Asia, where diabetes is one of the most common health issues and where the diet is often heavy in carbohydrate cereals (30). The crude fiber content of Kodo millet (8.5 g/100 g) was found to be higher than that of white rice (0.2 mg/100 g) and refined wheat flour (0.3 mg/100 g), which might explain why Kodo-based products have a lower GI than controls when carbohydrate content is changed (Liu et al. 2021). The presence of dietary fiber, type of carbohydrate, nature of starch granules, the physical shape of food, and processing, according to Ludwig et al. (1999), impact the glycemic effect of food. Furthermore, the ratio of amylose to amylopectin in starch, as well as an alpha-amylase inhibitor, decreases the GI of meals by delaying starch digestion (Liu et al. 2021).

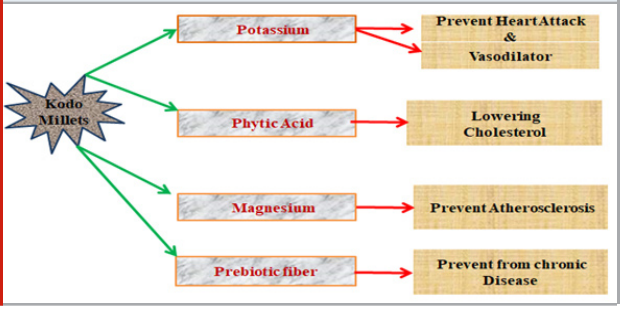
Incorporating high-fiber foods into a variety of goods can help to decrease a product's glycemic reaction. Dietary fiber lowers the postprandial blood glucose response simply by slowing carbohydrate absorption in the small intestine due to the development of a viscous gel. Millets outperform other cereals in terms of nutrients. Millet is high in dietary unavailable carbohydrates, beta-glucan, and soluble sugars, all of which help with glucose metabolism (Augustin et al. 2002; Liu et al. 2021). Kodo millet's therapeutic impact on reducing postprandial blood glucose response is most likely owing to its highly viscous soluble fiber, which is not hydrolyzed by digestive enzymes. Soluble fiber causes extremely viscous intestinal contents with gelling characteristics, which may delay absorption in the intestine. The quantity of carbohydrates ingested, as well as the GI of the carbohydrate diet, influences glucose and insulin response. Glycemic load represents both of these factors. The combination of low cereal dietary fiber consumption and high GL was linked to a higher risk of diabetes and coronary heart disease in women (Vijayalakshmi and Radha 2006; Liu et al. 2021).

Obesity: Obesity is India's fastest-growing problem, and it's linked to a variety of chronic diseases, including diabetes and cardiovascular disease. According to new research, eating a high-fiber diet lowers the risk of obesity (Alfieri et al. 1995; Liu et al. 2021). Dietary fiber-rich foods enhance intestinal function and delay the digestion and absorption process, lowering the risk of chronic illnesses. Millets have a greater dietary fiber content than other cereals, with 22% compared to 12.6 percent for wheat, 4.6 percent for rice, and 13.4 percent for maize. According to Chethan et al. (2007), finger millet grain contains 15.7 percent insoluble dietary fiber and 1.4 percent soluble dietary fiber. Finger millet comprises 22.0 percent total dietary fiber, 19.7% insoluble dietary fiber, and 2.5 percent soluble dietary fiber (Shobana and Malleshi 2017). Dietary fibers are divided into soluble and insoluble fibers, as we all know (Arya and Bisht 2022).

According to studies, eating a high-fiber diet improves bowel function and lowers the incidence of obesity by increasing digestion and absorption in the body, lowering the risk of chronic illnesses. Millets aid in weight control and the reduction of obesity by satiating appetite. Millets' high fiber content aids in the relief of constipation, gas, bloating, and stomach cramps. The retention of gastrointestinal diseases such as ulcers and colon cancers can be reduced with proper digestion and absorption (Reddy 2017; Arya and Bisht 2022).

