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Invited Review Article

Millet based composite dairy foods- A review

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Abstract

Cereal grains are the most important source of food consumed by the human beings since long. As one of the most important drought-resistant crops, millet is widely grown in the semi-arid tropics of Africa and Asia, and constitutes a major source of carbohydrates and proteins for people living in these areas. Millets are rich in phytochemicals, type and quantities of which vary greatly between and within different species. Millet grain is now receiving increasing attention from food scientists, technologists and nutritionists owing to its potential health benefits. It is advocated that millet should be used to complement dairy products and compensate for the deficiencies of the latter so that the resultant wholesome composite dairy foods can protect the people against malnutrition and nutrient deficiency. The aim of this article is to review the recent advances in research works on the nutritional quality and potential health benefits of millet based composite dairy foods.

Key words: Beverage, Dairy ingredients, Health, Milk, Millets

Highlights

- Millets are less allergic and easily digestible food.
- Millet is very good food for gluten sensitive patients.
- Millets are rich in essential amino acids, fatty acids and dietary fibre.
- Several composite products have been developed incorporating goodness of millets into dairy products.

INTRODUCTION

Millets have been a staple food throughout human history, particularly in Asia and Africa for the past 10,000 years. Millets are a group of diverse small-seeded grasses which are important crops in the semi-arid tropical regions of Asia and Africa, particularly in India and Nigeria. These crops are the primary sources of energy, protein, vitamins, and minerals for millions of the most vulnerable people in these regions (Yang *et al.*, 2012). The four main millets are foxtail millet (*Setaria italic*), pearl millet (*Pennisetum glaucum*), proso or white millet (*Panicum miliaceum*), and finger millet (*Eleusine coracana*). Minor millets include kodo millet (*Paspalum scrobiculatum*), guinea millet (*Brachiaria deflexa*), brown top millet (*Urochloa ramose*), barnyard millet (*Echinochloa* spp.) and small millet (*Panicum sumatrense*) (Hunt *et al.*, 2008; Bandyopadhyay *et al.*, 2017). About 97% of millet in the world is grown in low-income countries. In terms of global agricultural production, millet ranks as the sixth cereal crop and one of the most significant drought-resistant crops. Compared to other major cereals, millet has a shorter growing season, greater yield during droughts and greater resilience to pests and illnesses (Devi *et al.*, 2014). According to Meena *et al.* (2021), only seven of the 93 countries grow millet in an area larger than one million hectares. Yousaf *et al.* (2021) reported that developing nations produce and consume more than 97% of the world's millet. Millets aid in the management of conditions including diabetes mellitus, hyperlipidaemia, and other

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diseases (Veena, 2003). Karnataka state produces most millet in India.

Consumption of milk and milk products is nutritionally very important for populations in low- and middle-income countries. Milk and its products are generally a good source of nutrients like lipids, proteins, carbohydrates, minerals, vitamins and water (Muehlhoff *et al.*, 2013), but they lack in certain essential components such as micronutrients (iron, copper, etc.) and fibre. Therefore, milk and products could be complemented with various millets to formulate composite dairy foods. Millet proteins contain a good amount of sulphur containing amino acids (methionine and cysteine), which are a good source of antioxidants, such as phenolic acids and glycated flavonoids. Also, foods prepared from millets have enhanced viability or functionality of probiotics with substantial health benefits. When these millets are combined with other essential ingredients, such as milk, the quality of the resultant composite food, can be improved further (Chawla *et al.*, 2019).

Nutritional properties of millets

Nutritionally, millets are superior to wheat and rice. Millets have higher fibre and mineral contents than rice and wheat. They have at least double the amount of calcium compared to rice, while finger millet has thirty times more calcium than rice (Gull *et al.*, 2014). Millets are good sources of micronutrients, such as vitamins and beta-carotene. Methionine and cysteine, two important amino acids that contain sulphur, are particularly abundant in millet. They also have a higher fat content than corn, rice, and sorghum (Obilana and Manyasa, 2002). Major nutrient contents of millets are given in Table 1. In general, the amount of lysine and tryptophan in grain proteins, especially millet, is constrained and varies with variety (Table 2). However, most cereals contain vitamins and minerals in addition to the necessary amino acids (FAO, 2009; Devi *et al.*, 2014).

