JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Nutrient Composition and Microbial Quality of Fermented Millet-Based Porridges

[1]Jemima Beryl Mohankumar & [2]Stella Satheesh
[1]Department of Nutrition & Dietetics, PSGCAS, Coimbatore, INDIA
[2]PhD Research Scholar, Bharathiar University, Coimbatore, INDIA

I. Abstract

Introduction: The year 2023 is the International Year of Millets. Indian millets are a group of nutritiously rich, drought tolerant and mostly grown in the arid and semi-arid regions of India. They are small-seeded grasses belonging to the botanical family *Poaceae*. They constitute an important source of food and fodder for millions of resource-poor farmers and play a vital role in ecological and economic security of India. **Rationale:** Indian Millets are nutritionally superior to wheat and rice as they are rich in protein, vitamins and minerals. Pearl millet (*Pennisetum glaucum*) and Finger millet (*Eleusine coracana*) porridges were prepared and fermented with a view to use the beneficial probiotics for the digestive health of children. **Hypothesis:** Fermented Porridge from a blend of millet and rice can offer high quality of nutritional value and acceptability by consumers. **Method:** Spontaneously fermented finger millet and pearl millet porridges were prepared by making a slurry of fine millet flours with boiled cooled water; fermented for 15 hours; cooked with broken rice grits and excess water until well cooked and attained porridge consistency with further fermentation for 15 hours. **Conclusion:** Fermented millet-rice-blend based porridges in a ratio of 5:1 provided enhanced Lactic acid Bacteria compared to the unfermented porridges which may be recommended as a synbiotic food matrix supporting gut health among children with persistent diarrhoea or antibiotic-associated diarrhoeal issues. Absence of enteropathogens among the cooked and fermented porridges indicate safe food consumption.

Key words: millets; fermentation; porridge; nutrient composition; therapeutics

II. Introduction

Pearl millet (*Pennisetum glaucum*) known as Ragi and Finger millet (*Eleusine coracana*) were used in the present study. Finger millet porridges (FMP), rich in nutrient and non-nutrient compounds have been used in the traditional food cultures in Asia. Among all the cereals and millets, Pearl millet is also commonly known as bulrush millet on account of the shape of the grain head (Fig 1). It was introduced into India about 3000 years ago (House, 1995), and it is the most widely cultivated millet today. Ragi has the highest amount of calcium (344 mg %) and potassium (408 mg %). It has higher dietary fiber, minerals, and sulfur containing amino acids compared to white rice. Ragi is comparable to rice with regard to protein (6-8%) and fat (1-2%) and is superior to rice and wheat with respect to mineral and micronutrient contents (APEDA, 2022).

The grains of finger millets (*Eleusine coracana*) are very small in size with brown, light brown and white in colours based on different cultivars. The white cultivars have been developed mainly for the baking industry, the brown and light brown types used for porridge while the brown cultivar is utilized for brewing traditional opaque beer in Southern Africa. Finger millet has the highest source of calcium and iron when compared to the other cereals. Finger millet contains high concentration of carbohydrates, dietary fibre, phytochemicals and essential amino acids; presence of essential minerals; as well as a gluten-free status (Dhanushkodi, et al., 2023).

Finger millet grain possesses excellent storage properties and is said to improve in quality with storage. However, a number of studies showed that they are highly valued as a reserve food in times of famine and can be stored without damage up to 50 years (Srivastava & Sharma, 2012). Finger millet is used in the preparation of different foods both in natural and malted forms, like porridge, puddings, pancakes, biscuits, roti, bread, noodles, and other snacks. Besides this, it is also used as a nourishing food for infants when malted and is regarded as wholesome food for diabetic patients (Gull, et al., 2014). Finger millet is rich in nutrients and offers several health benefits. It consists of essential nutrients like carbohydrates, dietary fibre, essential amino acids, and minerals are present in sufficient amounts in finger millet (Ramashia, et al., 2019). The grains are a good option for those with celiac disease because they are free of gluten and are simple to digest (Muthamilarasan, et al., 2016).