CVD (Cardio Vascular Disease): Kodo Millets demonstrated that eating porso-millet protein concentrate influenced plasma lipid levels, with plasma high-density lipoprotein cholesterol and adiponectin levels notably raised (Kyung-Hye et al. 2015). Kodo millets are also high in magnesium, which has been linked to a lower risk of a heart attack. Millets are high in phytochemicals, including phytic acid, which helps reduce cholesterol and prevent cardiovascular disease by decreasing plasma triglycerides (Lee et al. 2010). According to studies, eating whole millet grains daily lowers the risk of cardiovascular disease. Kodo Millets are one of the greatest grains to include in your diet if you want to protect your heart, which is a concern that everyone has. Magnesium, which is abundant in Kodo Millet, is a vital element for lowering blood pressure and reducing the risk of heart attacks and strokes, especially in the case of atherosclerosis. Millets are also high in potassium, which acts as a vasodilator to lower blood pressure even further. They produce enterolactone, a substance that has been shown to protect against heart disease and several types of breast cancer when fermented (Reddy 2017; Arya and Bisht 2022).

Figure 2: Role of Kodo millets in CVD



Cancer: The antinutrients phenolic acids, phytates, and tannins found in Kodo Millets have been shown to help reduce the risk of colon and breast cancer. The phenolics in Kodo millet are effective in preventing cancer development and progression *in vitro*. Disrupting agents, in particular, prevent cancer from starting by preventing cellular target molecules, such as DNA, from interacting. In a study, phenolic extracts from Kodo millet inhibited the growth of human colon adenocarcinoma cells HT-29 in a time and dose-dependent manner (Chandrasekara and Shahidi 2011). Kodo millets contain linoleic acid, which has anti-tumor properties. Sorghum is widely known for its anti-carcinogenic properties. Polyphenols and tannins present in sorghum have anti-mutagenic and anti-carcinogenic characteristics and can work against human melanoma cells as well as advantageous melanogenic activity (Grimmer et al. 1992; Arya and Bisht 2022).

Sorghum intake was associated with a lower incidence of oesophageal cancer in China and other areas of the world (Rensburg 1981). The scientists investigated 21 villages in each nation over six years and discovered that sorghum intake was associated with reduced oesophageal cancer mortality than wheat and maize consumption. Many of the antioxidants contained in millets may clear up other toxins in your body, such as those in your kidney and liver, in addition to their positive effect on neutralizing free radicals, which can cause cancer. By encouraging appropriate excretion and neutralizing enzymatic activity in those organs, quercetin, curcumin, ellagic acid, and other helpful catechins can assist to clear your system of any external agents and poisons (Reddy 2017; Arya and Bisht 2022).

Celiac Disease: Celiac disease is a genetically predisposed illness brought on by gluten consumption. Since Kodo millets are used to help reduce celiac disease by reducing pain caused by gluten-containing cereal grains, they are gluten-free (Saleh et al. 2013). Regulating the digestive system can help with nutrition retention and reduce the chance of more serious gastrointestinal issues like gastric ulcers or colon cancer. Fiber content in Kodo millets aids in the elimination of diseases such as constipation, excessive steam, bloating, and cramps (Arya and Bisht 2022).

Celiac disease is an immune-mediated enteropathic illness that is often caused by gluten consumption in susceptible individuals (Catassi and Fasano 2008). In the grain food community, a gluten-free diet has a significant impact on food consumption. It can help gluten-free dieters replace gluten-containing grains like wheat, barley, and rye with gluten-free grains including rice, maize, sorghum, millet, amaranth, buckwheat, quinoa, and wild rice (Thompson 2009). Because Kodo millets are gluten-free, they have a lot of food and beverage potential. They'll help fulfill the growing demand for gluten-free meals and would be perfect for celiac disease sufferers (Arya and Bisht 2022).

Wound healing: Under ether anesthesia, a 4 cm2 (2 x 2 cm) excision incision on the shaved back of rats were made to test the effect of Kodo millet on rat dermal wound healing. For 16 days, finger millet or Kodo millet flour (300 mg) was administered topically once a day as an aqueous paste. Some biochemical parameters such as protein, DNA, collagen, and lipid peroxides were estimated using the granulation tissue produced on days 4, 8, and 12. Protein and collagen content increased significantly, whereas lipid peroxides decreased significantly. Biophysical factors such as contraction rate and epithelialization time were also investigated. In Kodo millet and finger millet-treated rats, the rate of contraction was 88-90 percent, compared to 75 percent in untreated rats. In comparison to untreated (16 days) rats, finger millet (13 days) and Kodo millet (14 days) treated rats required fewer days to complete wound closure. The findings suggest that finger millet and Kodo millet may have a therapeutic effect in speeding wound healing (Hedge et al. 2005; Arya and Bisht 2022).