Health benefits of millets

Millet diets are a rich source of phytonutrients, vitamins, minerals, and fibrous substances (non starch polysaccharides), all of which are necessary for healthy development, the management of type 2 diabetes, and overall nutritional wellbeing (Habiyaremye *et al.*, 2017). The bioactive phytochemicals present in millets, such as lignans, flavonoids, phenolics, beta-glucan, sterols, inulin, pigments, dietary fibre and phytate possess a number of health benefits (Gull *et al.*, 2014). Major health benefits of millets are listed in

Table 1. Proximate composition of millet grain varieties

Component (g/100 g)	Sorghum	Finger millet	Pearl millet	Foxtail millet	Little millet	Barnyard millet
Protein	8-15	8.2	14.8	11.5	7.7-15	6.2
Ash	3.67	2.7	1.64	0.47	4.74	4.27
Fat	1.9	1.8	4.86	2.38	4.7	2.2
Total CHO*	72.6	83.3	59.8	75.2	67	65.5
Crude fiber	1.6	3.5	12.19	NA	7.6	9.8
Moisture	13.64	13.1	12.4	11.2	11.02	10
Iron	41-127	3.9-7.5	7.5-16.9	2.8-19	9.3-20	5
Calcium	207-447	240-410	10-38	10-31	17-30	20
References	Shegro *et al.*, 2012	Devi *et al.*, 2014	Taylor *et al.*, 2010	Kamara *et al.*, 2009	Geervani & Eggum, 1989	Verma *et al.*, 2015

Total CHO* - Total carbohydrate; Sources: Amadou *et al.* (2013); Gopalan *et al.* (1971), USDA National Nutrient Database (2016)

Table 2. Amino acid composition of millets

Amino acids (g/100g) Essential amino acid	Foxtail millet	Proso millet	Peral millet	Finger millet
Isoleucine	4.59	4.1	5.1	4.3
Leucine	13.60	12.2	14.1	10.8
Lysine	1.59	1.5	0.5	2.2
Methionine	3.06	2.2	1.0	2.9
Phenylalanine	6.27	5.5	7.6	6.0
Threonine	3.68	3.0	3.3	4.3
Valine	5.81	5.4	4.2	6.3
Histidine	2.11	2.1	1.7	2.3
Tryptophan	NA	0.8	1.2	NA

Sources: Saldivar (2003), Kamara *et al.* (2009), Bagdi *et al.* (2011) Devi *et al.* (2014)

Table 3. Health benefits of millets

Name of the millets	Major health benefits	References
Pearl millet	Reduces the risk of inflammatory bowel disorders, lowers triglyceride levels, acts as a natural source of antioxidants, and prevents heart-related problems	Chandrasekara and Shahidi, 2011; Islam *et al.*, 2015; Kim and Je, 2016; Liu *et al.*, 2015
Finger millet	Lowers the chance of developing diabetes mellitus and gastrointestinal diseases, and has the capacity to scavenge free radicals	Muthamilarasan *et al.*, 2016
Barnyard mille	Acts as an inhibitor of cancer-developing cells while lowering cholesterol and blood sugar levels	Sharma *et al.*, 2016; Ugare *et al.*, 2014
Proso millet	Enhances glycemic responses and plasma levels and safeguards against liver damage brought on by D-galactosamine	Park *et al.*, 2008; Ito *et al.*, 2008
Little millet	Reduces cholesterol levels in cases of cardiovascular disease, and in diabetic people, lowers fasting blood sugar, blood glucose, and lipid parameters	Surekha, 2004
Foxtail millet	When used in diabetic settings, it serves as antihyperglycemic and antilipidemic drugs and blocks the pro-inflammatory and hypertrophic response	Choi *et al.*, 2005

Table 3. Biologically active compounds with antioxidant potential are found in millets and their dietary products (Izadi *et al.*, 2012). By neutralising free radicals, the minerals, vitamins, and flavonoids in millet grains aid in preventing unintentional harm to cell membranes and other body components. Millet grains' antioxidants have anticancer properties. Due to the presence of vitamins and bioactive substances, consumption of millet grains improves bone quality and boost antioxidant status of the subjects (Chethan and Malleshi, 2007; Devi *et al.*, 2014).

