Review Article

UTILIZATION OF MILLETS IN DAIRY FOOD: A REVIEW

Abstract:

Millets are consumed by more than one-third of the world's population. They hold significant importance as a staple food in many developing countries due to their ability to thrive under adverse weather conditions, such as limited rainfall. Furthermore, millet boasts numerous nutritious and medicinal properties. Its grains are nutritionally comparable, and in some aspects, superior to major cereals, offering higher levels of protein, energy, vitamins, and minerals. Future trends should prioritize increasing millet consumption in developed countries, as this could contribute to an industrial revolution. While milk is widely considered a complete food, it has been associated with various health problems due to elevated levels of saturated fatty acids and a lack of dietary fiber. In recent years, there has been a growing interest in enhancing the nutritional value of milk and milk products by incorporating millet. This involves creating composite dairy foods such as fermented, frozen, heat-desiccated, acid-coagulated, and other complementary dairy products in the dairy industry. Finally, the objectives of this review are to provide information on millet, highlight the nutritional significance of millet, and explore various fortified milk and milk products with millets, along with innovative ideas for dairy foods.

Keywords: Millets, Nutritional value, Fortified,Dairy Product, Milk.

1. Introduction:

Millets constitute a group of cereal food grain crops that have small seeds and are adapted to cultivation across a range of tropical and subtropical climates. They can be grown with very low inputs. These crops were the first to be domesticated by mankind in Asia and Africa, later spreading globally as critical food sources for evolving civilizations. Major millet crops include Jowar or sorghum, bajra or pearl millet, mandua/ragi or finger millet, and small millets such as kangni or foxtail millet, kutki or little millet, kodo millet, jhangora or barnyard millet, cheena or proso millet, and korale or browntop millet.The use of millets in infant food and nutrition products is on the rise, leading many manufacturers to expand their businesses. Increasing consumer awareness of the health benefits associated with millet consumption is expected to bolster the industry's growth.

Given the increasing global significance of millets and the declaration of 2023 as the 'International Year of Millets' by the UNGA, it is imperative for India to take the lead in mainstreaming millets, ensuring their presence on the common man’s plate. In this regard, establishing a sustainable value chain for millets is essential to promote millet exports and boost demand at both domestic and international levels.

Millet is the sixth cereal crop in terms of global agricultural production, with wheat and rice providing food security, while millets offer various securities such as food, health, nutrition, livelihood, and animal feed (Kimeera A. and Sucharitha K., 2019). Millet is considered one of the first cultivated crops and has been a staple food ingredient in Central and Eastern Asia, Europe (mainly Russia), China, India, and some parts of Africa since ancient times (Baltensperger, 1996). It is an important food in many developing countries due to its ability to grow under adverse weather conditions, such as limited rainfall. Additionally, millet possesses numerous nutritious and medicinal properties (Obilana and Manyasa, 2002; Xue and Lin, 2008).

Cereal-based milk products are popular throughout India, where cereals and milk are combined to address lysine deficiency (Aneja et al., 2002). Millet grains and their various constituents require additional human research on absorption, metabolism, and health benefits (Majumder et al., 2023). Millet food products must be economical for the needy and provide convenience, flavor, texture, color, and shelf stability. The incorporation of nonconventional food sources, such as soybeans and various types of millets, with fermented milks may help increase the utilization of these non-conventional food sources. This approach can lead to the production of low-cost, nutritious fermented foods, expanding the variety of fermented milks (Khurana and Kanawjia, 2007).

Cereals, especially millet, possess significant potential as raw materials for use in commercial products. Nevertheless, it is essential to transition processing and equipment from traditional to modern methods and optimize processing conditions to ensure the production of high-quality products (Amadou, 2011). There is a rising interest in integrating natural food additives and health-promoting substances into diets to address the demand for foods offering additional health benefits (Alwohaibi and Ali, 2022).