DNA scission inhibitory activity: The initial stage in many biological situations, such as cancer and aging, is the irreversible change of DNA as a result of oxidative stress. Base changes, the formation of base-free sites, DNA-protein cross-linkages, strand breakage, and aberrant chromosomal architecture are all examples of free radical-mediated DNA damage (Valko et al. 2004; Arya and Bisht 2022). The hydroxyl radical may extract hydrogen from the deoxyribose sugar moiety as well as pyrimidine and purine DNA bases, resulting in single strands. Breaks in the double strand that occur on both strands near each other might be caused by hydroxyl radical assaults, which could result in cell death. Two dosages of raw phenolic derivatives (0.25 and 0.5 mg/mL) were tested for free radical-mediated DNA strand scission prevention and the percentage of supercoiled DNA retention was measured in a study done by Chandrasekara and Shahidi (2010). Peroxyl and hydroxyl radicals both damage DNA strands, according to the research. Antioxidants and many other methods have proven polyphenols to be chemopreventive (Fresco et al. 2006; Zgórka et al. 2022). Millet grain phenolic extracts, in particular, have proved to be effective. DNA scission was produced by the inhibitory effect against peroxyl radical at both doses examined. Kodo millet inhibited DNA breaking completely and was comparable to 0.5 mg/mL ferulic acid in this regard. It's worth noting that Kodo millet's inhibitory behavior against peroxyl radical-mediated DNA split was the same (97 percent) (Fresco et al. 2006; Zgórka et al. 2022).

Madhujith and Shahidi (2007) earlier reported that phenolic extract of barley grains suppressed DNA break caused by peroxyl radicals. At a concentration of 4 mg/mL, supercoiled DNA scission-induced peroxyl radical inhibition of barley extract ranged from 78 to 92 percent. Supercoiled DNA retention toward hydroxyl radical driven oxidation ranged from 30% to 90% in the presence of Kodo millet grain extracts. It has been found that a similar quantity of Kodo millet extract (0.5 mg/mL) suppressed DNA breaking induced peroxyl radicals 2-3 times more than hydroxyl radicals. Madhujith and Shahidi (2007) found that phenolic extracts of several barley varieties were considerably more effective against DNA scission inhibition induced by peroxyl radicals than hydroxyl radicals. Parallel to the reaction with purine and pyrimidine bases, the deoxyribose backbone of the DNA molecule can be treated with a hydroxyl radical, resulting in few commodities with oxidative (Arya and Bisht 2022).

To prevent supercoiled DNA breaking induced by hydroxyl radicals and therefore inhibit the formation of hydroxyl radicals, two ways of chelating Fe ions are required to begin and catalyze the breakdown of H_2O_2 or the scavenging of H_2O_2 itself are required. The capacity of phenolic compounds to scavenge hydroxyl radicals produced in the system is the second mechanism. Two types of Kodo millet were effective metal chelators. In previous research, we discovered that phenolic extracts from Kodo millet effectively scavenge H_2O_2 and hydroxyl radicals *in vitro* systems (Chandrasekara and Shahidi 2011; Arya and Bisht 2022).

High fat diet-induced metabolic alterations: The underlying adiposity of chronic low-grade inflammation is one of the most important interaction services that contribute to comorbidities such as insulin resistance, diabetes type II, and hepatosteatosis (Asrih and Jornayvaz 2013). The recent alarming increase in the incidence of obesity highlights the need for strategies, resources, prevention, and preventative measures to manage this burden. In this regard, the search for new functional foods and dietary patterns that may be able to cure or prevent obesity has exploded (Baboota et al. 2013; Arya and Bisht 2022).

Increased intake of whole-grain cereals is a significant improvement in daily eating habits and has been shown to improve the body's metabolic profile. The polyphenol and dietary fiber content of these cereals are largely focused on, but not limited to, their health advantages (Baboota et al. 2013). Millets appear to have higher nutritional content than big grains in terms of phenolic acids, dietary fibers, and antioxidant capabilities (Kumar et al. 2018). KM is more effective at quenching free radicals than wheat and rice, the world's most popular cereals. When compared to rice products, KM food items have lower TG and C-reactive protein levels. kM has also been shown to provide a variety of health advantages, including glucose-lowering, wound-healing, and anti-obesity effects. However, research work is done on the role of millet polyphenols, particularly KM, in preventing HFD-induced obesity and other abnormalities. Kodo millet is well-known for its numerous health advantages. A polyphenol-rich extract from them has been shown to have antioxidant and hypoglycemic properties in several investigations (Arya and Bisht 2022).