Millets are soothing, easily digestible, and support the health of gut microflora which make it comparable to prebiotics (Banerjee *et al.*, 2017). According to Kunchala *et al.* (2016), utilization of millet as a prebiotic is acceptable and beneficial. Prebiotics are non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and activity of one or a limited number of bacteria in the colon. Millet's whole grain also shows prebiotic activity, which helps to increase the population of friendly bacteria that play a key role to promote digestion. Malting induces beneficial biochemical changes in the millet grain (Sarita and Singh, 2016). Millet foods are characterized as potential prebiotics and can enhance the viability and functionality of probiotics with significant health benefits, which are good for people suffering from celiac disease apart from being good sources of bioactive compounds (Amadou, 2022). The stimulatory effect of malted ragi (millet) milk was due to arabinoxylan, the fraction contributing prebiotic action/prebiotic precursor (Pokharia, 2008). Mondal *et al.* (2022) extracted oligosaccharides from pearl millet using membrane filtration. A positive prebiotic score, enhanced biofilm formation and capability of producing short chain fatty acids (i.e. acetate, propionate and butyrate) by different strains of Lactobacilli in presence of the extracted oligosaccharides proved their prebiotic potential.

Effect of processing on anti-nutritional properties of millets

Anti-nutritional compounds present in millets are α-amylase inhibitor, trypsin inhibitors, phytate and tannins which reduce the bioavailability of nutrients. Phytic acid in millets has ability to bind and decrease the bioavailability of minerals such as Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+} (Panwar *et al.*, 2016). Tannin compounds are concentrated in the bran and affect *in vitro* protein digestibility. Tannin combined with protein makes a complex which lowers the food efficiency, growth, and iron absorption in human body. Amylase inhibitors can behave as endogenous mammalian alpha-amylases, which bind to alpha-amylase and make them non-functional (Samtiya *et al.*, 2021).

According to Samtiya *et al.* (2021), the effect of anti-nutritional factors can be obviated by various processing methods. Decortication, process of removal of pericarp of grains, reduces phytic acid and polyphenolic content from millet grains, by up to 23%. Germination is an active phase of metabolism in which anti-nutrients are reduced. Germination is a good way to reduce phytic acid by up to 40%. The phytic acid content in different varieties of pearl millet varies from 588 to 1382 mg/100g. When pearl millet grains are germinated for 24 h at 30°C, it leads to reduction of phytates by more than 50% through hydrolyzation of phytic acid. Germination also reduced tannin content by 22.66-35.22% and phytic content by 25.87-32.84%. Non-fermented roasted and germinated pearl millet has high phytic acid content than fermented, roasted, and germinated pearl millet. Soaking in water for 12 to 18 h and discarding the water is quite effective in leaching out of polyphenols and proteolytic enzyme inhibitors. Soaking followed by germination can improve the nutritional quality of millets as it helps in reducing starch component, inducing hydrolytic enzymes for phytate reduction and some flavonoid components (Sheela *et al.*, 2018). Malting and fermentation of finger millet improves its digestibility, sensory and nutritional quality and exerts pronounced effect in lowering the anti-nutritional factors. Reduction of up to 70% of polyphenol was achieved when millet was treated with soaking, germination, microwave treatment and fermentation (Samtiya *et al.*, 2021).