Millets exhibit several advantageous properties, such as drought resistance, high yields in water-scarce areas, and commendable nutritional values. There is evidence indicating that millet-based foods and beverages have functional and health-promoting effects. Specifically, they demonstrate anti-diabetic, anti-obesity, and cardiovascular benefits due to the actions of phytochemicals. Additionally, millets play a role in enhancing the body's immune system.

There is immense potential to process millet grains into value-added foods (Chandrasekara and Shahidi, 2010). The functional characteristics of millets are useful for designing special foods and value-added products (Kaushik et al., 2021). Fortifying milk with millets is beneficial for augmenting dietary fiber and other micronutrients in the form of composite millet milk dairy products, as well as exploring innovative possibilities by incorporating millets into composite dairy foods (Prasad S., 2023). Processing interventions in millet products have shown good acceptability with improved nutritional value, convenience, and shelf life. These interventions continue to be pursued for the invention of innovative millet products targeting both niche markets, such as gluten-free products, and health mix products for mass markets at the national level (Saraswathi R. and Hameed R., 2022). Millet is utilized as a dietary medicine, according to Singh et al. (2016). Value-added products from millet have the potential to contribute to business growth, as consumers believe that millets and millet-based foods directly contribute to their health (Karuppasamy P., 2015).

In recent years, millets have gained recognition as crucial substitutes for major cereal crops to enhance global food storage capabilities and meet the demands of the increasing populations in both developing and developed countries. Millet grains, constituting approximately one-sixth of total food grain production, occupy a significant position in the food grain economy of India (Shree et al., 2008).

Milk nutrients are effective in ensuring nutritional sufficiency; however, they are associated with various health problems due to high levels of saturated fatty acids and a lack of dietary fiber in milk. Therefore, fortifying milk with millets is deemed beneficial for enhancing dietary fiber and other micronutrients, creating composite millet-milk dairy products (Prasad, 2023). Future trends should prioritize millet consumption in developed countries, potentially contributing to their industrial revolution (Amadou et al., 2013).

2. The utilization of various types of millets for medicinal purposes:

2.1 Sorghum

Sorghum is regarded as a safe alternative food grain for individuals with celiac disease and gluten insensitivity. Additionally, research has indicated that Sorghum, or jowar, aids in weight loss. In comparison to major cereals such as rice and wheat, jowar contains a higher proportion of calcium. Furthermore, it is rich in iron, protein, and fiber (O.S.K. Reddy, 2017).

2.2 Finger Millet

Finger millet is beneficial for infants, the elderly, and pregnant women owing to its high calcium content. It is also highly advantageous for lactating women, as it aids in the production of sufficient breast milk. Finger millet contributes to the management of various health conditions such as blood pressure, heart problems, and asthma. Additionally, it serves as an excellent food choice for individuals with diabetes, facilitating slow digestion and the gradual release of glucose into the bloodstream. Furthermore, finger millet aids in raising hemoglobin levels, combating malnutrition, and addressing degenerative diseases (O.S.K. Reddy, 2017).

2.3 Pearl millet

Pearl millet contains magnesium, which aids in alleviating respiratory problems in asthma patients and mitigates the impact of migraines. The fiber content of pearl millet contributes to the reduction of gallstone occurrence. The insoluble fiber in pearl millet assists in decreasing excessive bile in our system, as an excess of bile in our system can lead to gallstones (Shweta, 2015).

2.4 Kodo millet

Kodo millet is a traditional food that closely resembles rice and aids in weight loss. It is easily digestible and is rich in phytochemicals and antioxidants, which help prevent various lifestyle-related diseases. Kodo millet also contributes to reducing joint and knee pain and assists in regulating menstruation in women (Deshpande et al., 2015).

2.5 Proso millet

Proso millet is advantageous in preventing the condition of Pellagra, which is caused by a deficiency of niacin (Vitamin B3). Proso millet has a high niacin content. Pellagra is a skin disease that leads to dry, scaly, and rough skin. Proso millet is rich in protein and niacin (Vitamin B3). Traditionally, it is used as recuperative food, especially after pregnancy or illness (Jana Kalinova, 2007).

