Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 24(12): 25355-25375 https://doi.org/10.18697/ajfand.137.25025

Date	Submitted	Accepted	Published
	14th June 2024	16th September 2024	16th December 2024

A COMPREHENSIVE STUDY OF NUTRITIONAL PROFILE, ANTIOXIDANT ACTIVITY AND PHYTOCHEMICAL PROPERTIES OF INDIGENOUS INDIAN MILLETS

Mishra S[1] and R Singh[1]*

Sunita Mishra

Rajani Singh

*Corresponding author email: rajani.rs.fn@email.bbau.ac.in

[1]Department of Food and Nutrition, School of Home Science, Babasaheb Bhimrao Ambedkar University, Lucknow, 226026, India

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

The goal of the present study was to thoroughly examine the nutritional makeup, antioxidant activity, and various phytochemical contents of several millet flours, including ragi, bajra, kodo, kangni, and jowar. These millet types are increasingly being recognized as potential sources of functional and nutraceutical ingredients. The research started with the collection of selected millet grains, which were washed, soaked overnight, dried in the sun, and then ground into flour. The nutritional makeup of these millet flours was analyzed using standard AOAC methods. The antioxidant activity was assessed using DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity at five different concentrations, and the 50% inhibitory concentration (IC50) was determined using linear regression. The study outcomes showed considerable variations in the nutritional and phytochemical properties of various millet flours. Specifically, kangni millet flour exhibited the highest protein content at 13.56±0.05 grams per 100 grams, while ragi millet flour was found to be the top source of calcium, amounting to 576.19±0.032 milligrams per 100 grams. Furthermore, ragi (38.20±0.85 milligrams per 100 grams) and bajra (15.34±0.47 milligrams per 100 grams) millet flours displayed significantly higher iron content compared to the other millets that were examined. In terms of its antioxidant properties, jowar millet flour demonstrated the greatest ability to scavenge DPPH radicals, followed by ragi, bajra, kodo and kangni. The total phenolic content (TPC), which is a measure of the antioxidant potential, was highest in jowar millet flour (19.70±0.60 mg gallic acid equivalents (GAE)/100g), while kodo millet flour had the highest total flavonoid content (29±0.54 mg quercetin equivalents (QE)/100g). According to the study, millet flours are excellent sources of essential nutrients and possess abundant antioxidant properties with good radical scavenging activity. The researchers recommended using these millet flours in the development of functional foods, which can contribute to a healthier lifestyle and potentially help prevent or treat various degenerative diseases.

Key words: Millets, proximate content, nutritional content, mineral content, DPPH, phytochemical, antioxidants

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Millets, small-seeded grains of the Poaceae family, have been cultivated for millennia and play a crucial role in global food security, particularly in the arid and semi-arid regions of Africa and Asia. These versatile grains are classified into various species, including pearl millet (*Pennisetum glaucum*), foxtail millet (*Setaria italica*), finger millet (*Eleusine coracana*), kodo millet (*Paspalum scrobiculatum*), proso millet (*Panicum miliaceum*), small millet (*Panicum sumatrense*), Sorghum (*Sorghum bicolor*), and barnyard millet (*Echinochloa utilis*) [1]. Each millet variety exhibits distinct characteristics and nutritional profiles, contributing to its diverse applications in human consumption, animal feed, and industrial utilization.

The resilience of millets to adverse environmental conditions has conferred upon them the designation of climate-resilient crops. These grains demonstrate robust growth in environments characterized by elevated temperatures, low soil fertility, and limited water-holding capacity [2]. This adaptability renders millets particularly valuable in the context of climate change and increasing water scarcity because they can produce consistent yields under conditions where other cereal crops might fail. Furthermore, the abbreviated growing season and capacity to withstand extended periods of drought make them a viable option for agriculturalists in regions with unpredictable precipitation patterns.

The nutritional composition of millets is one of their most important characteristics, resulting in their classification as nutri-cereals and natural nutraceuticals [3, 4, 5, 6]. Millets are abundant sources of essential nutrients, including energy, proteins, fatty acids, minerals (such as calcium, iron, potassium, magnesium, and zinc), vitamins (including niacin, B6 and folic acid), dietary fiber, essential amino acids (particularly sulfur-containing ones), and various phytochemicals (for example, phytate, polyphenols, and antioxidants). This diverse array of nutrients contributes to the numerous health benefits associated with millet consumption.

Pearl millet (*Pennisetum glaucum*) is the predominant cultivated millet variety, constituting approximately 46% of the total global production [7]. Other minor millets, including little millet, Japanese barnyard millet, foxtail millet, and teff millet, also contribute substantially to overall millet production and exhibit nutritional profiles comparable to those of other cereal grains. The nutritional composition of millets is typically comprising 1.5–5% fat, 7.1–11% proteins, 2.7–7% crude fiber, and 60–70% carbohydrates [8]. This balanced nutrient profile renders millet a valuable source of energy, comparable to that of other cereal grains.

In addition to their macro and micronutrient contents, millets contain various bioactive compounds that contribute to their health-promoting properties. These include polyphenols, phytates, and other phytochemicals that are associated with

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

numerous health benefits [9]. Millet consumption has been correlated with cancer and cardiovascular disease prevention, tumor incidence reduction, blood pressure regulation, decreased risk of heart disease, modulation of cholesterol and lipid absorption, delayed gastric emptying, and enhanced gastrointestinal health through increased bulk provision.

One of the distinctive advantages of millet is its hypoallergenic and non-glutinous nature, rendering it suitable for individuals with gluten sensitivity or celiac disease [10]. Furthermore, their non-acid-producing properties and ease of digestibility contribute to their classification as nutraceuticals, emphasizing their potential as functional foods with nutritional and therapeutic benefits.

India has long been a significant global millet producer. However, despite the numerous advantages of millet cultivation, the area under production has gradually decreased since the green revolution [11, 12]. This decline can be attributed to various factors, including shifts in dietary preferences, government policies favouring other crops, and the perception of millet as a food source associated with lower socioeconomic status. Notably, while the harvested area of millet in India has declined, its output has remained relatively consistent at approximately 10 million tons on average, suggesting improvements in cultivation techniques and yields.

