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Comparative Nutritional Benefits of Kodo and Little Millets against other Cereals and their Role in Dairy Production

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Authors' contributions

This work was carried out in collaboration between both authors. Author KS designed the study, reviewed the data, and wrote the first draft of the manuscript. Author PV critically analyzed the review and suggested corrections. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Aim: This study aims to evaluate the nutritional benefits of Kodo and Little millet compared to other cereals and explore their applications in the dairy sector.
Millets are grass crops that have gained importance due to their excellent nutritional profile as well as their adaptability to climate change. Millets, including Kodo and Little millet, are increasingly recognized for their exceptional nutritional profiles and resilience to climate challenges. Unlike conventional cereals like rice and wheat, millets thrive in extreme conditions such as drought and heat. These grains are rich in minerals, antioxidants, and dietary fiber, making them vital in

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combating malnutrition and managing health conditions like diabetes and cardiovascular diseases. Their low glycemic index and high nutrient content also make them valuable for developing fortified dairy products. India, the largest producer of millets, has integrated these "Nutri-Cereals" into traditional diets across various states. This study compares the nutritional advantages of Kodo and Little Millet and looks at how they may improve products offered by the dairy sector. In this review, a few dairy-based goods are addressed. The dairy business has widespread customer acceptance, and adding millets can improve its nutritional profile.

Keywords: Nutri-cereal; Kodo millet; little millet; bioactive compounds; value addition.

1. INTRODUCTION

Since 2018, due to climate change and the lack of nutritional profile of conventional crops, there has been a lot of interest shown by the Government of India in promoting millets. The same year, millets were given the tag of “NUTRI-CEREALS” and 2018 was declared the national year of millets. India's government had asked the UN to declare 2023 the International Year of Millets (IYOM), for which 72 nations agreed with India's request, and on March 5, 2021, the United Nations General Assembly (UNGA) proclaimed 2023 the “International Year of Millets.” Millets were also included in the Ministry of Women & Child Development's “POSHAN MISSION” Abhiyan.

A/c to report published by Yes Bank and APEDA of 2022 [1], India is the largest producer of millet with 17.68% of the share in total production during the year 2020, followed by Nigeria (~11%) and China (~9%). In 2022, India produced 17.60 Million Metric Tonnes (MMT) of millets, contributing to 19% of the total millet production in the world. With 17.75 MMT, India was the biggest consumer of millets in 2022, followed by China (13.70 MMT) and Nigeria (8.80 MMT). Also, India is placed 10^{th} in terms of volume with 1.68 lakh MT (0.45% of global commerce) and seventh in terms of value, with millet exports totaling USD 65.10 Million (1.66% of global trade). Globally, there were 40.44 million hectares (ha) of sorghum planted in 2022, compared to 31.28 million hectares (ha) of other millets. Sorghum accounted for more than 66% (60.13 MMT) of total millet output, with the remaining 34% coming from other millets (small millets, finger millets, pearl millets, and so on).

According to the USDA [2], small millets account for 11% of the total millet production in India. Madhya Pradesh is the highest producer of small millets (33%), followed by Arunachal Pradesh, Karnataka and Tamil Nadu (9%), Chhattisgarh (7%), Uttarakhand (6%), and Gujarat and Andhra Pradesh (5%). The average production of millets during the last 5 years (2018-19 to 2022-23) was around 12,189 thousand tonnes.

Minor millets include Kodo millet or cow grass (*Paspalum scrobiculatum*), barnyard millet or sawa (*Echinochloa esculenta*), little millet or kutki (*Panicum sumatrense*), foxtail millet or Kakum (*Setaria italica*), proso millet or chenna (*Panicum miliaceum*), and two pseudo millets that do not belong to the grass family: Amaranth or Rajkira (*Amaranthus caudatus L*.) and Buckwheat or Kuttu (*Fagopyrum esculentum*).

2. KODO MILLET

2.1 Botanical Description

Kodo millet, or cow grass, belongs to family of *Poaceae* also known as the grass family. It is a long duration crop. The inflorescence of Kodo millet consists of 2–6 racemes that are widely dispersed along a short axis or subdigitate. The grain is protected by sticky, persistent, hard husks. Self-pollination is the norm since Kodo millet possesses a cleistogamous flower and because the proportion of open flowers does not surpass 15-20% [3]. While *Paspalum scrobiculatum var. commersonii* is the wild variety native to Africa, *Paspalum scrobiculatum var. scrobiculatum* is farmed as an important crop in India. It is a monocot plant with an approximate height of 4 feet. The leaves are 20-40 cm long. It produces small, ellipsoidal seeds that are 1.5 mm wide and 2 mm long and range in hue from light brown to dark grey, as shown in Fig. 1 [4]. The species *Paspalum scrobiculatum* is split into three races: Regularis, Irregularis, and Variabilis, based on the morphology of the inflorescence. (ICRISAT, 2017). During 2015-16, the area of production of Kodo millet was 1.96 lakh hectares, the production yield was 0.84 lakh tonnes and its total yield was 429 kg/ha. A total of 40 improved varieties have been released from 1989 to 2022 (Indian Farming, 2023). Various varieties released by the Indian Institute of Millet Research (IIMR) in Hyderabad are given in Fig. 2 [5].