Millet based composite dairy foods

Foods classified as composite dairy foods are those in which milk, milk products, or milk constituents are a significant component of the final product and non-dairy ingredients are not meant to substitute for milk, milk products, or milk constituents. Composite food may also be defined as "a foodstuff intended for human consumption that contains both processed products of animal origin and products of plant origin". The nutritional status and energy density of supplemental foods made from cereals are improved when milk and milk products are used. Cereals are good sources of protein, carbohydrate, vitamin B complex, vitamin E, iron, and other minerals as well as fibre. Cereals and milk together work synergistically to address the issue of nutritional deficit caused by one or more specific components, such as vitamins, minerals, vital amino acids, fatty acids, etc. Millet flours and malts have been mixed with dairy ingredients in the preparation of several composite products of frozen, fermented and non-fermented types having health benefits which are presented below:

Ice cream: Patel *et al.* (2014) prepared medium fat ice cream (6% fat) with different flavours by adding 9% gelatinized malted ragi flour roasted in butter to the mix (10% fat). Chocolate flavoured ragi ice cream was adjudged as best, followed by mango, caramel and vanilla ice cream. The iron and fibre contents of chocolate flavoured ragi ice cream were 12.8 ppm and 1.36%, respectively as against 1.5 ppm and 0.18%, respectively obtained in control. Heat shock treatment as well as storage up to 30 days had no adverse effect on the sensory quality of the chocolate flavoured ragi ice cream. Incorporation of finger millet in ice cream resulted in reduction in the amount of stabilizer used and effectively functioned as fat replacer in ice cream. Chaudhary (2013) supplemented normal ice cream mix (6% fat, 11% MSNF, 4.9% protein, and 15% sucrose) with 9% of finger millet malted flour for the production of probiotic ice-creams and checked the viability of the probiotic micro-organisms (*Lb. helveticus* MTCC5463 and *Lb. rhamnosus* MTCC5462) along with sensory analysis of the samples. During storage of 60 days, the probiotic organisms survived more when the ice-cream mix was supplemented with millet, suggesting that millet had a protective effect on the Lactobacilli. The viable counts of Lactobacilli remained above 7 log CFU/g in both ice-creams with or without millet, higher number in millet supplemented ice cream.

The octenyl succinyl anhydride (OSA) esterified pearl millet (*Pennisetum typhoides*) starch was evaluated as fat replacer in soft serve ice cream in comparison to other common fat replacers viz. inulin, whey protein concentrate-70 and commercial starch. OSA-esterified pearl millet starch improved the product's consistency indicating its potential as fat replacer in reduced fat ice cream (Sharma *et al.*, 2017). Amrita *et al.* (2021) used barnyard millet in ice cream and reported that such ice cream had higher amounts of carbohydrates, protein, fat, calcium and phosphorus. They opined that the ice cream was beneficial for people who are suffering from lactose intolerance and cow milk protein allergy, apart from being suitable for the people who prefer vegan diet.

Beverages: Fasreen *et al.* (2017) worked on the development of a probiotic beverage using milk, finger millet flour, cocoa powder (7.9 g/L) and sucrose (46 g/L). The heat treated (78°C/10 min) and cooled (40°C) mix was inoculated with *Lactobacillus casei* 431 culture (0.031 g/L) and incubated at 37°C for 4 h for fermentation. The probiotic organisms grew well in the finger millet containing product. The fermentation time of 4 h increased the number of organisms rapidly to 2.0×10^8 CFU/mL. The viability decreased with the progression of the storage period. Even after 6th week, the count was 7.0×10^7 CFU/mL. Sometimes the flavour associated with finger millet is a cause of concern in beverages which could be overcome by using intense flavours. This approach was followed by Shaikh and Sreeja (2017) who experimented with different concentrations of sugar and flavour to develop a desirable probiotic drink, with incorporation of finger millet and probiotic organisms. Curd was prepared using toned milk added with 20% malted finger millet flour. The probiotic organisms used were *Lb. helveticus* MTCC 5460 and *Lb. acidophilus* MTCC 5463 (2%) and the inoculated mix was incubated at 40°C till the acidity reached to 0.7%. The product formed was cooled to 5±2°C, curd broken and flavours such as caramel essence, chocolate syrup and strawberry essence were added separately at 0.8, 1 and 0.4% levels (on curd basis), respectively to the mix to obviate the slight off flavour of finger millet.