English: Pearl Millet; Bengali: Bajra; Gujarati: Bajri; Hindi: Bajra; Kannada: Sajje; Marathi: Bajri; Oriya: Bajra; Punjabi: Bajra; Tamil: Kambu; Telugu: Sajja.
English: Finger Millet; Bengali: Marwa; Gujarati: Nagli, Bavto; Hindi: Ragi, Mandika,
Marwah; Kannada : Ragi; Marathi : Nagli, Nachni; Oriya : Mandia; Punjabi : Mandhuka, Mandhal; Tamil : Keppai, Ragi, Kelvaragu; Telugu : Ragi Chodi

Fig: 1 Pearl millet and Finger millet

Finger millet contains protein 6.12 %, fat 1.06%, ash 2.13%, carbohydrate 79.52%, starch 69.26 % and total sugar 1.33% (Pandhre, et al., 2011). The raw finger millet flour had good amounts of crude protein (4.6%), crude fat (3.06%) and crude fibre (14.8%). Ragi is a versatile crop with a high nutrient profile of protein (6-8%), fat (1.3%), calcium (296 mg), carbohydrate (70-76%), lysine (2.86%), tryptophan (1.39%) and methionine (2.86%) (Aparna & Ansari, 2017).

Table 1 Nutrient Content of Millets*

Millet	Protein (g)	Fiber (g)	Minerals (g)	Iron (mg)	Calcium (mg)
Sorghum	10	4	1.6	2.6	54
Pearl millet	10.6	1.3	2.3	16.9	38
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8	3.3	2.8	31
Proso millet	12.5	2.2	1.9	0.8	14
Kodo millet	8.3	9	2.6	0.5	27
Little millet	7.7	7.6	1.5	9.3	17
Barnyard millet	11.2	10.1	4.4	15.2	11
Teff	13	8	0.85	7.6	180
Fonio	11	11.3	5.31	84.8	18
Brown top millet	11.5	12.5	4.2	0.65	0.01

*ICAR-IIMR, 2023. www.millets.res.in

III. Methodology

3.1 Preparation of fermented Millet Porridge

Table 2 –Ingredients for porridge preparation

Ingredients	Quantity (g)
Millet flour (Finger/ Pearl)	100
Broken rice	20
Salt	2
Water	4 to 5 cups

Pearl millet (*Pennisetum glaucum*) and Finger millet (*Eleusine coracana*) were procured from the local market and underwent a thorough cleaning and washing process several times to eliminate any impurities or dust particles. Subsequently, the dried millets were finely ground into flour. A quantity of one hundred grams of flour was used for each porridge preparation i.e finger and pearl millet porridge to which 20 grams each of broken rice was added while cooking. List of ingredients used for finger millet and pearl millet porridge is shown in Table 2.