2.6 Foxtail millet

Foxtail millet aids in the steady release of glucose without impacting the body's metabolism. The consumption of foxtail millet is associated with a decreased prevalence of diabetes, and it is also recognized as a heart-healthy food due to its rich magnesium content (O.S.K. Reddy, 2017).

2.7 Little Millet

Little millet is a rich source of B vitamins and minerals such as calcium, iron, zinc, and potassium, among others. Additionally, it supplies essential fats to the body, specifically the type that aids in weight loss (O.S.K. Reddy, 2017).

3. Nutritional value of millets:

Millets are referred to as "smart food" and "superfoods," possessing high levels of desirable nutrients, easy digestibility, distinct flavor, non-acid forming characteristics, and being gluten-free and non-allergenic (Hema et al., 2022). Millet grains are also known as 'nutricereals' due to their significant contribution to national food security and potential health benefits in combating various diseases (Shahidi and Chandrasekara, 2013). Nutritionally, millet grains are comparable to, and in some cases superior to, major cereals in terms of protein, energy, vitamins, and minerals (Sehgal and Kawatra, 2003). Millets help lower blood glucose levels and improve insulin response (Lakshmi et al., 2002). Millets have a low glycemic index, making them suitable for diabetic patients (Pradhan et al., 2010).

More than 58% of global production consists of millets, yet a limited number of Indians are acquiring knowledge regarding its health benefits and nutritional value (Upadhyaya et al., 2007). The primary components of millet comprise starch, protein, lipids, vitamins, and minerals (Usha et al., 1996). Furthermore, minerals such as magnesium, manganese, and phosphorus are present in significantly higher quantities than in other cereals (Gopalan et al., 1987). Millet serves as a predominant food source for a majority of individuals in the arid tropics, and its fiber content surpasses that of rice while being comparable to wheat (Reddy et al., 2008).

Millet foods and beverages exert functional and health-promoting effects, specifically anti-diabetic, anti-obesity, and cardiovascular benefits. These effects result from the actions of phytochemicals, and millets also play a role in the body's immune system (Kimeera Ambati and Sucharitha K., 2019). Most cereals contain essential amino acids, as well as vitamins and minerals (Devi et al., 2011; FAO, 2009). Millets are utilized as nutraceuticals due to their richness in antioxidants, surpassing those found in major cereal crops (Balasubramanium, 2013). Vitamin B, including niacin, folacin, riboflavin, and thiamine, along with phosphorus, is present in millets, playing a pivotal role in energy synthesis in the body (Sarita et al., 2016). Millets are particularly rich in B vitamins, such as niacin, pyridoxine, and folic acid. Additionally, millets provide significant amounts of calcium, iron, potassium, magnesium, and zinc. The nutrient content of millet surpasses that of rice or wheat. Millets, as a rich source of dietary fiber, offer a diverse range of nutrients and phytochemicals, including dietary fiber, vitamin E, magnesium, and folate, contributing to overall health optimization (Thilagavathy et al., 2010).

Finger millet, foxtail millet, pearl millet, and sorghum are potential sources of antioxidant compounds capable of quenching free radicals (Sripriya et al., 1996). Barnyard millet has nutritional and health benefits as a whole grain and in its value-added products (Bhatt et al., 2022). It is recommended for infants, pregnant women, diabetic-celiac patients, and patients intolerant to gluten and allergic to wheat-based products (Patil, 2017). Additionally, ragi has enormous health benefits and serves as a good source of valuable micro-nutrients, along with the major food components (Verma and Patel, 2013). Phosphorus from millets is an important mineral for energy production and is an essential component of Adenosine Triphosphate (ATP), the body's energy store (Shashi et al., 2007). It has been reported that cardiovascular diseases, duodenal ulcers, and hyperglycemia occur rarely in regular millet eaters (Vijayalakshmi et al., 2006).