Kumar *et al.* (2020) blended finger millet and oats in different ratios for preparing a milk-based probiotic beverage, using double-toned milk. The malted finger millet and oat groats were milled separately and mixed in 60:40 ratios. This powder was used in double toned milk along with sugar (6.5%) to obtain a relishing drink. Fermented composite beverages of finger millet and milk are popular, nutritious, traditional foods in many parts of Zimbabwe. Mugocha *et al.* (2000) used composite milk containing finger millet-gruel (1:1), inoculated and incubated it at 30 to 45°C till a pH of about 4.5 was attained. The final product had thick yoghurt like consistency. In another study by Shaikh *et al.* (2017), toned milk (3.0% fat, 8.5% SNF) was pre heated to 40°C and added with malted and unmalted finger millet flour at 10% level (on milk basis) and mixed to ensure uniform mass. The mixture was heated to 80°C for no hold, cooled to 40°C, inoculated with probiotic Streptococcal culture (2%) and was incubated at (37±2°C) till the titratable acidity reached to about 0.7% LA. The product was cooled (5±2°C), the curd broken to obtain a uniform viscous product (similar to stirred dahi), filled in HDPE bottles and stored at refrigeration temperature (7±2ºC). Fermentation decreased starch and long chain fatty acids contents in the product. The authors concluded that the use of malted finger millet flour improved the product quality attributes in comparison to unmalted flour especially in terms of probiotic Streptococcal counts and titratable acidity development.

Thomas and Karuna (2019) prepared a ready-to-drink beverage using malted ragi flour, sugar, water, milk, jaggery, beaten rice and water which were mixed to get a pourable consistency (TS about 25%), filled in bottles and retorted at 121°C for 20 min. A pearl millet based 'novel health drink' was reported by Vanishree *et al.* (2016). It consisted of a mixture made of 50% pearl millet flour and remaining 50% of finger millet flour, malted soya flour, amaranth seed powder and sugar powder. It was suggested to mix this mixture with milk in desired amounts to create a healthy drink. Bansal and Kaur (2018) developed five milk-based beverages by supplementing malted ragi. Control samples were prepared by using milk, fruits (banana, kiwi, strawberry, papaya and mango) and honey. In test samples, malted ragi was added at different levels ranging from 5-15%. Banana based malted ragi beverage supplemented with 5% malted ragi obtained highest overall acceptability score. The most acceptable malted ragi beverage had 11.78 g crude protein, 6.81 g of crude fat, 1.21 g of crude fibre, 27.44 g of carbohydrates, 594.3 mg of tryptophan, 517.6 mg of methionine, 372.3 mg of lysine, 172.6 mg of calcium, 3.73 mg of iron, 102.2 mg of phosphorus and 0.596 mg of zinc per 100 mL.

Smoothies: A composite milk and sorghum-based smoothie containing varying levels of sorghum flour (2-4%, w/w), sugar (9-11%, w/w) and pectin (0.2-0.4%, w/w) was optimised by Rani *et al.* (2016) using response surface methodology on the basis of sensory and physical (viscosity, sedimentation and wheying off) attributes. Flour and pectin levels influenced the flavour, consistency, viscosity and sedimentation significantly. Sugar helped to increase the overall preference and had a positive correlation with sedimentation. An optimised smoothie composition of acceptable quality was obtained with 2.79% (w/w) germinated sorghum flour, 10.30% (w/w) sugar and 0.35% (w/w) pectin. Brukina, a fermented milk, and millet smoothie, is a popular indigenous beverage in northern Ghana. Steam cooked millets are mixed thoroughly with fermented milk and sugar to make this product (Baidoo and Kunadu, 2018). To prepare Gappal, a millet-based product of Burkino Faso, bajra (*Pennisetum glaucum*) flour dough is mixed with milk/sour milk (1:4), added with sugar and aroma, mixed and packaged (Tankoano *et al.*, 2017).