Notwithstanding the numerous advantages of millet, including its nutritional profile, climate resilience, and potential health benefits, there remains a limited understanding of the full spectrum of bioactive compounds in different millet varieties and their specific health effects. Furthermore, the decline in millet cultivation area since the Green Revolution, particularly in major producing countries such as India, underscores the necessity for strategies to promote millet consumption and production. This study aimed to address these gaps by conducting a comprehensive analysis of the nutritional profiles of various millet species, focusing on their bioactive compounds and potential health benefits, and exploring strategies to promote millet consumption and production. Through this investigation, this research endeavours to contribute to a more comprehensive understanding of millet's potential in addressing global food security, nutrition, and sustainability challenges, ultimately leveraging their nutritional and environmental benefits to reverse the trend of declining cultivation.

MATERIALS AND METHODS

Procurement and processing of millets

All the five Millets viz. Ragi Millet (Finger millet), Bajra Millet (Pearl Millet), Kodo Millet (Cow Grass Millet), Jowar Millet (Sorghum), and Kangni Millet (Foxtail Millet) were collected from the "Millet Mela" organized in the "Chatori Gali" of Lucknow,

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Uttar Pradesh, India. It was procured and sold by the local vendor named "Shree Anna" in the Millet Fair.

Processing of the millets

All the five selected millet samples (Ragi, Bajra, Kodo, Kangni and Jowar) were processed and analyzed in the food laboratory of Department of Food and Nutrition. The following steps are involved in the processing of the millets.

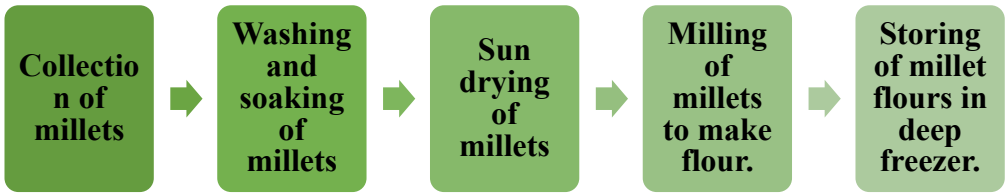

Figure 1: Processing of millets

Proximate analysis

Proximate composition of all the selected millet flours was done using (AOAC) standard methods such as moisture oven-drying method [13], ash-charring method [14] protein- kjeldhal method [15], crude fiber acid-base extraction method [16], and fat-soxlet extraction method [17]. Carbohydrate content was calculated by subtracting the total of moisture, fat, protein and ash from 100.

Mineral analysis by ICP-OES

To determine the mineral content of the millet flours, a comprehensive methodology involving sample preparation, acid digestion, dilution, filtration, and elemental analysis using inductively coupled plasma-optical emission spectroscopy (ICP-OES, Agilent 5800) was implemented to quantify the major minerals (Ca, Mg and K) and trace minerals (Zn, Mn and Fe) in the digested samples of the millet flours. The procedure commenced with pulverization of the millet flour samples into a fine powder, followed by acid digestion using concentrated HNO_3 and H_2O_2 in a microwave digestion system. After digestion, the samples were diluted, filtered, and analysed via ICP-OES to quantify the concentrations of the targeted macro- and micronutrients. The mineral content was subsequently calculated based on the ICP-OES results and the initial sample mass, with the results expressed in appropriate units for each element detected. Quality control measures, including the use of blank samples and certified reference materials, were implemented to ensure analytical accuracy and precision.

DPPH radical scavenging activity

All the selected processed millet flour extract was tested for 1,1 -diphenyl- 2 -picrylhydrazyl (DPPH) free radical scavenging activity as given by Phushpraj and Urooj [18]. In brief, a 0.1 mM methanolic DPPH solution (4 mL) was mixed with 1 mL of various sample concentrations. The mixture was vortexed and kept at room

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

temperature for 30 minutes in the dark. The absorbance of the solutions was measured at 517 nm with a spectrophotometer and a suitable blank. The activity was calculated with the following formula:

$$\text{DPPH scavenging activity (\%)} = \frac{A_0 - A_1}{A_0} \times 100$$

Where, A_0 = Absorbance of control, and A_1 = Absorbance of sample.

Standard testing utilized 1.0 mL of ascorbic acid solutions (1-100 µg/mL) instead of sample extract. The IC50 (Half Inhibitory Concentration) value in the DPPH free radical scavenging technique is the sample concentration that scavenges 50% of the DPPH free radical, calculated using logarithmic regression.

Phytochemical properties

Preparation of extract

With the little variation in the method given by Hassan et al [19] each sample of millet flours was dried separately, weighed and loaded in thimble and put inside the Soxhlet apparatus. They were then successively extracted with methanol by the hot Soxhlet extraction method. The apparatus was run for 72 hours till the coloured solvent appeared in the siphon for obtaining the crude extracts of the samples. After complete extraction, the solvent was evaporated in a rotary vacuum evaporated at 65°C under reduced pressure. The obtained extracts were then dried in a water bath. The dried extracts were sealed inside 20 ml sterilized culture tubes and stored in the refrigerator at 2-8°C for further analysis.

Determination of total phenolic content

The concentration of the phenolic compounds in the extract was quantified utilizing spectrophotometry. The Folin-Ciocalteu method was employed to quantify total phenolic content [1]. The reaction mixture comprised 1 ml of the extract and 9 ml of distilled water. Folin- Ciocalteu phenol reagent (1 mL) was added to the mixture and thoroughly homogenized. After 5 min, 10 ml of 7% Na_2CO_3 solution was introduced to the mixture. The final volume was adjusted to 25 ml. A series of gallic acid standard solutions (20, 40, 40, 60, 80 and 100 µg/ml) was prepared as previously described. The samples were incubated for 90 min at 30°C, and the absorbance of the test and standard solutions, along with a reagent blank, was measured at 550 nm using a UV-visible spectrophotometer. The total phenolic compound content was expressed as mg GAE/g of the extract.

Determination of total flavonoid content

Colorimetric assay was used to determine the total content of flavonoid with a little modification [20]. Using aluminium chloride for the reaction, the extract of 1 ml and distilled water of 4 ml was taken in a 10 ml flask, then 0.30 ml of 5 % sodium nitrite

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

and after 5 minutes, 0.3ml of 10 % aluminium chloride was mixed in the flask. Five minutes later, 2 ml of 1M NaOH was treated and diluted using 10 ml distilled water. A set of standard solutions of quercetin (20, 40, 60, 80 and 100µg/ml) were prepared as mentioned earlier. The absorbance was measured for test and standard solutions using reagent blank at 510nm wavelength by UV-Visible spectrophotometer. The total content of flavonoid was denoted as mg of QE/gm of extract.