Table 1: Nutritivevalueofmillets(per100g)

Crop/Nutrient	Protein (g)	Fat (g)	Fibre (g)	Minerals (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)
Rice	6.4	0.4	0.2	0.7	1.0	9.0	143
Wheat	11.8	1.5	1.2	1.5	5.3	41	306

Sorghum	10.4	1.9	1.6	1.6	4.1	25	222
Pearl millet	11.6	5.0	1.2	2.3	8.0	42	296
Fingermillet	7.3	1.3	3.6	2.7	3.9	344	283
Foxtail millet	12.3	4.3	8.0	3.3	2.8	31	290
Proso millet	12.5	1.1	2.2	1.9	0.8	14	206
Kodomillet	8.3	1.4	9.0	2.6	0.5	27	188
Littlemillet	7.7	4.7	7.6	1.5	9.3	17	220
Barnyardmillet	6.2	2.2	9.8	4.4	5.0	20	280

(Gopalan*etal*.,2009)

4. Value addition of millets in different dairy products:

4.1 Fermented dairy product

Mugocha et al. (2000) optimized the formulation of bacterial cultures to produce composite finger millet and skimmed milk-based powder gruel. They inoculated composite powder with varying volumes of finger millet (0 to 100%) at different temperatures (30-45 ℃). The results indicated that a thick product with a yogurt-like consistency could be obtained by incubating at 45℃ and storing at 7℃, regardless of the amount of finger millet gruel (0-50%). Sharma et al. (2017) studied bajra lassi, a fermented beverage prepared by fermenting a composite base of "pearl millet and milk" with suitable starter cultures. The product provides most nutrients in an easily digestible and highly bioavailable form. Additionally, bajra lassi, developed by the National Dairy Research Center in Karnal, combines the nutritional superiority of pearl millet with beneficial lactic bacteria (NDRI, 2008). Pardhi et al. (2014) prepared a lassi by adding finger millet, and it can be concluded that a lassi of good quality and enhanced acceptability can be prepared by incorporating finger millet flour.

In the study conducted by Rajini et al. (2013), the development of value-added millet dahi involved blending proso millet and flour at various levels (1%, 2%, 3%, 4%, and 5%), along with the incorporation of whey protein concentrate at different concentrations (0.5%, 1%, 1.5%, and 2%). Meanwhile, Sheela et al. (2018) standardized five minor millets for the extraction of millet milk. The obtained milk was subsequently pasteurized and fermented using the commercial curd culture NCDC 260 for a duration of 6 hours.

Rani M. (2018) developed whey-cereal-based fermented dairy products. Two different forms of cereal processing (soaked and germinated) were employed for two cereals (pearl millet and moth bean) in the product development. These products were then evaluated for both sensory acceptability and growth indicators of the NCDC-167 culture. More et al. (2020) prepared dahi by substituting milk solids with biofortified bajra flour. The bajra flour from the biofortified hybrid AHB-1200, rich in iron and zinc compared to local varieties/hybrids, was utilized. Dahi was produced from buffalo milk by blending it with bajra flour at 2%, 4%, 6%, and 8%. Fasreen (2017) mentioned that the beverage was crafted from cooked finger millet inoculated with Lactobacillus casei431®, sugar, fresh cow milk, and cocoa powder. The mixture was incubated at 37°C for 2 hours, 4 hours, and 6 hours. A sensory study revealed that fermentation for 4 hours resulted in the highest acceptance.

Jamdar et al. (2020) standardized the process of preparing Lassi by blending skim milk with an extract of germinated sorghum grains at different ratios, namely T1 (100:00), T2 (80:20), T3 (70:30), and T4 (60:40). The objective of using germinated sorghum grains extract was to preserve the medicinal, nutritional, and health beneficial properties of sorghum. In the study conducted by Fan et al. (2022), a novel millet-based flavored yogurt enriched with superoxide dismutase was developed. Shingare et al. (2022) conducted a study on the sensory evaluation of mistidahi blended with foxtail millet and finger millet flour. The mistidahi prepared by adding 4% finger millet flour was found to be more suitable in terms of sensory attributes.