2.2 Nutritional Composition of Kodo Millet

According to Muragod et al. [6], the physico-chemical composition of Kodo millet includes its size (1.7 mm), thousand grain weight (2.8 gm), thousand grain volume (1.2 ml), bulk density (1.84), and hydration capacity in gm per 1000 seeds (0.54), while its hydration index is 24.52%. The swelling capacity in gm per 1000 seeds and swelling index is 0.55 and 42.30%, respectively. The proximate composition per 100 g of Kodo millet includes its moisture (11.2%), fat (1.3 g), protein (8.1 g), carbohydrate (64.3 g), and fiber (8.3 mg). The Kodo millet also has significant quantities of minerals like iron (0.5 mg), phosphorus (169 mg), and calcium (32 mg) [6]. Another author also reported similar findings, saying that Kodo grains have 8.35% protein, 1.45% fat, 65.65% carbohydrate, and 2.95% ash. The study also revealed that Kodo millets are high in vitamin B_3, vitamin B_6, folic acid, and minerals including calcium, potassium, magnesium, and zinc, as well as having medical advantages for diabetes, celiac disease, cancer, cardiovascular disease, and so on [7]. The vitamin and mineral profile is given in Table 1. The energy value of Kodo millet is between 340-342 kcal/100 g [8]. Kodo millet has more ash and dietary fiber content as compared to wheat and rice [9,10] (Table 2).

2.3 Bioactive Compounds in Kodo Millet

Malnutrition is common nowadays because individuals are not obtaining adequate nutrition from traditional crops, and dining out is popular in cities, which boosts junk food intake among children. This culture is the root cause of many ailments in today's society, including cancer. It may be avoided in the future by replacing wheat and rice with millets, which are high in bioactive chemicals.

Kodo is an ancient millet grain that originated in tropical Africa and was domesticated 3000 years ago in India. This Indian cow grass is also referred to as Kodra and Varagu. The three categories of bioactive chemicals include alkaloids, terpenes, and phenolic compounds, which include phytochemicals such as naringin, catechin, luteolin, apigenin, daidzein, naringenin, etc. These compounds have various health benefits [11]. They are also called secondary metabolites. Secondary metabolites in plants are divided into three categories based on their metabolic pathways: (a) nitrogen-containing chemicals like alkaloids, glucosinolates, and cyanogenic glycosides, (b) phenolic compounds like phenylpropanoids and flavonoids, and (c) terpenes. Alkaloids are a type of nitrogen-containing chemical generated in plants in response to biotic or abiotic stimuli, endowing alkaloids with extraordinary biological activity, while shikimate, pentose phosphate, and phenylpropanoid pathways in plants are the sources of phenolic components, which include an aromatic ring with one or more hydroxyl groups. Also, terpenoids are the most prevalent category of secondary metabolites generated by plants and are found in flowers, vegetative tissues, and roots. They exhibit a wide spectrum of biological actions that lead to reduced total cholesterol, triglycerides, or LDL cholesterol, as well as blood pressure [12]. Some bioactive compounds reported by Khare et al. [13] in Kodo millets are naringin (11.9 ppm), catechin (1.10 ppm), ferulic acid (2.45 ppm), sinapic Acid (7.9 ppm), and *P*-coumaric acid (1.38 ppm) [13].

Fig. 1. Kodo millet seeds

Table 1. Vitamin and mineral profile of millets compared to cereals

S.no	Name of cereal/ and millets	Vitamin B_1 (mg)	Vitamin B_2 (mg)	Vitamin B_3 (mg)	Total folates (µg)	Iron (mg)	Phosphorus (mg)	Calcium (mg)	Sodium (mg)	Magnesium (mg)
1.	Whole wheat	0.46	0.15	2.68	30.09	3.97	315	30.94	2.04	125
2.	Rice	0.05	0.05	1.69	9.32	0.002	96	7.49	2.34	19.3
3.	Little millet	0.26	0.05	1.29	36.20	1.26	130	16.06	4.77	91.41
4.	Kodo millet	0.29	0.2	1.49	39.49	2.34	101	15.27	3.35	122