Determination of total alkaloid content

With a slight modification published by Tambe and Bhambar [21], 1 mg of the extract was dissolved in dimethyl sulfoxide, and then 1 ml of 2N HCl was added and filtered. This solution was transferred to a separate funnel and 5 ml of bromocresol green solution was added, followed by 5 ml of phosphate buffer. The mixture was vigorously agitated with 1, 2, 3 and 4 ml of chloroform before being collected in a 10 ml volumetric flask and diluted to volume with chloroform. Reference standard solutions of atropine (20, 40, 60, 80 and 100µg/ml) were prepared using a previously reported method. A UV/visible spectrophotometer was used to measure the absorbance of the standard and test solutions at 470 nm on a reagent blank. The alkaloid content was expressed as mg of AE/g of extract.

Determination of total Saponin content

With a minor modification by Mora *et al.* [22], a calibration curve was constructed using saponins as the standard (CAS-No 8047-15-2) with a purity of 100%. Two milligrams of the standard were weighed on an analytical balance and dissolved in 70% ethanol. To determine the wavelength of maximum absorption, 1 mL of the standard solution and 3.5 mL of Liebermann-Burchard reagent (16.7% acetic anhydride in concentrated sulfuric acid) were added to the spectrophotometer and scanned between 325 and 600 nm. Dilutions (0-0.4 mg/mL) of the concentrated standard solution were prepared using the same solvent. After adding 1 mL of the reagent to each solution, the absorbance was measured after 30 min. The calibration curve was measured in triplicates.

Determination of total tannin content

The total tannin content was quantified using the Folin-Ciocalteu method. Approximately 0.1 ml of plant extract was introduced into a 10 ml volumetric flask containing 7.5 ml of distilled water, 0.5 ml of Folin-Ciocalteu phenol reagent, 1 ml of 35% Na_2CO_3 solution, and diluted to 10 ml with distilled water. The reagent mixture was thoroughly homogenized and maintained at 30°C for 30 min. A series of gallic acid solutions (20, 40, 60, 80 and 100 µg/ml) was prepared as previously described. The absorbance of the standard and test solutions was measured against a blank at 725 nm by using a UV-visible spectrophotometer. The total tannin content was reported in mg GAE/g of extract [21].

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Statistical analysis

Data were reported as mean ± S.D (standard deviation) and median for three replications, performed using Statistical Package for Social Sciences (SPSS) software (version 22.0.)

RESULTS AND DISCUSSION

Proximate composition

This study's analysis of Ragi millet flour's proximate composition revealed both similarities and differences when compared to other millet varieties documented in scientific literature.

The moisture level in ragi millet flour (5.71%) was found to be less than that of bajra (6.51%), kodo (6.12%), and kangni (6.51%) millets, but exceeded that of jowar (4.45%). Generally, a reduced moisture content suggests improved storage longevity.

Regarding ash content, ragi (1.97%) was similar to bajra (1.93%) and kodo (1.86%) millets, marginally lower than kangni (2.09%), and higher than jowar (1.72%). These findings indicate comparable mineral levels across the various millet types.

Ragi's fat content (2.34%) was lower in comparison to bajra (4.2%), kodo (5.02%), kangni (3.84%) and jowar (3.51%). While this reduced fat content may contribute to extended shelf life, it could potentially result in lower energy density.

The protein level in ragi (7.22%) was found to be less than that of bajra (10.6%), kodo (9.75%), kangni (13.56%) and jowar (9.08%). This suggests that ragi might not be as rich in protein as the other millet varieties examined. A study examined the crude fiber levels in several grains, including ragi, bajra, kodo, kangni, and jowar. The findings indicated that ragi had the greatest crude fiber content at 3.46%, with jowar coming in second at 2.36%. Bajra contained 1.95% crude fiber, while kangni and kodo had lower levels at 1.46% and 1.02%, respectively. The high fiber content found in ragi could potentially offer advantages for digestive health, a conclusion supported by research conducted by Vali pasha *et al.* [24]. The carbohydrate content of ragi (79.3%) was higher than that of bajra (74.81%), kodo (76.23%) and kangni (72.54%) but comparable to that of jowar (78.88%). This suggests that ragi could be a good energy source [25].

The varied nutritional content across different millet types highlights the importance of incorporating multiple millet varieties into one's diet for comprehensive nutrient consumption. The nutritional variations observed among millet species can be attributed to several factors, including genetic variability, environmental influences during cultivation, and the methods used for processing after harvest.

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

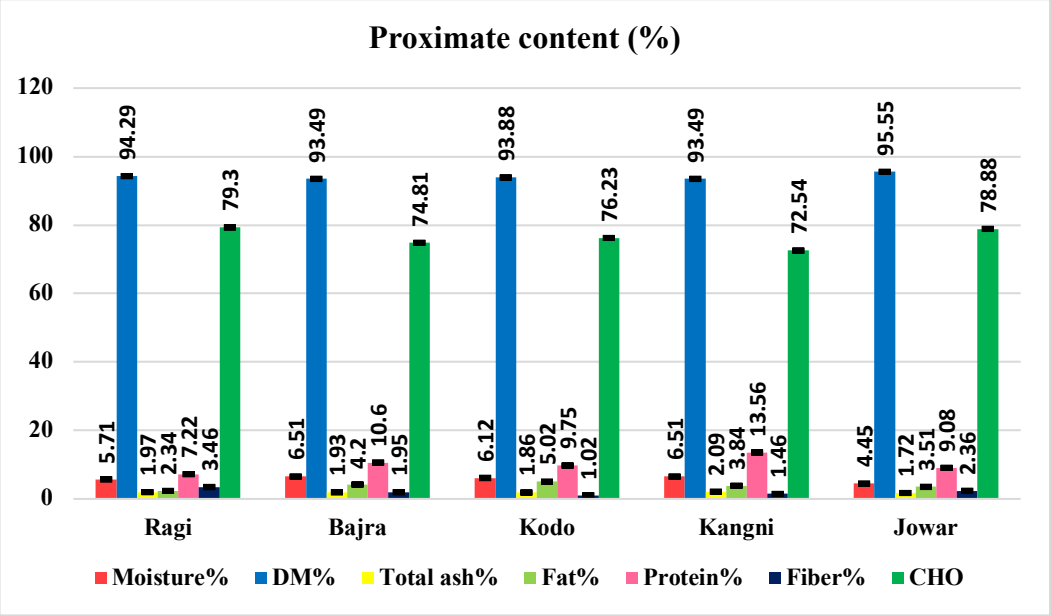

Figure 2: Proximate content of millet flours

Mineral composition

The analysis uncovered notable differences in mineral content among the various millet types, showcasing their distinct nutritional characteristics.