Dried products: Modi (2009) prepared spray and tray dried complementary food from blends of whey, skim milk, germinated barley malt, pearl millet and corn flour. Germinated and roasted pearl millet flour (20%), barley malt extract (15%), maltodextrin (5.69%), corn flour (5%) and whey-skim milk blend (4:1) were mixed and the mix heated at 80°C for 15 min. The heated mix was dried using cabinet drying (70°C for 48 h) or spray drying with inlet air temperature 195°C and outlet air temperature 95°C to obtain a dried product having less than 4% moisture content. The developed technology is reported to be quite simple and suitable for industrial production due to lower processing and raw material cost. Murthy *et al.* (2016) prepared a complementary food by using malted foxtail millet flour, wheat flour, skim milk powder, whey protein concentrate, ghee and sugar, and compared it with a commercial sample. The prepared product obtained higher score for overall acceptability than the commercial sample (Cerelac). Singh *et al.* (2013) prepared a dry mix by dry blending multigrain dalia (maize, pearl millet and sorghum), sugar and skim milk powder.

Tarhana, a fermented air-dried product, is produced by mixing yogurt with wheat flour (1:1) and allowing the mixture to continue fermenting for several (l-7) days (Robinson and Cadena, 1978). Baker's yeast is also incorporated in the mixture. The mix is then air-dried and consumed in the form of a soup. Tarhana is rich in protein and vitamins. Other ingredients such as paprika, salt, tomato and onions are often incorporated into tarhana for flavour (Campbell-Platt, 1987). Erkan *et al.* (2006) reported a method for preparation of tarhana using barley flour instead of wheat flour. Tarhana can be considered as a functional probiotic food as it is prepared by fermenting the mix with LAB and yeast apart from being a good source of B vitamins, minerals, organic acids and free amino acids. The African product Kindimu is prepared by sun drying of admixture of fermented milk and germinated-sorghum flour (Tatsadjieu *et al.*, 2004). Owing to less cohesive nature of millet flours, mixing of proso and kodo millet flours in yoghurt whey before spray drying, helped in easy operations, enhanced free flowing properties of resultant whey powder and also increased yields (Malik *et al.*, 2021). The acid whey-millet complementary food powder is shelf stable and has free-flowing characteristics. The reconstitution properties of formulation were similar to those of commercial baby food powder.

Food mixture: Arora *et al.* (2010) formulated food mixture using non-germinated and germinated barley flour, whey powder and tomato pulp (2:1:1, w/w) which was autoclaved, cooled and fermented with 5% *Lactobacillus acidophilus* curd (10^6 cells/mL) at 37°C for 12 h. The cell count was significantly higher (8.88 log CFU/g) in the fermented food mixture formulated from germinated flour as compared to that made using non-germinated barley flour. A significant drop in pH with corresponding increase in titratable acidity was found in the germinated barley flour-based food mixture. Ganguly *et al.* (2014) developed a composite dairy-cereal substrate consisting of whey, skim milk, germinated pearl millet flour, and liquid barley malt extract which was heat processed, and fermented using probiotic *L. acidophilus* NCDC 13. A high count of 13.22 log CFU/mL was reported in the substrate with 4% inoculum level and 8 h incubation at 37°C. Phytic acid, polyphenol and phytate phosphorus contents were reduced by 80.0, 47.2 and 76.5%, respectively with concomitant increase by 69.0 and 64.0% in the bio-availability of Ca and Fe, respectively. The protein and starch digestibility of the mixture increased from 45.4 and 43.4%

to 62.4 and 57.8%, respectively.

Nishad *et al.* (2017) prepared a simple mixture of millets for a health drink. Millet was soaked for 5 h, sprouted overnight and the sprouts were shade dried for 12 h. For development of flavour, grains were dry roasted at 60-70°C in a wok, temperature of which was maintained at about 100°C. After roasting, the millets were cooled to room temperature, ground into flour in an electric grinder, sieved through 80 mesh sieve and stored separately in polyethylene bags before using. For preparation of a healthy drink, it was recommended to mix 100 g of mixture of above treated millets (50% finger millet+20% kodo+20% little and 10% barnyard millets) in 1000 mL milk along with desired quantity of sugar. Suresha *et al.* (2018) tried to enhance the nutritional value of malted millet flour mixes by incorporating whey protein hydrolysate and skim milk powder.