Nonetheless, the protective role of a polyphenol-rich extract from Kodo millets in combating obesity caused by a high-fat diet has yet to be studied. Khare et al. (2020), investigated the role of polyphenol-rich extracts in decreasing lipopolysachharides-induced inflammation in murine macrophage cells and attenuating high-fat diet-induced metabolic complications in Swiss albino male mice in research. The results showed that polyphenol-rich extracts from Kodo millets had a greater polyphenol content, which prevented obesity. Furthermore, the polyphenol-rich extracts from Kodo millets were more effective in preventing weight gain, hepatic steatosis, diabetes, hypertrophy of adipose tissue & systemic inflammation (Khare et al. 2020).

According to the findings, polyphenol-rich extracts from Kodo millets might be utilized to make functional diets or nutraceuticals to combat obesity and comorbidities (Khare et al. 2020). The microbiota of the gut has a key role in obesity and the inflammatory diseases that accompany it. In research done by Khare et al. (2020), the caecal material showed a greater percentage of Bacteroidetes to Firmicutes with KM-PRE, which is believed to be an indication of weight reduction. Furthermore, KM-PRE fed mice had low levels of LPS in their circulatory system, but HFD fed mice exhibited higher levels (Magne et al. 2020).

LPS is produced in the gastrointestinal tract by Gram-negative bacteria, particularly pathogenic types linked to dysbiosis in the gut microbiota, and is transported to the bloodstream in obese animals and humans owing to weakened gut barrier function (Chakaroun et al. 2020). This systemic LPS has been proven to promote low-grade inflammation in obesity and related comorbidities. 40 KM-PRE protected against the degradation of gut barrier control caused by HFD feeding by avoiding these negative alterations. Nutritional phenols are found as glycoside conjugates that are converted into physiologically active aglycones by gut bacteria and free sugar could have been used to encourage SCFAs by gut bacteria (Duda-Chodak et al. 2015).

In one research, KM-PRE, a marker of increased gut bacterial dysbiosis, restored the decrease in propionic acid produced by the HFD. Some polyphenols or polyphenol-rich extracts have been shown to activate Bifidobacteria and Lactobacilli, while others have been shown to stimulate *Akkermansia muciniphila*, the primary bacterial actors in HFD-induced obesity (Ley et al. 2006). The expression of PPAR and SREBP-1c in the vWAT of mice fed with KM-PRE was shown to be lower. This is attributed to the Mitigation of adipocyte hypertrophy and hyperplasia, as apparent from histology, which induces greater PPARγ expression, C/EBP-alpha and SREBP-1c the indicators of diet mediated obesity (Moseti et al. 2016).

Polyphenols like coumaric acid, quercetin, catechin, chlorogenic acid, resveratrol, and curcumin have been shown to reduce PPAR synthesis and efficiently respond to insulin, according to Khare et al. 2020. 44-46 SREBP-1c expression has been linked to an increase in hepatic lipid buildup. In a biochemical study conducted by KM-PRE, reversing the HFD resulted in a rise in liver SREBP-1c expression as well as a decrease in liver lipid, indicating that it has a favorable influence on hepatic steatosis as well as enhanced insulin sensitivity. The KM-PRE-PR treatment reversed HFD-induced glucokinase and G6Pase levels in the liver, as well as the HOMA-IR and QUICKI indices further, confirms this finding (Magne et al. 2020).

CONCLUSION

The findings of the present study revealed that the Kodo Millets are nutritionally dense when compared to the number of grains consumed. They have a greater mineral content when compared to rice and wheat. Some of them weigh fifty times as much as rice. Finger millet contains thirty times the calcium content of rice, whereas every other millet has at least half the calcium content. Rice isn't even close to the competition when it comes to iron content, thanks to the abundance of foxtail and small millet. Even the most fortunate rice, ironically, lacks this critical vitamin.