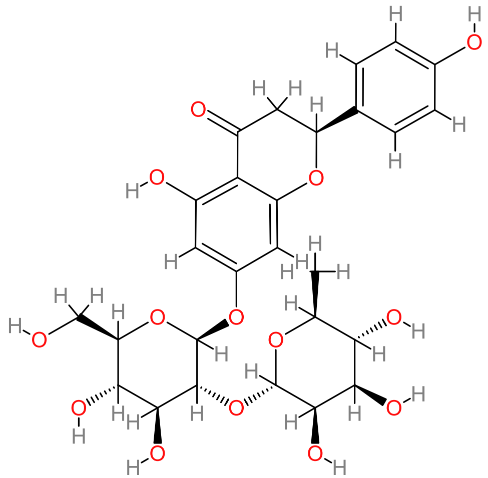
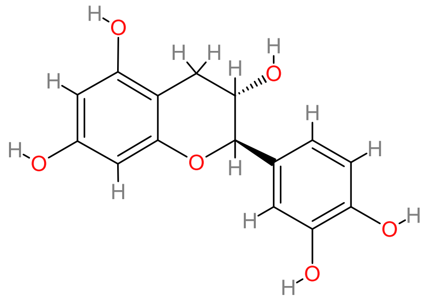
Source: Dayakar Rao et al., [9] (Indian Institute of Millet Research); Dey et al., [11]

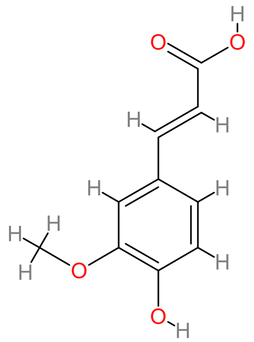
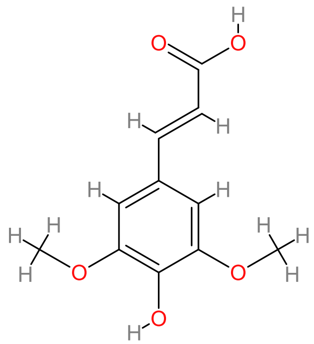
Table 2. Nutritional comparison of millets with wheat and rice per 100 gm

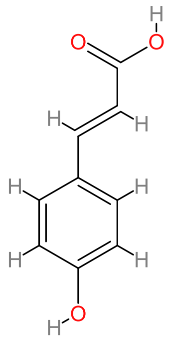
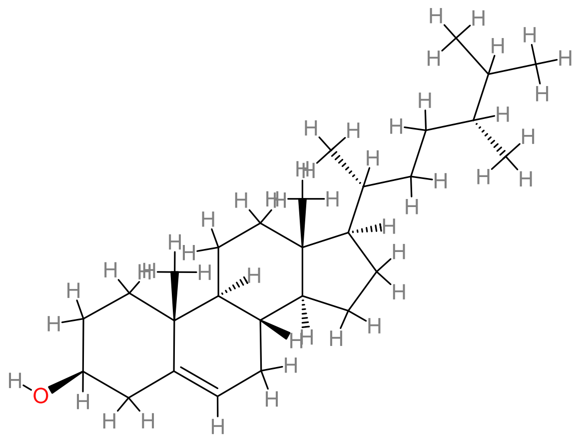
S.no	Name of cereal and millets	Moisture (g)	Fat (g)	Ash (g)	Protein (g)	Carbohydrate (g)	Total dietary fiber (g)	Energy (kcal)
1.	Whole wheat	10.58	1.47	1.42	10.6	64.70	11.23	1347
2.	Rice	9.93	0.52	0.56	7.94	78.24	2.81	1491
3.	Little millet	14.23	2.55	1.72	8.92	65.55	6.3	1449
4.	Kodo millet	11.6	4.2	2.95	10.6	59.2	10.2	346

Source: Dayakar Rao et al., [9] (Indian Institute of Millet Research), Indian superfood millet APEDA report; Bunkar et al., [10]

Table 3. Bioactive compounds found in Kodo millet and their protective functions

S.no	Name of bioactive compound	Molecular Formula	PubChem CID	Molecular Structure	Nature of Protective Functions	Reference
1.	Naringin	$C_{27}H_{32}O_{14}$	442428		Anti-oxidant and anti-inflammatory, treatment of Parkinson's disease, Alzheimer's disease lowers cholesterol and reduces the risk of CVDs	[13,15,16]
2.	Catechin	$C_{15}H_{14}O_{6}$	9064		Anti-inflammatory, Anti-cancer, Anti-oxidative properties	[13,17]

S.no	Name of bioactive compound	Molecular Formula	PubChem CID	Molecular Structure	Nature of Protective Functions	Reference
3.	Ferulic acid	$C_{10}H_{10}O_4$	445858		Anti-oxidant, anti-microbial, anti-viral, anti-cancerous, vasodilator activity and anti-diabetic activity	[13,18]
4.	Sinapic Acid	$C_{11}H_{12}O_5$	637775		Anti-viral property against SARS Cov, Anti-inflammatory, Anti-cancer	[13,19,20]