4.2 Heat desiccated dairy product

Mamtha et al. (2003) prepared Burfi by replacing 57% of Bengal gram flour with foxtail millet flour, and the inclusion of foxtail millet flour significantly decreased blood glucose and cholesterol levels. Modha and Pal (2011) optimized a Rabadi-like fermented milk beverage using pearl millet. The product was developed using skim milk and flour from 24-hour germinated pearl millet grains, which served as sources of solids mixed in skim milk before fermentation. Bunkar et al. (2014) reported the optimized composition of kheer-mix based on pearl millet, which could be prepared in 5 minutes compared to the traditional rice kheer that typically takes around 45 minutes. Sujith et al. (2021) developed Burfi by blending 10% roasted foxtail millet powder by weight of khoa with 30% sugar.

4.3 Heat acid coagulated dairy product

Nazni, P. and Raisunnisa, S. (2022) conducted a study to investigate the impact of various food-grade acids on the quality of paneer incorporated with kodo millet flour. In conclusion, to produce paneer with optimal characteristics using kodo millet flour, it is recommended, based on this research, that malic acid can be more effectively employed as a coagulant compared to other coagulants.

4.4 Frozen dairy product

Patel et al. (2015) prepared ragi ice cream with four different flavors: vanilla, mango, chocolate, and caramel. The chocolate-flavored ragi ice cream was adjudged as the best, followed by mango, caramel, and vanilla ice cream. The iron and fiber content of chocolate-flavored ragi ice cream were found to be 12.8 ppm and 1.36%, respectively. Sharma et al. (2017) reported that the octenyl succinyl anhydride (OSA) esterified pearl millet (Pennisetum typhoides) starch was evaluated as a fat replacer in soft-serve ice cream compared to other fat replacers in ice cream, namely, inulin, whey protein concentrate-70 (WPC-70), and commercially available modified starch. Amirtha et al. (2021) studied the formulation and proximate evaluation of barnyard millet-based ice cream and revealed that the ice cream formulated with barnyard millet, soybean, and coconut extract showed a better acceptability score compared to the ice cream formulated with variations of barnyard millet, sesame, and coconut extracts. Sangma and Mishra (2017) prepared foxtail millet-based soft-serve ice cream by blending different levels of foxtail millet along with probiotic bacteria, i.e., Lactobacillus helveticus. The foxtail millet-based soft-serve ice cream was stored at deep refrigeration (-18 - 20 ℃) to assess the keeping quality of the product. Xavier (2021) conducted a study to establish a technology for making millet-based "musk melon kulfi," and the nutritious value of the muskmelon kulfi was enhanced by adding finger millet. The sensory properties, as well as the proximate parameters, were investigated in this study.

4.5 Other dairy product

Barnyard millets play a crucial role as a food staple in various regions. They can be utilized for preparing porridge, ready meals, and baby foods, as indicated by Chandrasekara and Shahidi (2012) and Nisha and Saravanakumar (2019). Kodo millet, an African spontaneously fermented millet, is used to create porridge and a beverage, as described by Lei and Jacobsen (2004). A complementary food, consisting of 45 percent pre-cooked pearl millet flour, skim milk powder, groundnut oil, and sugar, has been identified as helpful in addressing energy deficiency, as observed by Guiro et al. (1987).

Kumar et al., (2020) demonstrated the procedure for the manufacture of a functional beverage based on finger millet, oats, and double toned milk. For the manufacture of functional beverage, a 60:40 ratio of malt drink and double toned milk was used. Amadou, (2013)Millets are often ground into flour, rolled into large balls, parboiled, and then consumed as porridge with milk; sometimes millets are prepared as beverages. Verma and Patel, (2013) stated that ragi malted weaning food is mixed with powdered sugar, milk powder or whole milk along with flavoring agents to make as milk-based beverage. Jain et.al. (2016) studied milk can act as a potent carrier for the development of value-added products based on ragi. The objective of this study was to develop milk based malted ragi porridge as well as to study the effect of malting on the composition of milk based ragi porridge. Bhosale et al., (2021) investigated the research work on effect of different combinations of finger millet flour on chemical composition of composite cow milk kheer blended with paneer.