Calcium levels fluctuated considerably, with Ragi exhibiting the highest concentration (576.19 mg/100 g) and Bajra the lowest (56.96 mg/100 g). This marked disparity indicates Ragi's superiority as a calcium source among the examined millets.

Iron content showed significant variation, with Jowar containing the most (38.20 mg/100 g) and Kodo millet the least (9.82 mg/100 g). This observation suggests Jowar's potential as an excellent dietary iron source.

Magnesium was most abundant in Bajra (265.62 mg/100 g) and least in Kodo millet (157.25 mg/100 g), positioning Bajra as a key magnesium provider.

Manganese levels displayed a remarkable range, with Ragi containing exceptionally high amounts (74.73 mg/100 g) compared to other millets, while Bajra had the lowest concentration (2.69 mg/100 g).

Potassium was relatively abundant across all varieties, with Ragi and Jowar leading (855.27 mg/100 g and 734.11 mg/100 g, respectively) and Bajra showing the lowest level (806.37 mg/100 g).

Zinc was most prevalent in Bajra (8.53 mg/100 g) and least in Kodo millet (2.45 mg/100 g), highlighting Bajra's potential as a significant zinc source.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

These outcomes demonstrate the nutritional diversity among millet varieties and their capacity to substantially contribute to a mineral-rich diet, as noted by Deshpande *et al.* [26] in their research. The observed differences suggest that various millet types can be tactically incorporated into diets to address particular nutritional requirements or deficiencies. For example, Ragi is advised for calcium intake, Jowar for iron, and Bajra for zinc and magnesium.

These findings also underscore the importance of including multiple millet varieties in dietary planning to ensure a wide range of mineral intake. This variation in mineral composition highlights the value of millets as nutrient-dense alternatives to more common cereal grains, potentially leading to improved nutritional outcomes in populations that depend on these grains as staple foods.