Kheer: Jha *et al.* (2013) prepared a ready-to-eat kheer using 18.49% dairy whitener and 6.0% pearl millet employing a process temperature of 87.5°C. The yield of the product was 46.76% on milk basis. Mugale *et al.* (2022) developed a sanwa (barnyard millet) kheer using milk (fat 6% and SNF 9%) heat (85°C) concentrated to 75% of original volume and added with 5% sanwa (source of fibre). The mix was cooked, added with 6% sugar (on milk basis) and 1.5% rose petal powder (source of antioxidants), and cooled to prepare the sanwa kheer. A formulation of another type of kheer mix with 15 g sugar, 30 g dairy whitener and 20 g pearl millet was developed by Bunkar *et al.* (2014). The moisture, fat, protein, carbohydrate and ash contents of the dry mix product were 2.8, 4.38, 5.84, 85.88 and 1.1%, respectively. Bhosale *et al.* (2020) also reported on millet kheer preparation. Chetna *et al.* (2017) used little millet in place of rice for kheer preparation. The highest mean scores for colour and appearance, consistency, flavour, sweetness and overall acceptability were obtained for the sample having 4% little millet and two times concentration ratio. The yield of kheer was 66.5% (on milk basis).

Yoghurt: Production of yoghurt using millet milk (millet extract) has disadvantage of low cohesiveness. To improve the consistency of such product, millet milk was partially replaced with cow milk by Samira *et al.*, (2021). Results showed that replacement of 10% millet milk with low-fat milk increased pH and decreased syneresis and protein content. Upon increasing the millet milk content to 15 and 20%, pH, dry matter and fat content decreased and syneresis, protein and phenolic compounds content increased significantly ($P<0.05$). Addition of 20% millet milk resulted in increase in fibre content to 0.09% and decrease in calcium content to 40.5 mg/kg in yoghurt. Yoghurt containing 10% and 20% millet milk had the highest and lowest acceptability, respectively. The authors recommended addition of 10% millet milk for making yogurt like product to obtain best results. Glycemic index of sorghum was reduced when incorporated in fermented milk as porridge. This is advantageous for diabetics (Amwoma *et al.*, 2022).

Other composite foods: Millet products were used in the preparation of several other dairy products. For example, a sweet burfi like product was prepared by incorporating 10% of little millet flour and 30% sugar in milk and cooked till semisolid consistency was obtained in the product. The product kept well for one week under refrigerated conditions (Sandey *et al.*, 2009).

A product similar to raabdi was manufactured by Modha and Pal (2011) using pearl millet germinated flour. Curd was prepared from skim milk admixed with 5.3% germinated pearl millet flour, the curd was broken and mixed with 72% water and spices. Malting of grains enhanced the probiotic count in the product. Pintu and Verma (2019) developed a technology for the manufacture of sorghum based raabdi-like fermented milk beverage. Skim milk was heated to 40°C, added with flour at the rate of 4.7% (on skim milk basis), mixture heated to 90°C for 5 min, cooled to 37°C, inoculated and incubated at the same temperature for 8 to 10 h. Traditional milk-cereal based beverages like raabdi are popular among people of Haryana, Rajasthan and Punjab. However, shelf-life of raabdi is limited to about two days which poses difficulties for its industrial production.

Pardhi *et al.* (2014) developed finger millet lassi. Milk was heat treated at 85°C/10 min, cooled to 20°C, added with culture (1.5%), incubated at 30°C/12 h, cooled to 7°C, coagulum broken and was added with 3% finger millet flour, 10% sugar, and 20% water. The mixture was blended, packaged in polystyrene (200 mL) cups and stored at 7°C. The final product had 2.26% fat, 3.75% protein, 15.25% total sugar, 0.78% ash and 24.78% total solids.

Jain *et al.* (2016) worked on the development of finger millet-based milk porridge by admixing 5% of malted and unmalted finger millet flour with milk. Malting led to an increase in the protein, ash, crude fibre, calcium, phosphorus and vitamin C contents of porridges.