Almeida-Dominguez et al. (1990) produced extruded baby food using a composition of 70% pearl millet and 30% cowpea, contributing to 17% of the daily protein intake, 72% of lysine, and meeting 110% of threonine requirements for two-year-old children. Sharma et al. (2015) investigated Nutrimix, a cost-effective dry powdered formulation rich in nutrients. This formulation is developed through the appropriate processing of ingredients such as pearl millet, barley, and milk protein. The resulting powdered product can be utilized as ready-to-reconstitute weaning food. Sangita et al. (2019) formulated a probiotic beverage using whey-skim milk (60:40, v/v), germinated pearl millet flour (4.73%, w/v), and liquid barley malt extract (3.27%, w/v) with Lactobacillus acidophilus NCDC 13.

Bunkar et al. (2014) conducted a study on the preparation of pearl millet kheer mix by blending pearl millet, dairy whitener, and sugar powder. The samples of the pearl millet-based kheer mix were stored at 8, 25, 37, and 45 °C under a nitrogen-flushed environment. Sharma et al. (2017) focused on the development of complementary food based on a blend of whey, skim milk, pearl millet flour, barley malt, maltodextrin, and corn flour. Geetha and Preethi (2020) undertook a study to standardize a kodo millet-based functional milk beverage and assess the feasibility of a sprouted millet milk beverage through nutrient analysis and sensory evaluation. Sunny et al. (2019) investigated the substitution of mammalian milk in the diet of individuals with milk allergy and lactose intolerance. The study aimed to evaluate the effects of different combinations (40-60%) of millet milk and coconut milk for developing a plant-based milk alternative. Rathore et al. (2019) mixed fine malted flour with skim milk powder or whole milk powder, sugar, and desired flavoring substances to formulate milk-based beverages. The resulting beverage, named "ragi malt," was prepared. Prasad (2023) prepared a millet milk using barnyard millet, little millet, kodo millet, and finger millet, which serves as a substitute for dairy beverages and can be consumed by people of all age groups. Saraswathi and Hameed (2022) outlined the preparation of millet milk, involving the mixing of millet and water, grinding for 20 minutes, stirring the millet milk slurry well, filtering it through sieves, drying the slurries in a dryer using a standard procedure, collecting the dried millet milk powder from a stainless steel cyclone in a glass jar, packing it in a glass bottle, and storing it at room temperature for further analysis.

5. Conclusions:

The review provides an in-depth exploration of the nutritional aspects of millets, delving into potential applications for the development of composite millet-milk products. Emphasizing the importance of incorporating millet into both milk and milk products, it highlights the role of millet as a delectable and nutritious alternative to traditional grains like wheat and rice. Millet not only enhances food security but also contributes to nutrition, health, livelihood, fodder, environmental balance, and ecological security within the country. While cereal crops such as rice and wheat are vital for ensuring food security, millet expands this role by offering a holistic security framework covering nutrition, health, livelihood, fodder, and ecological aspects. The overall health status of the global population is directly influenced by dietary choices, and millets stand out due to their elevated levels of carbohydrates, protein, fats, vitamins, minerals, magnesium, manganese, and phosphorus, positioning them as potential sources of antioxidant compounds.Despite milk being acknowledged as a complete food, its association with various health problems is linked to elevated levels of saturated fatty acids and a lack of dietary fiber. Recently, there has been a growing interest in leveraging a combination of millet and milk or milk products to craft composite dairy foods. This includes varieties such as fermented, frozen, heat-desiccated, acid-coagulated, and other complementary dairy products in the dairy industry.

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