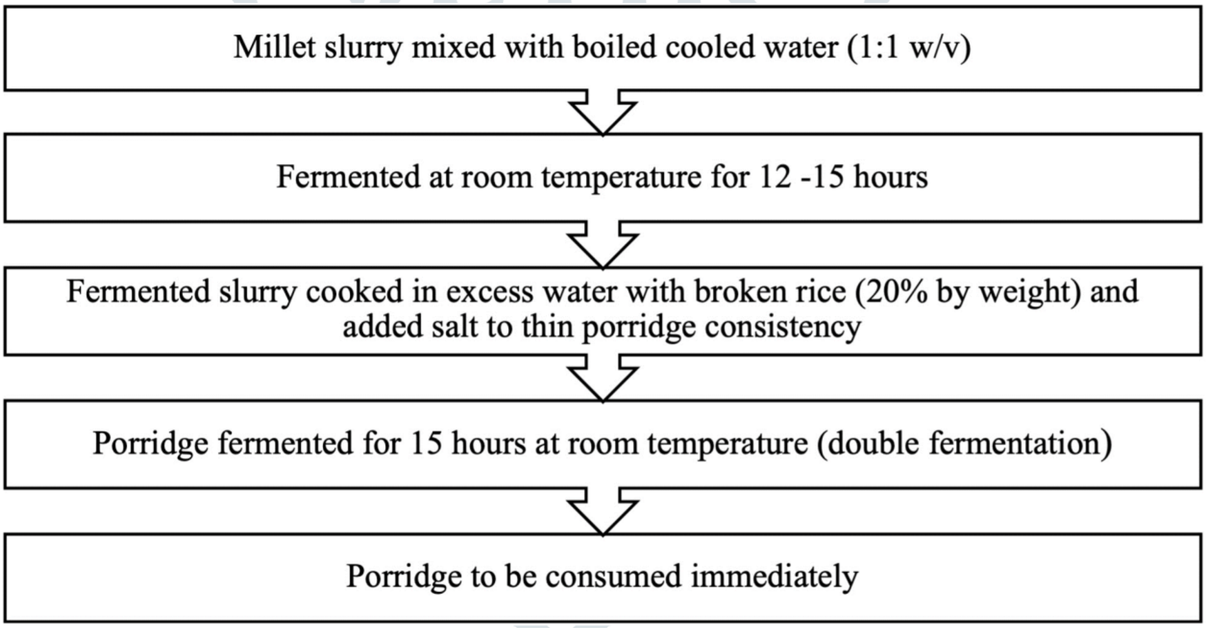

Fig 1: Flow Chart of Fermented Millet Porridge Preparation

The fermented porridges were prepared in the traditional method (Ilango and Antony, 2014) and then compared with unfermented pearl millet and finger millet porridges prepared using similar ingredients as given in table 2. Nutrient analyses as well as microbial culture was carried out for all four samples.

3.2 Nutrient Analysis of the Porridges

This comprehensive analysis included the macronutrients and micronutrients. Five hundred grams of the prepared samples were transported in sterile plastic containers which were labeled and transported in thermally insulated containers filled with ice pack. Samples of cooked millet porridge, both unfermented and fermented, were analyzed in triplicates at a NABL accredited food lab in Chennai.

The presence of tannins an anti-nutritional factor was evaluated in all four samples.

The method of analyses and nutrient profile for all samples is presented in table 3.

IV. Results

Millet porridge contains a variety of nutrients, mainly including amino acids, protein (Choi, et al., 2005), starch, and fatty acids (Lee, et al., 2012). It is a more complex system than rice porridge, including liquid and solid. In the process of cooking millet porridge, the starch is heated and gelatinized, and then cooled to produce a gelling system (Muoki, et al., 2012; Wu, et al., 2016). The macro-nutrient and micro-nutrient composition for 100g of fermented and unfermented finger millet and pearl millet porridges are shown in Table 3. The energy, carbohydrates, total fat and iron content remains nearly similar between fermented and unfermented finger millet porridge as well as both the pearl millet porridges with changes in nutrients being shown post fermentation.

Table 3 Nutrient Analyses of Fermented and Unfermented Finger Millet and Pearl Millet Porridge

Nutrients	Analyses Method	FFM	UnFM	FPM	UnPM
Energy (kcal/100g) (By calculation)	FAO method	118	113	115	114.4
Carbohydrates (g/100g) By Difference	CTL/SOP/FOOD/262-2014	24.2	24.9	23.9	23.6
Total fat g/100g	AOAC 20th Edition 2016,954.02	0.8	0.5	0.6	0.8
Protein (g/100g) (Nx6.25)	AOAC 20th Edition 2016,986.25	3.5	2.1	3.4	3.2
Sodium as Na (mg/100g)	AOAC 20th Edition 2016,969.23	12.5	9.3	12.3	8.1
Potassium as K (mg/100g)		32.9	17.4	51.8	34
Calcium as Ca (mg/100g)	IS 5949:1990 (RA.2003)	75.2	36.4	42.6	9.7
Iron as Fe (mg/100g)	AOAC 20th Edition 2016,999.11	2.65	2.33	3.9	0.56
Tannins (g/100g)	CTL/SOP/FOOD/314-2015	0.11	0.1	0.09	<0.04

FFM- Fermented finger millet porridge; UnFM- Unfermented finger millet porridge; FPM- Fermented pearl millet porridge; UnPM-Unfermented pearl millet porridge

In terms of meeting nutritional requirement of under 5 children the values were compared to the Estimated Average Requirements of Indians (ICMR, 2020). It was observed that 100 grams of the porridges provided an estimated 11.35% of energy for the age group 1 to 3 years and 8.4% of energy for the age group 4 to 6 years as per ICMR table classification.

In terms of other macronutrients such as protein it was estimated that the fermented finger millet porridge met 38% of the EAR for the age group 1 to 3 years compared to 22.8 % of the unfermented porridge. This showed a substantial increase in protein levels (15.2%) post fermentation. Similarly in pearl millet fermentation improved the protein levels which when compared to EAR values as percentage showed an increase from 34.7% to 36.95% in the age group of 1 to 3 years. The carbohydrates provided from the samples compared to 100 g recommended values ranged from 23.6% to 24.9% in all samples.