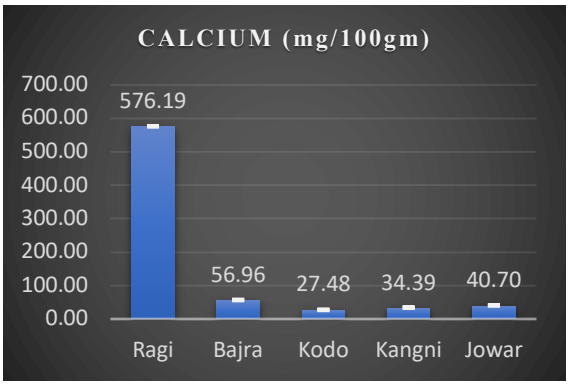

Figure 3: Calcium content of millet flours

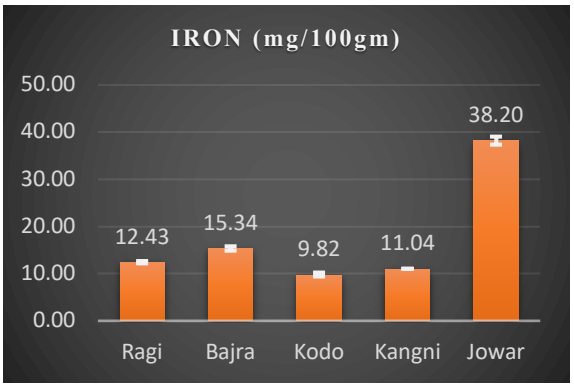

Figure 4: Iron content of millet flours

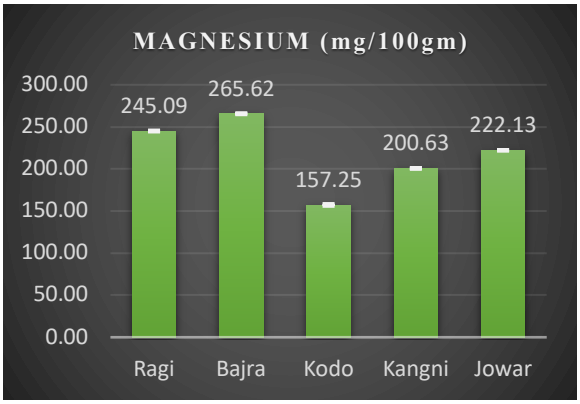

Figure 5: Magnesium content of millet flours

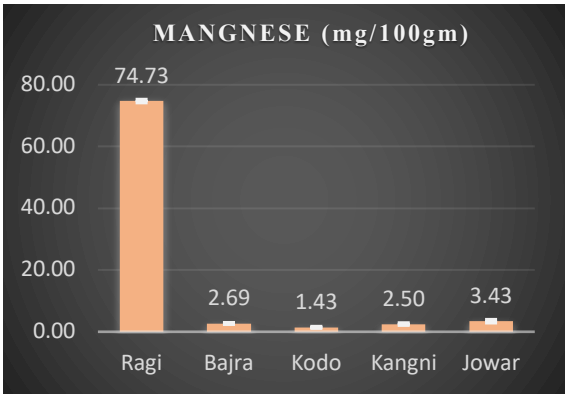

Figure 6: Mangnese content of millet flours

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

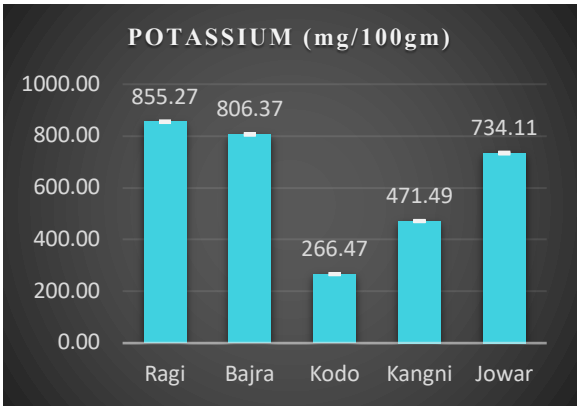

Figure 7: Potassium content of millet flours

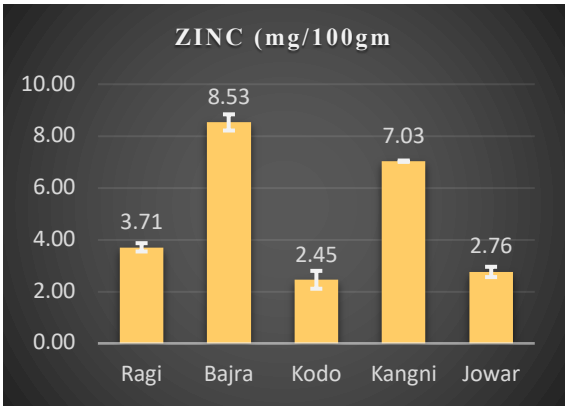

Figure 8: Zinc content of millet flours

Antioxidant activity by DPPH radical scavenging activity

The DPPH radical scavenging activity experiment yielded significant information about the antioxidant capabilities of different millet flours. This test evaluates how effectively antioxidants in millet flours can convert the stable DPPH radical to non-radical DPPH-H through hydrogen donation [10].

IC50 values, which indicate the sample concentration needed to neutralize 50% of DPPH radicals, varied from 29.27 to 83.61 mg/ml among the millet flours tested. A lower IC50 value signifies stronger antioxidant activity, as less sample is needed to achieve the same level of radical neutralization.

Among the samples, jowar millet flour demonstrated the most potent antioxidant activity with the lowest IC50 value of 29.27 mg/ml, suggesting it has the greatest capacity to neutralize free radicals. Ragi and bajra millet flours also showed robust scavenging activity, with IC50 values of 33.16 and 41.27 mg/ml, respectively. These findings suggest that these three millet flours possess strong antioxidant properties and may offer considerable health advantages related to reducing oxidative stress. On the other hand, kodo and kangni millet flours exhibited relatively weaker antioxidant activities, with higher IC50 values of 67.39 and 83.61 mg/ml, respectively. While these values still indicate substantial scavenging activity [27], they are noticeably less potent compared to the other millet flours examined.

The observed variations in antioxidant activity among millet flours may be due to differences in their phytochemical profiles, including phenolic compounds, flavonoids, and other bioactive molecules. These differences could be influenced by factors such as millet variety, growing conditions, and processing techniques.

These results have significant implications for the fields of nutrition science and food technology. Millets with higher antioxidant activities, like jowar, ragi, and bajra, could be particularly valuable for incorporation into functional foods or dietary strategies

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

aimed at combating oxidative stress. Additional studies could investigate the specific compounds responsible for the observed antioxidant activities and explore potential synergistic effects when these millet flours are combined with other ingredients.

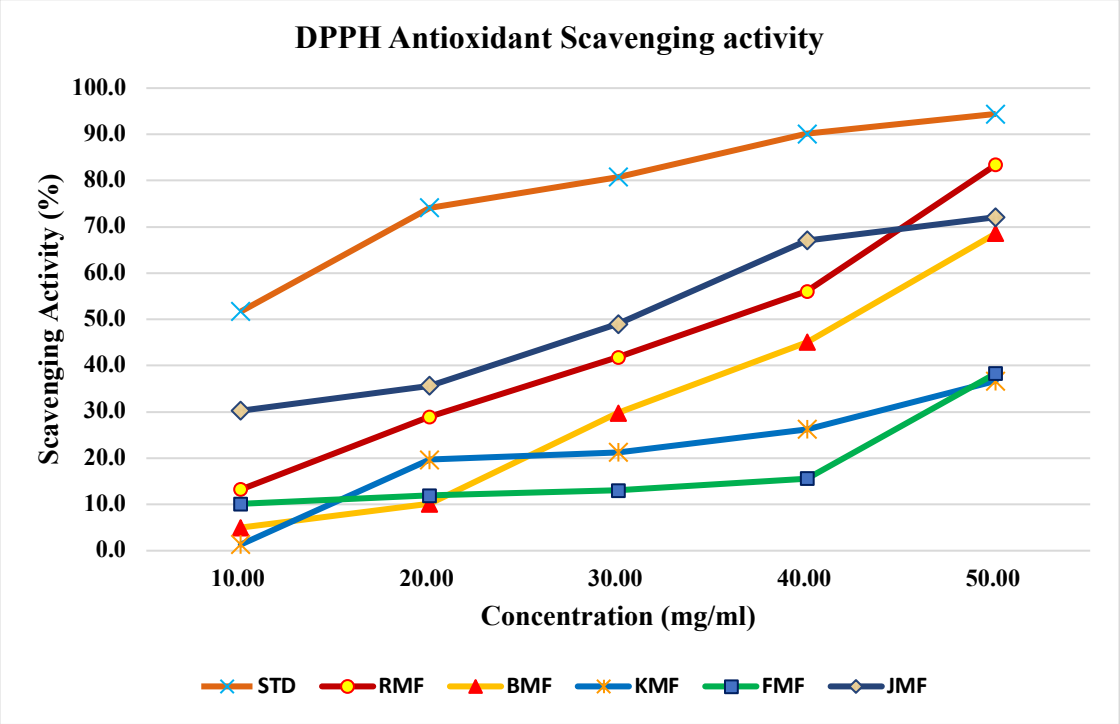

Figure 9: Radical scavenging activity of millet flours

STD - $y = 1.0147x + 47.797$, $R^2 = 0.9096$
RMF - $y = 1.6755x - 5.5653$, $R^2 = 0.976$
BMF - $y = 1.6211x - 16.916$, $R^2 = 0.9659$
KMF - $y = 0.7739x - 2.1586$, $R^2 = 0.9022$
FMF - $y = 0.6006x - 0.2203$, $R^2 = 0.6651$
JMF - $y = 1.1512x + 16.3$, $R^2 = 0.9649$