S.no	Name of bioactive compound	Molecular Formula	PubChem CID	Molecular Structure	Nature of Protective Functions	Reference
5.	*P*-Coumaric acid	$C_9H_8O_3$	637542		Anti- inflammatory, Anti-cancer, Anti-oxidant, treatment of Rheumatoid arthritis; Anti-obesity	[13,21,22,23]
6.	Campesterol	$C_{28}H_{48}O$	173183		Lowers cholesterol, Anti-cancerous	[24]

Source of images: PubChem

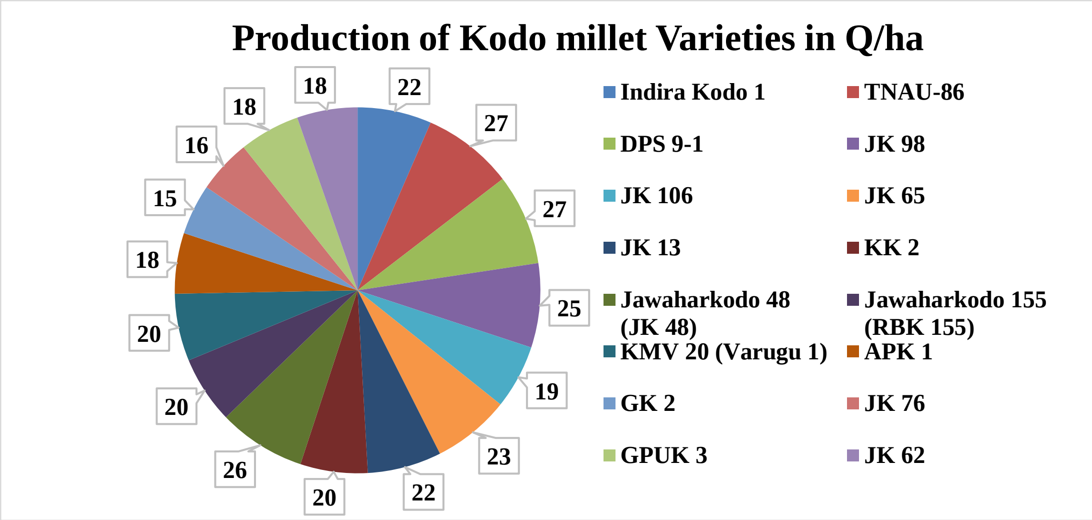


Fig. 2. Production of Kodo millet Varieties in Q/ha [5]

Another author reported that the concentration of campesterol in raw Kodo millet was 0.31%, while after germination the concentration increased to 2.6% [14]. The protective functions of different bioactive compounds are given in Table 3.

3. LITTLE MILLET

3.1 Botanical Description

Little millet (*Panicum sumatrense*), also known as Samai or Kutki, is a minor millet that is of the *Poaceae* family. It is native to the Indian subcontinent. It is self-pollinated with chromosome number 36. The inflorescence of the little millet is a panicle that is 15-45 cm long and 1-5 cm broad. The spikelet is 2.0-3.5 mm in length. At maturity, panicle branches are scabrous and drooping. The lower is sterile, whereas the top is fertile or bisexual with no rachilla extension. Spikelets are elliptical, acute, and compressed dorsally [25]. *P. sumatrense* is divided into two subspecies based on inflorescence morphology: *psilopodium* and *sumatrense*. The races *Nana* and *Robusta* are subspecies of Sumatrense. The race Nana has two subraces: *Laxa* and *Erecta,* and the race Robusta has two subraces: *Laxa* and *Compacta* [26]. The grain is 1.8-1.9 mm in length and is smooth on the surface. The major states involved in its cultivation are Orissa, Madhya Pradesh, Andhra Pradesh, Karnataka, Maharashtra, and Gujarat. It is resistant to both waterlogging and drought [27]. During 2015-16, the area of production of little millet was 2.34 lakh hectares, the production yield was 1.27 lakh tonnes and its total yield was 544 kg/ha. A total of 32 improved varieties have been released from 1989 to 2022 [28]. Various varieties released by IIMR of little millet with their average yield are given in Fig. 3 [29].