ACKNOWLEDGMENTS

The the necessary facilities for this study were provided by the Faculty of Biosciences, Institute of Bio-Sciences and Technology, Shri Ramswaroop Memorial University, Barabanki, Uttar Pradesh, India.

Conflict of Interests: Authors declare no conflicts of interests to disclose.

REFERENCES

Abotaleb, M., Liskova, A., Kubatka, P., et al. (2020). Therapeutic potential of plant phenolic acids in the treatment of cancer. Biomolecules, 10(2), 221.

Alfieri, M. A. H., Pomerleau, J., Grace, D. M., et al. (1995). Fiber intake of normal weight, moderately obese, and severely obese subjects. Obesity Research, 3(6), 541-547.

Amadou, I., Gounga, M. E., and Le, G. W. (2013). Millets: Nutritional composition, some health benefits and processing-A review. Emirates Journal of Food and Agriculture, 501-508.

Arya, C., and Bisht, A. (2022). Small Millets: Path to Food and Nutrition Security. In Small Millet Grains. Springer, Singapore, pp. 161-190.

Asrih, M., and Jornayvaz, F. R. (2013). Inflammation as a potential link between nonalcoholic fatty liver disease and insulin resistance. J Endocrinol, 218(3), R25-36.

Augustin, L. S., Franceschi, S., Jenkins, D. J. A., et al. (2002). Glycemic index in chronic disease: a review. European journal of clinical nutrition, 56(11), 1049-1071.

Baboota, R. K., Bishnoi, M., Ambalam, P., et al. (2013). Functional food ingredients for the management of obesity and associated co-morbidities–A review. Journal of Functional Foods, 5(3), 997-1012.

Baghele, M., Mishra, S., Meyer-Rochow, V. B., et al. (2021). Utilization of snails as food and therapeutic agents by Baiga tribals of Baihar tehsil of Balaghat District, Madhya Pradesh, India. International Journal of Industrial Entomology, 43(2), 78-84.

Bhat, S., Nandini, C., and Tippeswamy, V. (2018). Significance of small millets in nutrition and health-A review. Asian Journal of Dairy and Food Research, 37(1), 35-40.

Brand-Miller, J., Hayne, S., Petocz, P., et al. (2003). Low–glycemic index diets in the management of diabetes: a meta-analysis of randomized controlled trials. Diabetes care, 26(8), 2261-2267.

Catassi, C., and Fasano, A. (2008). Celiac disease. Gluten-free cereal products and beverages, 1-I.

Chakaroun, R. M., Massier, L., and Kovacs, P. (2020). Gut microbiome, intestinal permeability, and tissue bacteria in metabolic disease: perpetrators or bystanders?. Nutrients, 12(4), 1082.

Chandrasekara, A., and Shahidi, F. (2010). Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. Journal of agricultural and food chemistry, 58(11), 6706-6714.

Chandrasekara, A., and Shahidi, F. (2011). Inhibitory activities of soluble and bound millet seed phenolics on free radicals and reactive oxygen species. Journal of Agricultural and Food Chemistry, 59(1), 428-436.

Chethan, S., and Malleshi, N. G. (2007). Finger millet polyphenols: Characterization and their nutraceutical potential. American Journal of Food Technology, 2(7), 582-592.

Coulibaly, A., Kouakou, B., and Chen, J. (2011). Phytic acid in cereal grains: structure, healthy or harmful ways to reduce phytic acid in cereal grains and their effects on nutritional quality. American Journal of Plant Nutrition and fertilization technology, 1(1), 1-22.

Duda-Chodak, A., Tarko, T., Satora, P., et al. (2015). Interaction of dietary compounds, especially polyphenols, with the intestinal microbiota: a review. European journal of nutrition, 54(3), 325-341.

Faruqui, S. H. A., Du, Y., Meka, R., et al. (2019). Development of a deep learning model for dynamic forecasting of blood glucose level for type 2 diabetes mellitus: secondary analysis of a randomized controlled trial. JMIR mHealth and uHealth, 7(11), e14452.

Fresco, P., Borges, F. I. G. M., Diniz, C., et al. (2006). New insights on the anticancer properties of dietary polyphenols. Medicinal research reviews, 26(6), 747-766.

Gopalan, A. B., Yuwen, T., Kay, L. E., et al. (2018). A methyl 1 H double quantum CPMG experiment to study protein conformational exchange. Journal of biomolecular NMR, 72(1), 79-91.