Shahi *et al.* (2016) prepared low fat milk nuggets having good to very good acceptability using coagulum obtained from 2% fat milk and other ingredients *viz.* refined wheat flour, spices and condiments. Addition of 15% barnyard millet flour to low fat milk nuggets increased the cooking yield significantly.

Oluwafunmilayo (2019) prepared composite biscuits with mixtures of whole grain sorghum and cowpea flour which are known to have some health benefits including anti-diabetic, anti-cancer and anti-hyperlipidemic effects. Sorghum and cow pea composite flour was useful for lowering postprandial hyperglycaemia through the inhibition of starch-hydrolysing enzymes. Mathur *et al.* (2020) reported on the development of multigrain fibre and protein enriched composite bar and observed that the blend of whey proteins and soy protein produced sensorially superior product.

Nazni and Raisunnisa (2022) showed that paneer like product can be prepared with millets. Kodo millet flour was admixed with milk and the heat-treated hot milk was coagulated with 2-3% solution of malic acid. The resultant product was highly acceptable. However, excess addition of millet flour may adversely affect body and texture of paneer. Narayanan (2014) reported that use of more than 1% ragi flour and wheat flour resulted in pasty consistency in paneer.

Packaging and shelf life

Dairy products, especially ready-to-eat, ready-to-drink and ready-to-serve type are known to have low shelf life. Composite dairy foods also have similar shelf-life property. Incorporation of millets into dairy products seems to have little impact on shelf life. However, malting process improved microbial shelf life of milk-based porridge when compared with control (unmalted ragi porridge). The porridge when packed in polystyrene cups was microbiologically safe up to 9 days of refrigeration storage (Jain *et al.*, 2017). An energy bar prepared using milk solids, finger millet flour and other ingredients had a shelf life of 135 days at 15°C when packed in metallised laminate (Jetavat *et al.*, 2020). The treated energy bar had nonsignificant difference in shelf life with that of control prepared without the millet flour.

Efforts were made to enhance the shelf life of a sorghum based fermented milk beverage by using nisin (400 RU/mL), MicroGARD (1%), potassium sorbate (0.15%) and thermization treatment (65 °C/5 min) (Hussain *et al.*, 2014). Addition of potassium sorbate without thermization was the best preservation technique for enhancing the shelf life of salted sorghum lassi at 6 ± 1°C. The authors concluded that nisin, MicroGARD and potassium sorbate could be used to preserve salted sorghum lassi for about 3 weeks at 6±1°C. Modha and Pal (2011) found that the pearl millet based fermented milk beverage in glass bottles had a shelf-life of 7 days without any preservative at refrigerated storage (5-7°C). Chetna *et al.* (2017) noticed that the shelf life of little millet kheer packaged in polystyrene cups was 10 days at 6±1°C. Its pH decreased significantly ($p<0.05$) while acidity and viscosity increased during storage. The SPC increased from 1.65 CFU/g to 5.1 CFU/g at the end of 10 days storage. The shelf-life studies of composite dairy foods indicated that millets exerted little effect on the shelf- life of dairy foods.

Conclusion

Millets are environment-friendly plants and can easily grow in harsh situations like drought. They are rich in minerals, gluten-free protein, B vitamins and antioxidants, and have a low glycemic index. Consumption of millet-based foods can boost the general health of the community apart from providing a good income to the farmers. However, scientific approaches need to be adopted to overcome limitations, such as presence of anti-nutritional components in millets and the low sensory acceptance of millet-based products. Processing techniques including boiling, roasting, sprouting, and fermentation can inactivate the anti-nutritional elements. Sensory acceptability of millet-based foods can be improved if millet flour is combined with dairy ingredients. Protein, calcium, and iron deficiencies among people in developing nations can be greatly reduced by including millet-based dairy products in various nutrition programmes. Presence of millets in fermented dairy products boosted probiotics growth. Composite dairy foods incorporated with millets need to be popularised for the benefit of both consumers and millet farmers.

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