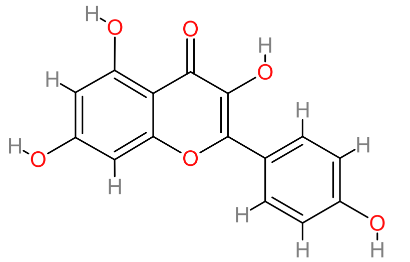
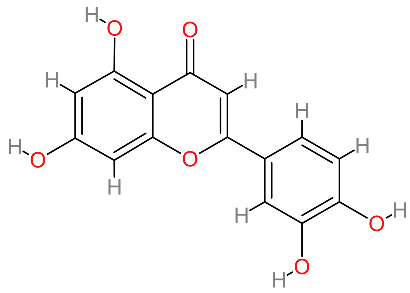
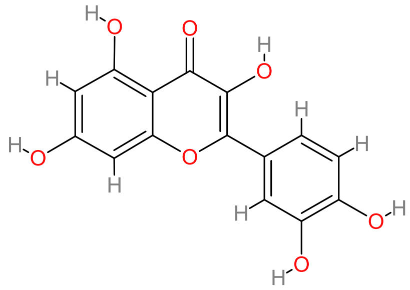
3.2 Nutritional Composition

Kamatar et al. [30] investigated little millet specimens from Karnataka's study districts for physical properties and classified them based on seed color. They were divided into four groups: light brown, reddish brown, creamish brown, and blackish brown. The grain's test weight ranged from 2.40 to 2.80 g, while its bulk density ranged from 0.81 to 1.40 g/ml. The grains' mean hydration capacity varied between 9.13 and 21.50%, whereas their swelling capacity ranged from 11 to 51%. The grain required 10-15 minutes for cooking. After cooking, the hydration capacity (160-260 %) and swelling capacity (220-280%) increased significantly [30]. Another author studied the physical characteristics of *Sukshema*, an enhanced cultivar of a local genotype of little millet. The results revealed that the grain's length, width, and thickness were 1.74 mm, 1.53 mm, and 1.09 mm, respectively. The solubility was 23.4%, and water the absorption capacity was 0.88 g/g. The total dietary fiber was 8.81 g/100 g. Total sugar was around 4.14 g/100 g. Table 2 describes the proximate composition of little millet [31].

3.3 Bioactive Components

Little millet also has various bioactive components, which may have the ability to protect against several diseases.

Table 4. Important bioactive components in little millet

S.no	Name of Compound	Molecular formula	PubChem CID	Molecular Structure	Protective Functions	Reference
1.	Kaempferol	$C_{15}H_{10}O_6$	5280863		Anti-inflammatory	**[35]**
2.	Luteolin	$C_{15}H_{10}O_6$	5280445		Anti-inflammatory, Anti-cancer	**[36]**
3.	Quercetin	$C_{15}H_{10}O_7$	5280343		Anti-inflammatory, Anti-obesity	**[37]**

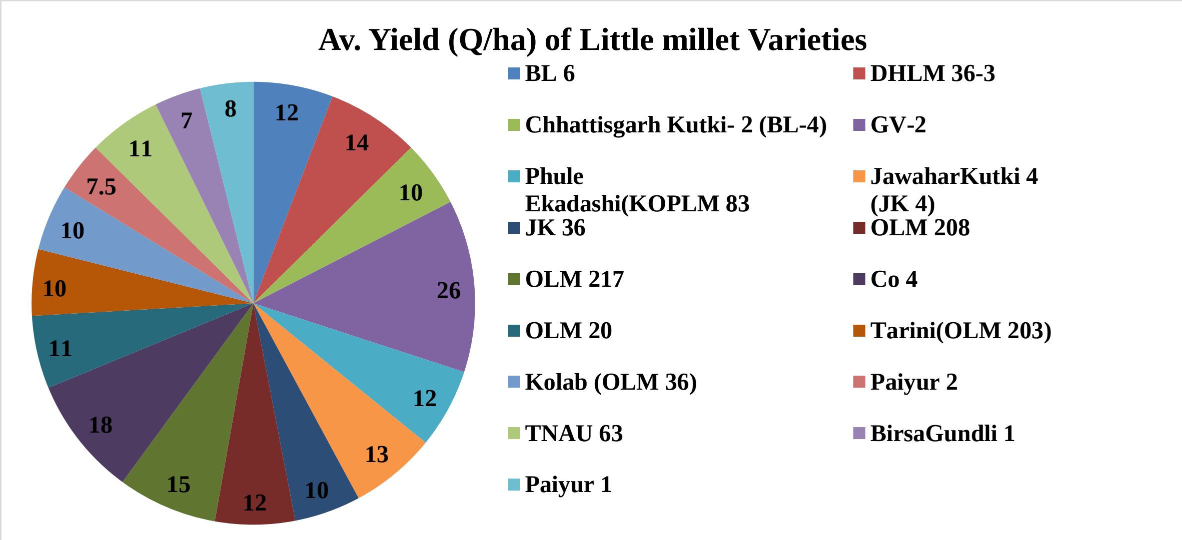


Fig. 3. Av. Yield (Q/ha) of little millet varieties [29]