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

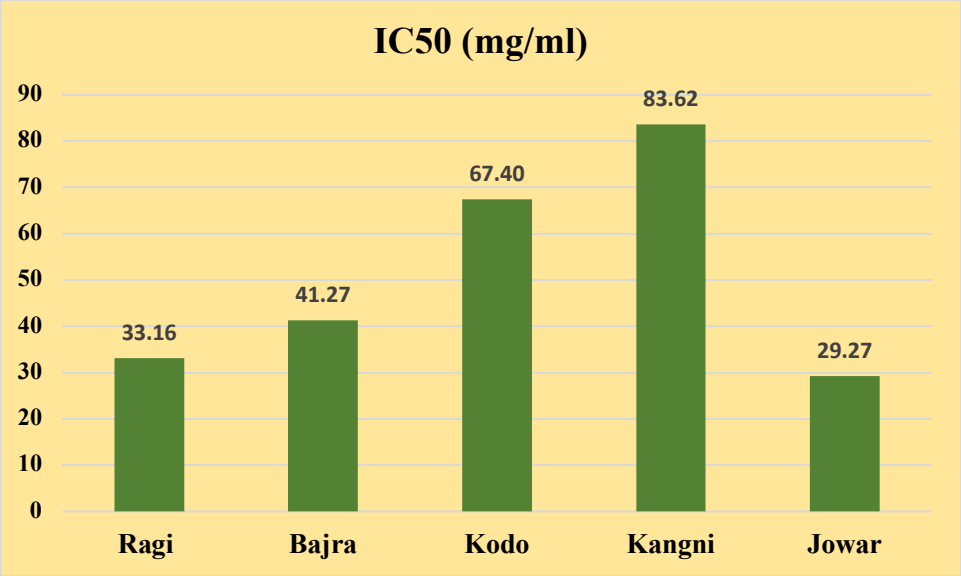

Figure 10: IC50 value of millet flours

Phytochemical properties

The antioxidant and antinutritional properties of the selected millet flours are shown in Table 3. Total phenolic content of the millet flours ranged from 16.70 to 19.70 mg GAE/100g, with the highest concentration observed in Jowar millet flour, followed by ragi millet flour, kodo millet flour, foxtail millet flour, and bajra millet flour at 18.12, 18.05, 17.16 and 16.70 mg GAE/100g, respectively.

Total flavonoid content of millet flours ranged from 130 to 0.32 mg QE/100gm, with the highest content found in kangni millet flour (FMF), followed by kodo millet flour, ragi millet flour, bajra millet flour, and jowar millet flour at 129, 120, 0.037 and 0.032 mg QE/100g, respectively. Studies reported that the total flavonoid content were found to be 391 mg QE/100 g in roasted proso millet.

Total alkaloid content of millet flour ranged from 18.10 to 10.2 mg AE/100gm, with the highest concentration in kangni millet flour, followed by ragi millet flour, kodo millet flour, jowar millet flour, and bajra millet flour at 17.16, 14.13, 12.2 and 10.2 mg AE/100gm, respectively [28].

Total saponin content of the millet flours ranged from 0.52 to 0.95%, with the highest concentration in ragi millet flour, followed by kodo millet flour, kangni millet flour, bajra millet flour, and jowar millet flour at 0.78, 0.62, 0.55 and 0.52%, respectively. The total tannin content of the millet flours ranged from 12.1 to 22.1 mg GAE/100gm, with the highest concentration observed in kangni millet flour, followed by kodo millet flour, ragi millet flour, jowar millet flour, and bajra millet flour, respectively supported by the finding of Rajeswari and Priyadharshini [29].

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

The heterogeneous concentrations of antioxidants and antinutritional compounds observed in diverse millet flour varieties suggest potential disparities in their nutritional compositions, health benefits, and functional properties. This compositional diversity indicates that distinct millet cultivars may be suitable for various applications in food product development, with certain varieties potentially offering enhanced antioxidant properties, whereas others may require additional processing to mitigate antinutritional factors. These findings could inform the selection of specific millet varieties for targeted nutritional interventions or product formulations in the food industry.