Grimmer, H. R., Parbhoo, V., and McGrath, R. M. (1992). Antimutagenicity of polyphenol-rich fractions from sorghum bicolor grain. Journal of the Science of Food and Agriculture, 59(2), 251-256.

Hegde, P. S., Anitha, B., and Chandra, T. S. (2005). In vivo effect of whole-grain flour of finger millet (*Eleusine coracana*) and kodo millet (*Paspalum scrobiculatum*) on rat dermal wound healing. Indian Journal of Experimental Biology, 43(3), 254-258.

Hill, K. D., Baldwin, H. S., Bichel, D. P., et al. (2020). Rationale and design of the STeroids to REduce Systemic inflammation after infant heart Surgery (STRESS) trial. American heart journal, 220, 192-202.

Yazanabadi, F.I., Esmaeilpour, U., Behdani, M. A., et al. (2015). Hepatotoxicity in sheep and goats caused by experimental feeding with foxtail millet (*Setaria italica*). Iranian Journal of Veterinary Medicine, 9(2), 79-86.

Kamal, A. (2014). Qualitative phytochemical analysis of *Madhuca longifolia*. Indian J Plant Sci, 3(4), 38-41.

Khare, P., Maurya, R., Bhatia, R., et al. (2020). Polyphenol rich extracts of finger millet and kodo millet ameliorate high fat diet-induced metabolic alterations. Food and Function, 11(11), 9833-9847.

Krishnan, R., Dharmaraj, U., and Malleshi, N. G. (2012). Influence of decortication, popping and malting on bioaccessibility of calcium, iron and zinc in finger millet. LWT-Food Science and Technology, 48(2), 169-174.

Kulkarni, V. N., Rai, K. N., Dakheel, A. J., et al. (2006). Pearl millet germplasm adapted to saline conditions. International Sorghum and Millets Newsletter, 47, 103-106.

Kumar, A., Tomer, V., Kaur, A., et al. (2018). Millets: a solution to agrarian and nutritional challenges. Agriculture and food security, 7(1), 1-15.

Kumar, D., Patel, S., Naik, R. K., et al. (2016). Study on physical properties of indira kodo-I (*Paspalum scrobiculatum* L.) millet. International Journal of Engineering Research and Technology.

Kyung-Hye, S., Ji-Eun, R., Lee, S. J., et al. (2015). Anti-hyperglycemic activity of polyphenols isolated from barnyard millet (Echinochloa utilis L.) and their role in