One article reported that the Total phenolic content (TPC) of little millet was around 521 mg GAE/100 g with compounds like gallic acid, proto-catechuic acid, kaempferol, ferulic acid, p-hydroxy-benzoic acid, gentisic acid, vanillic acid, syringic acid, and trans-cinnamic acid [32]. Similarly, another study also suggested that little millet can be used as a functional food component to control postprandial hyperglycemia. The TPC content of 3 cultivars of little millet was reported to be between 23 and 24 μmol ferulic acid equivalents/g, and Total soluble flavonoid content was between 11.33 and 13.64 μmol catechin equivalents/g. Among the 3 cultivars, the compounds identified were catechin, luteolin, naringenin, quercetin, apigenin, quercetin, and kaempferol. According to the results shown by the study, kaempferol and luteolin were the most abundant flavonoids. The luteolin content was highest in the CO4 cultivar (69.24±2.13 μg/g), while kaempferol (60.57±2.15 μg/g) was highest in the CO2 cultivar of little millet. The DPPH scavenging activity was also highest in the CO2 [33].

Luteolin is a flavonoid that occurs naturally as a glycosylated form in a variety of fruits and vegetables. It has antioxidant, anti-cancer, anti-inflammatory, and neuroprotective properties. Kaempferol is also a flavanol that belongs to the flavonoid family and is found in a variety of plant genera, including Delphinium, Berberis, Camellia, Citrus, and others. Kaempferol is useful in a variety of inflammatory disorders, including cardiovascular, cancer, and neurological diseases. Kaempferol's anti-inflammatory properties are attributable to its reduction of inflammatory cell activity as well as its inhibition of proinflammatory cytokines and chemokine expression [34].

The molecular structure and protective functions of bioactive molecules found in little millet are presented in Table 4.

4. CHANGES IN THE NUTRITIONAL COMPOSITION OF MILLETS UNDER DIFFERENT PROCESSING CONDITIONS

Dehusking, soaking, milling, germination, fermentation, malting, heating, and roasting are all part of the processing process. All these practices have a significant impact on the nutritional and nutraceutical properties of millets.

Germination is a natural process used to activate grains biologically in order to increase their nutritional and functional qualities. Soaking, sprouting, and drying are part of the malting process. Roasting, parboiling, and puffing are examples of heat treatments. These treatments improve millet's eating quality, although their impact on nutritional qualities such as TPC varies according to the heating method [38]. The sprouting of millets can increase their nutritional profile with essential amino acids, antioxidants, minerals, etc. During germination, kernels are often soaked in water before being allowed to germinate in a controlled atmosphere. As a result, sprouting circumstances and water content have a significant influence on its metabolic process. Soaking the kernel at ambient temperature for a few to 24 hours, with a seed weight/volume ratio of 1:1.5 to 1:20, is a common practice performed prior to seed germination. The ideal temperature for germination is 20-30°C [39]. Soaking also reduces anti-nutritional factors like phytates in cereal crops. A comparative study of 5 different millets revealed that 24 hours of soaking and 24 hours of germination were superior for creating nutritionally enhanced millet products. 50% tannin content was reduced in little millet, while in Kodo millet it was reduced from 1.42 mg/g to 0.52 mg/g after treatment. Also, DPPH activity rose from 34.12% to 56.16% in little millet and from 56.71% to 78.34% in Kodo millet after 24 hours of soaking and germination [40].

Guha et al. [41] also reported that processing conditions like germinating, steaming, and roasting of little millet also influence the concentration of bioactive components. The comparison between native and processed millets shows that TPC content was highest in roasted little millet. The decreasing order of TPC value was: roasted (521.0 mg GAE/100 g), > steamed (485 mg GAE/100 g), > germinated (453 mg GAE/100 g), > unprocessed (429 mg GAE/100 g). The trend was similar in the case of Total Flavonoid content [41].

Similar results were reported by another author, where TPC content increased from 27 to 34 mg TAE/100 g after 12 h of soaking, and 48 h of germination and popping of Kodo millet increased TPC content to 63.58 mg TAE/100 g [42].

Other studies also indicate that protein content increased significantly from 6.7% to 7.9%, minerals increased from 232.82 to 251.73 mg/100 g, dietary fibers increased from 35.30 to 38.34 g/100 g, and GABA content increased from 9.36 to 47.43 mg/100 g, while tannins and phytates reduced from 1.603 to 0.234 mg/100 g and 1.344 to 0.997 mol/kg, respectively, in the sprouted Kodo millet sample. It was also seen that lipid content decreased from 3.6 to 2.8%. Similarly to prior investigations, the DPPH radical scavenging activity (%) was raised (67.35 to 91.34%) [43].