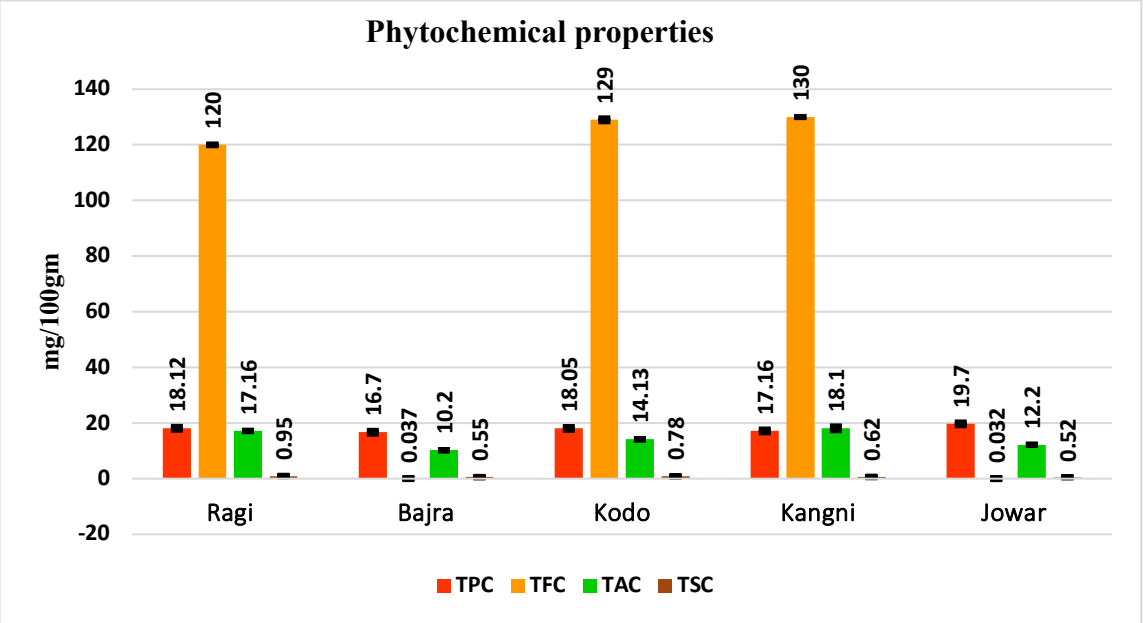

Figure 11: TPC, TFC, TAC, TSC of millet flours

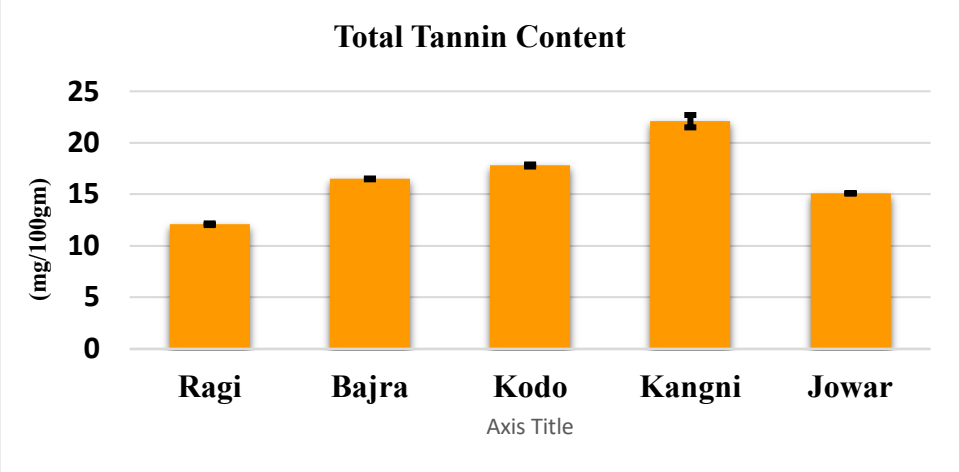

Figure 12: TTC of millet flours

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

A comprehensive analysis of five millet flours—ragi, bajra, kodo, kangni, and jowar—revealed their diverse nutritional profiles, antioxidant activities, and phytochemical contents. Each millet type demonstrated distinct characteristics, with kangni exhibiting a high protein content and ragi displaying exceptional calcium levels. This investigation highlighted significant variations in mineral composition, with jowar excelling in iron content and bajra excelling in zinc and magnesium. Notably, jowar exhibited the highest antioxidant activity and total phenolic content, whereas kangni had the highest flavonoid and alkaloid content. These findings underscore the potential of millet flour as a functional food ingredient to address various dietary requirements and health concerns. Future research should focus on promoting dietary diversification through the incorporation of these millets, developing functional foods that leverage their properties, and conducting further investigations to explore their bioactive compounds and their potential synergistic effects. Additionally, encouraging millet cultivation, educating consumers, and fostering innovation in the food industry can facilitate the utilization of the full potential of these nutritionally rich grains, thereby significantly contributing to global nutritional security and health promotion.

Key recommendations derived from the analysis of the five millet flours encompass the following: integrating diverse millet varieties to achieve a balanced nutrient intake, developing functional food products utilizing high-antioxidant millets, employing specific millet varieties for targeted nutritional interventions, conducting research on bioactive compounds and the effects of processing, promoting the cultivation of diverse millet varieties, disseminating information to consumers regarding the nutritional benefits of millet, encouraging innovation within the food industry, exploring the potential of millet to address specific health concerns, and investigating the application of millet flours in gluten-free product formulations. These strategies aim to enhance nutritional security, promote sustainable agricultural practices, and leverage the unique nutritional profiles of various millet varieties to improve health outcomes and to advance product development in the food industry.

ACKNOWLEDGEMENTS

The authors wish to thank the support of ICSSR for funding the study.

Conflict of Interest

The authors declare no conflict of interest.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Proximate composition

	Moisture %	DM %	Total Ash%	Fat %	Protein%	Fiber%	CHO
Ragi	5.71±0.08	94.29±0.04	1.97±0.02	2.34±0.01	7.22±0.02	3.46±0.06	79.3±0.06
Bajra	6.51±0.06	93.49±0.06	1.93±0.04	4.2±0.03	10.6±0.04	1.95±0.04	74.81±0.04
Kodo	6.12±0.08	93.88±0.05	1.86±0.01	5.02±0.04	9.75±0.02	1.02±0.03	76.23±0.02
Kangni	6.51±0.06	93.49±0.06	2.09±0.05	3.84±0.05	13.56±0.05	1.46±0.02	72.54±0.04
Jowar	4.45±0.07	95.55±0.04	1.72±0.03	3.51±0.06	9.08±0.01	2.36±0.04	78.88±0.05

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Mineral composition

Minerals	Millets	Mean± S.D.	Median
CALCIUM	Ragi	576.19±0.32	576.20
	Bajra	56.96±1.16	57.28
	Kodo	27.48±1.21	28.08
	Kangni	34.39±0.53	34.23
	Jowar	40.70±0.37	40.86
IRON	Ragi	12.43±0.25	12.40
	Bajra	15.34±0.47	15.26
	Kodo	9.82±0.43	9.80
	Kangni	11.04±0.02	11.04
	Jowar	38.20±0.85	38.46
MAGNESIUM	Ragi	245.09±0.55	245.02
	Bajra	265.62±0.59	265.45
	Kodo	157.25±1.05	157.68
	Kangni	200.63±0.24	200.62
	Jowar	222.13±0.30	222.06
MAGNESE	Ragi	74.73±0.42	74.60
	Bajra	2.69±0.12	2.71
	Kodo	1.43±0.17	1.40
	Kangni	2.50±0.26	2.40
	Jowar	3.43±0.42	3.38
POTASSIUM	Ragi	855.27±0.42	854.90
	Bajra	806.37±0.48	806.42
	Kodo	266.47±0.56	266.30
	Kangni	471.49±63	471.65
	Jowar	734.111.78	734.86
ZINC	Ragi	3.71±0.16	3.72
	Bajra	8.53±0.31	8.45
	Kodo	2.45±0.34	2.52
	Kangni	7.03±0.03	7.02
	Jowar	2.76±0.20	2.80

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Phytochemical in millet floursSamples

	TPC (mg GAE/100g)	TFC (mg QE/100g)	TAC (mg AE/100g)	TSC (%)	TTC (mg GAE/100g)
Ragi	18.12±0.22	120±0.15	17.16±0.10	0.95±0.10	16.5±0.04
Bajra	16.70±0.63	0.037±0.19	10.2±0.09	0.55±0.10	12.1±0.08
Kodo	18.05±0.15	129±0.54	14.13±0.10	0.78±0.12	17.8±0.10
Kangni	17.16±0.73	130±0.39	18.10±0.70	0.62±0.11	22.1±0.60
Jowar	19.70±0.60	0.032±0.20	12.2±0.07	0.52±0.08	15.1±0.02

REFERENCES

1. **Salar RK, Certik M and V Brezova** Modulation of phenolic content and antioxidant activity of maize by solid state fermentation with Thamnidium elegans CCF 1456. *Biotechnol Bioprocess Eng.* 2012; **17:** 109-16.