inhibiting α-glucosidase. Applied Biological Chemistry, 58(4), 571-579.
Lee, S. H., Chung, I. M., Cha, Y. S., et al. (2010). Millet consumption decreased serum concentration of triglyceride and C-reactive protein but not oxidative status in hyperlipidemic rats. Nutrition Research, 30(4), 290-296.
Ley, R. E., Turnbaugh, P. J., Klein, S., et al. (2006). Human gut microbes are associated with obesity. nature, 444(7122), 1022-1023.
Liu, X., Li, X., Xia, B., et al. (2021). High-fiber diet mitigates maternal obesity-induced cognitive and social dysfunction in the offspring via gut-brain axis. Cell metabolism, 33(5), 923-938.
Liu, Y., Zhao, T., Ju, W., et al. (2017). Materials discovery and design using machine learning. Journal of Materiomics, 3(3), 159-177.
Ludwig, D. S., Majzoub, J. A., Al-Zahrani, A., et al. (1999). High glycemic index foods, overeating, and obesity. Pediatrics, 103(3), e26-e26.
Madhujith, T., and Shahidi, F. (2007). Antioxidative and antiproliferative properties of selected barley (Hordeum vulgarae L.) cultivars and their potential for inhibition of low-density lipoprotein (LDL) cholesterol oxidation. Journal of Agricultural and Food Chemistry, 55(13), 5018-5024.
Magne, F., Gotteland, M., Gauthier, L., et al. (2020). The Firmicutes/Bacteroidetes ratio: a relevant marker of gut dysbiosis in obese patients?. Nutrients, 12(5), 1474.
Marciani, D. J., Press, J. B., Reynolds, R. C., et al. (2000). Development of semisynthetic triterpenoid saponin derivatives with immune-stimulating activity. Vaccine, 18(27), 3141-3151.
Mohan, V., Sharp, P. S., Cloke, H. R., et al. (1986). Serum immunoreactive insulin responses to a glucose load in Asian Indian and European type 2 (non-insulin-dependent) diabetic patients and control subjects. Diabetologia, 29(4), 235-237.
Moseti, D., Regassa, A., and Kim, W. K. (2016). Molecular regulation of adipogenesis and potential anti-adipogenic bioactive molecules. International journal of molecular sciences, 17(1), 124.
Naczk, M., and Shahidi, F. (2004). Extraction and analysis of phenolics in food. Journal of chromatography A, 1054(1-2), 95-111.
Nazaruk, J., and Borzym-Kluczyk, M. (2015). The role of triterpenes in the management of diabetes mellitus and its complications. Phytochemistry Reviews, 14(4), 675-690.
Neelam, Y., Kanchan, C., Alka, S., et al. (2013). Evaluation of hypoglycemic properties of kodo millet based food products in healthy subjects. J Pharm, 3, 14-20.
Pradesh, H. (2011). Geographical area in 1972-73 to only 19 per cent in 1999-2000. The. Socio-economic Profile of Rural India (series II).: North and central India (Punjab, Haryana, Himachal Pradesh and Madhya Pradesh), 5, 212.
Radhika, G., Van Dam, R. M., Sudha, V., et al. (2009). Refined grain consumption and the metabolic syndrome in urban Asian Indians (Chennai Urban Rural Epidemiology Study 57). Metabolism, 58(5), 675-681.
Ratnavathi, C. V. (2017). Nutritional Qualities and Value Addition of Millets. Millets and Sorghum: Biology and Genetic Improvement, 323-340.
Reddy, O. S. K. (2017). Smart Millet and Human Health. Green Universe Environmental Services Society.
Saleh, A. S., Zhang, Q., Chen, J., et al. (2013). Millet grains: nutritional quality, processing, and potential health benefits. Comprehensive reviews in food science and food safety, 12(3), 281-295.
Sharma, A., Sharma, P., Tuli, H. S., et al. (2018). Phytochemical and pharmacological properties of flavonols. eLS, 1-12.
Sharma, S. K., and Mandhyan, B. L. (1992). Engineering, milling and hydration properties of kodo. Indian Journal of Agricultural Engineering (India).
Sharma, S., Saxena, D. C., and Riar, C. S. (2017). Using combined optimization, GC–MS, and analytical technique to analyze the germination effect on phenolics, dietary fibers, minerals, and GABA contents of Kodo millet (*Paspalum scrobiculatum*). Food chemistry, 233, 20-28.
Shobana, S., and Malleshi, N. G. (2007). Preparation and functional properties of decorticated finger millet (*Eleusine coracana*). Journal of Food Engineering, 79(2), 529-538.
Singh, J. P., Kaur, A., Shevkani, K., et al. (2016). Composition, bioactive compounds, and antioxidant activity of common Indian fruits and vegetables. Journal of food science and technology, 53(11), 4056-4066.
Tadele, Z. (2016). Drought adaptation in millets (pp. 639-662). InTech.
Thompson, T. (2009). The nutritional quality of gluten-free foods. Gluten-free food science and technology, 1, 16-27.
Valko, M., Izakovic, M., Mazur, M., et al. (2004). Role of oxygen radicals in DNA damage and cancer incidence. Molecular and cellular biochemistry, 266(1), 37-56.
van Rensburg, S. J. (1981). Epidemiologic and dietary evidence for a specific nutritional predisposition to esophageal cancer. Journal of the National Cancer Institute, 67(2), 243-251.
Vijayalakshmi, P., and Radha, R. (2006). Effect of little millet supplementation on hyperlipidemia. Ind J Nutr Dietet, 43, 469.
Zgórka, G., Maciejewska-Turska, M., Makuch-Kocka, A., et al. (2022). *In Vitro* Evaluation of the Antioxidant Activity and Chemopreventive Potential in Human Breast Cancer Cell Lines of the Standardized Extract Obtained from the Aerial Parts of Zigzag Clover (*Trifolium medium* L.). Pharmaceuticals, 15(6), 699.
Zhang, G., and Hamaker, B. R. (2009). Slowly digestible starch: concept, mechanism, and proposed extended glycemic index. Critical reviews in food science and nutrition, 49(10), 852-867.