Roasting also influences the bioavailability of nutrients. Singh et al. [44] reported that roasted samples of finger millet showed a reduction in phytochemical elements such as phenols and antioxidant activity. This may be due to may be due to exposure to heating. The fat and protein content also decreased, while total carbohydrate increased after roasting. The iron content increased from 3.45 to 3.91 mg/100 g and the calcium content increased from 337-341 mg/100 g [44].

Fermentation is an ancient technique that is quite popular for increasing probiotic content in food and influencing the nutrients present in food. One of the studies reported that little millet fermented with *Saccharomyces boulardii* and *Lactobacillus acidophilus* compared to germinated one has significant impact on its nutrients. The results revealed that protein content increased from 9.86 to 10.95%, fat content decreased from 3.26 to 2.61%, ash content increased from 2.27 to 2.34, and carbohydrates were reduced from 84.54 to 82.01%. The phytic acid content was reduced as well upon fermentation. So, it can be inferred that germination and fermentation, when combined, will improve the nutritional quality of the food [45].

A similar study was reported on Kodo millet malt beverage inoculated with 4 different strains, namely *Pediococcus acidilactici*, *Lactobacillus plantarum, and Lactobacillus fermentum.* The results were similar to those of fermented little millet. The protein, antioxidants, and crude fat increased [46].

5. MILLETS IN DAIRY INDUSTRY

The value-added products of millets have been gaining popularity for the last 5-6 years. In the past decade, weaning mixes, health drinks, and imitation dairy products using millets were developed by the researchers. Millet's starch functionality is equivalent to that of other cereals. Millets are appropriate constituents in various food compositions for certain target groups due to their increased proportion of non-starchy polysaccharides, dietary fiber, and low glycemic index. Millet's alkaline composition also makes it beneficial for people suffering from acidosis and gastric ulcers [47]. Some product categories are described below:

5.1 Health Drinks

Health drinks are gaining popularity among consumers due to their high nutrient profile. Several studies of milk and millet-based health drinks have been of interest to researchers. Kumar et al. [48] developed health drink powder by combining malted finger millet (*Eleusine* *coracana*), pulse combinations, and skim milk powder. Compared to other health beverages available on the market, it has a fairly high protein (25.01%) and calcium (Ca-1018.7 mg/100 g) content. Sensory analysis revealed that it has better acceptance among consumers and is also a cost-effective product [48]. Parvathi et al. [49] also developed a millet-based dairy health drink targeting malnutrition in children. The product was developed by utilizing pearl, Kodo, and whole wheat that had been germinated, as well as pulses. The dried, germinated millets were roasted until the husks split apart, and they were then ground into fine flour in a burr mill. Green gram flour, roasted bengal gram flour, and skim milk powder were then added to the flour. The health mix's DPPH scavenging activity was found to be 0.664 0.08 mg/g. In every 100 g of the standardized mix, there were 17.08% protein, 4.05% fiber, 20.68 mg of calcium, and 7.57 mg of iron [49]. Another study was done on health drinks targeting diabetic people using millets like Bajra and Ragi. Organoleptic and nutritional composition as well as phytochemical analysis showed that multigrain health mix was a superior product and could be used for diabetic people [50]. Similarly, a milk-based iron rich health drink was developed to combat malnutrition using sprouted and dried pearl millet flour, finger millet powder, malted soy flour, sugar powder, milk powder, and popped and milled amaranth seed powder in different combinations. The effect of sprouting on the nutritional content of a bajra-based health drink indicated that sprouting reduced the carbohydrate (67.46 g), fat (5.30 g), moisture, and fiber contents (1.12 g) compared to the control (100% pearl millet flour). The fat content decreased due to the action of lipolytic enzymes, and the protein content increased from 11.2 g to 13.54 g [51]. Another author developed a millet-based health drink using germinated Kodo millet, barnyard millet, small millet, and finger millet and compared it with other health drinks available on the market. The results revealed that, apart from energy, a health drink made from minor millets contains vital nutrients and is economically feasible for consumers [52].

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5.2 Porridge/Kheer Mix

A ready-to-constitute kheer mix powder using pearl millet, dairy whitener, sugar, and cardamom was developed. The millet was autoclaved for 15 minutes at 121°C and incubated at 35°C for 30 minutes before making the kheer mix. RSM (Response surface methodology) was used to optimize the final product, which showed that an increase in dairy whitener had a positive effect on Overall Acceptability (OA) score [53]. A similar study was conducted where nutrient-enriched millet-based composite flour using skimmed milk powder and vegetables was developed for children aged 6 to 59 months. Finger millets were germinated, roasted, and combined with pumpkin seeds, carrots, cowpea leaves, and skimmed milk powder to make composite flour. The findings indicate that increasing the germination time improved the protein, protein digestibility, and total sugar content of millet flour by 0.03%, 0.79%, and 0.07%, respectively, while decreasing total phytates by 0.005 mg/g [54]. Also, Bunkar et al. [55] developed an instant Kodo Millet-Based porridge mix using Kodo millet and skim milk powder with stevia at 8%. The optimized product had 72.6± 4.34 g/100g of anti-oxidant content and 72.6± 4.34 g/100 g of ash content [55].