For the age group 4 to 6 years the porridges provided protein at a level of 27% in the fermented finger millet porridge compared to unfermented porridge that provided 16.4%, an increase in protein by 10.6% post fermentation of finger millet. This matches with existing literature where fermentation increases the protein content since microbes release various hydrolytic enzymes which are responsible for converting complex proteins into simple proteins and enhancing certain amino acids like tryptophan, lysine and methionine (Nassar et al., 2008; Mohapatra et al. 2019).

The total fat provided from the samples were low ranging from 2% to 3.2% for all samples. This was adequate for gut health. The porridges provided nutrients such as iron, calcium, sodium and potassium at adequate levels. Finger millet porridges had higher calcium compared to pearl millet which aligns with existing literature. These showed that the food samples prepared were adequate in terms of macronutrients and micronutrients and provided minerals such as sodium and potassium which could be beneficial in the case of loss of fluids from the body as in cases of diarrhoea.

3.3 Microbial Analyses

All the chemicals and reagents used were analytical grade, Hi Media Mumbai. Standard plate count was done in Nutrient agar medium, standard plate count for Lactobacillus was done using MRS agar.

Plates were aerobically incubated at 30°C for 72 hours. The total count of enteropathogens such as salmonella, shigella, Total coliforms, yeasts and moulds were assessed. The methods used were standard procedures as specified in the table 4.

Table 4 Microbial Analyses of Millet Porridges

Parameters	Analyses Method	FFM	UnFM	FPM	UnPM
Standard Plate count (CFU/g)	IS 5402:2012	9000	3000	15000	4000
Salmonella (Per 25 g)	IS 5887(PART 3) :1999	Absent	Absent	Absent	Absent
Shigella (Per 25 g)	IS 5887(PART 7) : 1999 (RA.2005)	Absent	Absent	Absent	Absent
Total Coliform (CFU/g)	IS 5410: PART 1 (2002)	<10	<10	<10	<10
Yeast & Mould (CFU/g)	IS 5403: 1999 (R.A.20090)	<10	<10	<10	<10
Lactobacillus (CFU/g)	IS 5887: (Part 6) :2012	2500	700	4000	900
FFM- Fermented finger millet porridge; UnFM- Unfermented finger millet porridge; FPM- Fermented pearl millet porridge; UnPM- Unfermented pearl millet porridge					

Additionally, the samples were tested for the presence of lactic acid bacteria growth and the potential presence of pathogenic bacteria including Salmonella, Shigella, Coliform, and other gram-negative pathogens.

The microbial analyses revealed a bacterial population of 9 x 10^3 CFU/g in fermented finger millet porridge compared to the value of 3 x 10^3 CFU/g in unfermented finger millet porridge. The growth of Lactobacillus species is notable with 2.5 x 10^3 CFU/g in the fermented finger millet porridge from a value of 0.7 x10^3 CFU/g in unfermented porridge.

Similarly in pearl millet porridge the fermented sample showed 15 x 10^3 CFU/g compared to the unfermented pearl millet sample which had 4 x 10^3 CFU/g. Regarding the growth of Lactobacillus species the pearl millet fermented sample had an increase from 0.9 x 10^3 CFU/g to 4 x 10^3 CFU/g.

The entero-pathogens such as salmonella, shigella and total coliforms were found to be absent or less than 10 CFU/g. The presence of yeasts and moulds were also found to be less than 10 CFU/g of the samples.

The presence of phenolic compounds such as tannins, isoflavones and stilbenes have shown antibacterial activity in cereal grains such as millets against salmonella, shigella, bacillus, clostridium as well as inhibitory activity against yeast and viruses (Alvesalo et al., 2006). The presence of tannins in the present analyses have shown similar results.

V. Discussion

Millets are small pack of grains with several health benefits and dense nutrients including protein, essential fatty acids, dietary fiber, B-vitamins, and minerals. However, its utilization is still limited to the local consumers due to the lack of convenience food products. Processing technology, such as fermentation, is being used to prepare traditional millet products in Asian and African countries. For millet fermentation, specifically two types of fermentation are used, i.e., lactic acid bacteria fermentation and yeast fermentation that can be spontaneous or nonspontaneous. Fermentation technology is known to improve the nutritional quality of food products though it has some limitations such as contamination with toxic microorganisms, etc. In most traditionally fermented beverages natural uncontrolled fermentation is employed while in few cases starter cultures are used, even though, the predominant microorganisms are lactic acid producing microorganisms, yeasts, and molds. The indigenous millet brewing technology is similar to the modern brewing technology except for the differences in the scale of level of technology used (Semwal, et al., 2021).