2. **Chandel G, Meena RK, Dubey M and M Kumar** Nutritional properties of minor millets: neglected cereals with potentials to combat malnutrition. *Current Science*. 2014; **110(107):** 1109-11.

3. **Klopfenstein CF and RC Hoseney** Nutritional properties of sorghum and the millets. In: Sorghum and millets: chemistry and technology. 1995. p. 125-68.

4. **Amadou I, Gbadamosi OS and GW Le** Millet-based traditional processed foods and beverages—A review. *Cereal Foods World.* 2011; **56(3):** 115.

5. **Pontieri P, Troisi J, Di Fiore R, Di Maro A, Bean SR, Tuinstra MR, Roemer E, Boffa A, Giudice AD, Pizzolante G, Alifano P and DG Luigi** Mineral contents in grains of seven food-grade sorghum hybrids grown in a Mediterranean environment. *Aust. J. Crop Sci.* 2014; **8(11):** 1550-9.

6. **FAO.** (2012) FAOSTAT. http://faostat.fao.org *Accessed February 2024.*

7. **FAO.** (1995) Sorghum and millets in human nutrition. Rome: FAO.

8. **El Hag ME, El Tinay AH and NE Yousif** Effect of fermentation and dehulling on starch, total polyphenols, phytic acid content and in vitro protein digestibility of pearl millet. *Food Chemistry*. 2002; **77(2):** 193-6.

9. **Abah CR, Ishiwu CN, Obiegbuna JE and AA Oladejo** Nutritional composition, functional properties and food applications of millet grains. *Asian Food Sci. J.* 2020; **14(2):** 9-19.

10. **Kulla S, Hymavathi TV, Kumari BA, Reddy RG and CV Rani** Impact of germination on the nutritional, antioxidant and antinutrient characteristics of selected minor millet flours. *Ann Phytomed. Int. J.* 2021; **10:** 178-84.

11. **Amadou I, Gounga ME and GW Le** Millets: Nutritional composition, some health benefits and processing-A review. *Emirates Journal of Food and Agriculture*. 2013; **501(5):** 501-8.

12. **Michaelraj PS and A Shanmugam** A study on millets-based cultivation and consumption in India. *Int. J. Mark Financ Serv. Manag Res.* 2013; **2(4):** 49-58.

13. **AOAC.** Official Methods of Analysis for moisture in flour. 18th edn. 2005. Arlington, VA: Association of Official Analytical Chemists.

14. **AOAC.** Official Methods of Analysis for ash in flour. 18th edn. 2005. Arlington, VA: Association of Official Analytical Chemists.

15. **AOAC.** Official Methods of Analysis for protein. 18th edn. 2005. Arlington, VA: Association of Official Analytical Chemists.

16. **AOAC.** 962.09-Crude fibre analysis in feeds by filter bag technique - Official Methods of Analysis of the Association of Analytical Chemists. 20th edn. Maryland: Association of Official Analytical Chemists, International. 2016.

17. **AOAC.** 922.06 and 2003.06 - Crude fat in Feeds, Cereal grains and forages; Randall/Soxtec/Hexanes Extraction-Submersion method, Official Methods of Analysis of the Association of Analytical Chemists. 20th edn. Maryland: Association of Official Analytical Chemists, International. 2016.

18. **Suma Pushparaj F and A Urooj** Antioxidant activity in two pearl millet (*Pennisetum typhoideum*) cultivars as influenced by processing. *Antioxidants.* 2014; **3(1):** 55-66.

19. **Hassan KZ, Noor HM and J Kader** Antibacterial efficacy of three different extracts of *Polygonum minus* (Huds.). In: International Conference on Waste Management, Ecology and Biological Sciences; 2015; Kuala Lumpur.

20. **Eom SH, Park HJ, Jin CW, Kim DO, Seo DW, Jeong YH and DH Cho** changes in antioxidant activity with temperature and time in Chrysanthemum indicum L. (Gamguk) teas during elution processes in hot water. *Food Sci Biotechnol.* 2008; **17(2):** 408-12.

21. **Tambe VD and RS Bhambar** Estimation of total phenol, tannin, alkaloid and flavonoid in Hibiscus tiliaceus Linn. wood extracts. *J. Pharmacogn. Phytochem.* 2014; **2(4):** 41-7.

22. **Mora-Ocación MS, Morillo-Coronado AC and EH Manjarres-Hernández** Extraction and quantification of saponins in quinoa (*Chenopodium quinoa* Willd.) genotypes from Colombia. *Int. J. Food Sci.* 2022.

23. **Gull A, Prasad K and P Kumar** Evaluation of functional, antinutritional, pasting and microstructural properties of Millet flours. *Journal of Food Measurement and Characterization.* 2016; **10:** 96-102.

24. **Vali Pasha K, Ratnavathi CV, Ajani J, Raju D, Manoj Kumar S and SR Beedu** Proximate, mineral composition and antioxidant activity of traditional small millets cultivated and consumed in Rayalaseema region of south India. *J. Sci. Food Agric.* 2018; **98(2):** 652-60.

25. **Mounika D, Sangeetha U and G Sireesha** Estimation of phytochemicals in Millets and selected Millet products. *Indian J. Appl. Pure Bio.* 2022; **37:** 810-20.

26. **Deshpande SS, Mohapatra D, Tripathi MK and RH Sadvatha** Kodo millet-nutritional value and utilization in Indian foods. *J. Grain Processing and Storage*. 2015; **2(2):** 16-23.

27. **Pontieri P, Pepe G, Campiglia P, Merciai F, Basilicata MG, Smolensky D, Calcagnile M, Troisi J, Romano R, Del Giudice F, Aletta M, Guida M, Alifano P and DG Luigi** Comparison of content in phenolic compounds and antioxidant capacity in grains of white, red, and black sorghum varieties grown in the mediterranean area. *ACS Food Sci Technol.* 2021; **1(6):** 1109-19.

28. **Owheruo JO, Ifesan BO and AO Kolawole** Physicochemical properties of malted finger millet (*Eleusine coracana*) and pearl millet (*Pennisetum glaucum*). *Food Sci Nutr.* 2019; **7(2):** 476-82.

29. **Rajeswari N and VP Priyadharshini** Evaluation of Nutritional and Nutraceutical Content of Polished and Unpolished Barnyard Millet-An Analytical. *Current Research in Nutrition and Food Science.* 2021; **9(3**). https://doi.org/10.12944/CRNFSJ.9.3.31