5.3 Weaning Mix

Weaning is a phase of transition in which the infant's nutrition changes in terms of source and consistency. Weaning is a phase when children are nutritionally vulnerable. To benefit from increased micronutrients, cereals in composite mixes might be substituted with millets in the formulation with milk. Both milk and millets can provide balanced nutrition to children. Several studies were conducted, one of which was on weaning food based on Barnyard millet, foxtail millet, soyabean, and skim milk powder**.** Millets were malted while soy beans were roasted to create the mix. The product was rich in protein (18.37%) and ash content (4%). The calcium and ascorbic acid content was also high. The sensory analysis indicated that the product was highly accepted by the consumer, with OA score of 7.7 [56]. Similarly, Balasubramanian et al. [57] also developed a weaning mix using pearl millet, barley, whey protein concentrate, vegetable oil, and skim milk powder. He used extrusion to create extrudates of raw and malted pearl millet and barley. The overall acceptability of the optimized product was between 6.60 and 8.20 [57]. Another study was done on weaning mixes for children using little, Kodo, Foxtail, and Finger Millet in different proportions. All millets were germinated before use. In comparison to the wheat-based market sample, millet-based weaning mixtures were higher in protein (14.3 to 23.17%), ash (2.8 to 7.6%), and crude fiber (2.5 to 6.0%). The calcium content of formulated millet-based goods is similar to that of the market sample without fortification [58].

5.4 Fermented Milk-Millet Foods

Fermented foods are sources of probiotics, which are becoming popular in developing countries. Fermentation of grains is an old and low-cost technique of food preservation. One of the products developed was a fermented skim milk and pearl millet product. Skim milk and ungerminated pearl millet flour were used as raw materials, and curry patta (*Murraya koenigii*), black pepper (*Piper nigrum*), cumin (*Cuminum cyminum*), and salt were used as flavouring agents. The milk was inoculated with 2% S. thermophilus and L. rhamnosus RSI3. The study revealed that the product has 5.01% protein, 0.82% ash, 8.95 cfu/g LAB count, 0.73% fat, and 82.18% moisture. The product was similar to Rabadi in consistency [59].

Another author also developed a milk and millet-based fermented drink using S. thermophilus C106 and L. rhamnosus GR-1. 1 litre of 3.25% homogenized milk was mixed with hulled millet and heated at 85-90°C for 3-60 minutes. Then, the culture was added after cooling it at 40°C. Sensory tests revealed that millet fermented in milk was the most appealing. Viable counts of probiotic bacteria were more than 106 colony-forming units (CFU)/ml [60]. Also, millet milk curd was developed by germinating foxtail millet, little millet, Kodo millet, Proso millet, and barnyard millet. Germinated millets are used to extract milk and are inoculated with NCDC 26. The curd-like mass obtained was analysed, and it was observed that acidity ranged from 0.74 to 1.2%, while pH ranged from 3.5 to 4.5 [61]. Similarly, a probiotic rich millet milk was developed using Lactobacillus kefir. Kefir millet fermented milk had much more protein, polyphenols, viable count, and acidity than the other commercially available comparable drinks [62].

6. CONCLUSION

Minor millets are not only cost-effective but are excellent tools for value addition due to their nutraceutical properties. Minor millets are a field that is already getting attention due to their potential to decrease malnutrition as well as their bioactive profile. Kodo and little millet are two of the oldest grains and have been sources of micronutrients in various traditional recipes. Also, with a shortage of conventional cereal crops all around the world, millet can be an excellent replacement. Not only are they drought-resistant, but they also have the ability to resist other climatic stress conditions. So, it is important to encourage millet production. Commercialization of millet-based products can attract consumers to make millet part of their staple diet. Today's consumer is health conscious and demands healthy and tasty food. So, there is a great opportunity to undertake extensive research for developing higher quality millet goods that are healthy, delicious, have a long shelf life, are appealing in colour and appearance, as well as accessible to customers of all economic levels. Dairy products have wider acceptability among consumers, so they are an excellent tool for value addition. Millets can compensate for nutrients like iron, which is deficient in milk. There are now a number of dairy products developed from millets that have the potential to be commercially successful, and researchers will have many more chances in the future.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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