Fermented millet-porridge is a nutritious meal for adults, the aged and children in Africa and other parts of the globe. In Ghana, it is prepared using millet, ginger, garlic, black pepper, chili pepper, etc. The millet is soaked in water for about 72 h to ferment, it is strained, and the flour is mixed with water to form the dough. The dough ferments for about 2–4 days before it is used to prepare porridge. Different methods are used to ferment millet to produce millet products, among them are the natural, water-based, flour-based, and dried millet-based fermentation techniques. Fermented millet porridge-like other fermented beverages, possess superior nutrients, particularly amino acids. Besides, fermented millet porridge can improve digestibility; it is a suitable diet for people with celiac disease and type 1 diabetes. It may affect oxidative-stress, inflammation, hyper-glycemia, and carcinogenesis. Also, the safe processing of fermented-millet porridge containing probiotic culture may lessen the incidence of diarrhea and malnourishment among young children, thereby improving their gastrointestinal health. Also, it may decrease chronic illnesses due to the high amount of dietary fiber, carbohydrates, iron, calcium, magnesium, and phosphorus in millet (Newlove, et al., 2022).

In vitro studies of indigenous fermented cereals indicate that the fermentation process induces anti-diarrhoeal functions (Tetteh et al., 2004). In addition, indigenous fermented foods have been proven effective in preventing diarrhoea and in obtaining improved nutritional health (Saran et al., 2002).

Indigenous lactic acid fermented foods may have potential as probiotic treatment for diarrhoea, due to high levels of lactic acid bacteria. In this study the effect of a millet drink, spontaneously fermented by lactic acid bacteria, as a therapeutic agent among Ghanaian children with diarrhoea, was assessed. Children below 5 years of age coming to Northern Ghana health clinics for treatment of diarrhoea were randomised to two groups. Children of both groups received treatment for diarrhoea given at the local clinic. The intervention group in addition received up to 300 ml fermented millet drink (KSW) daily for 5 days after enrolment. The clinical outcome of diarrhoea and reported well-being were registered every day for the 5-day intervention and again 14 days after diagnosis. Among 184 children (mean age 17.4, standard deviation 11.3 months) included, no effects of the intervention were found with respect to stool frequency, stool consistency and duration of diarrhoea. However, KSW was associated with greater reported well-being 14 days after the start of the intervention ($p \leq 0.02$). The fact that no effect of KSW on diarrhoea was observed could be because many children had a mild form of diarrhoea, and many were treated with antibiotics. Either this could have affected the lactic acid bacteria, or the lactic acid bacteria in KSW had no probiotic effects. It is speculated that the effect after two weeks could be due to a preventing effect of KSW on antibiotic-associated diarrhoea which could help reducing persistent diarrhoea (Lei, et al., 2006).

The observations by Subastri, et al., (2015), concluded that porridge prepared from germinated & non-fermented FMF contains higher level of carbohydrate, protein and glycoprotein, however germinated & fermented *koozh* has increased aminoacids, phytochemicals and free radical scavenging activity. Hence it is suggested that the consumption of *koozh* made from germinated & fermented FMF may provide easily digestible and energetic nutrients for healthier life.

VI. Conclusion

Fermentation stands out as a simple, cost-effective and convenient approach to improve the shelf life, palatability, sensory qualities, nutritional value, and functional attributes of cereals, particularly at the community level (Borreson et al., 2012; Blandino et al., 2003; Mokeona et al., 2016; Hutkins, 2018). The significance of fermented foods cannot be over-emphasized, as they hold crucial role in dietary and nutritional practices (Mokeona et al., 2016). In recent times, the intake of fermented foods containing live microorganisms has gained prominence as a significant dietary approach to enhance overall gut health of the human (Marco et al., 2017).

The microorganisms commonly found in fermented foods are predominantly lactic acid bacteria (LAB) from various genera, such as Lactobacillus, Streptococcus, and Leuconostoc. Alongside LAB, yeast and fungi also contribute to this process (Slashinski et al., 2012). Lactic acid fermentation of cereals helps to reduce anti-nutrients content in food like phytate and tannins through the activation of endogenous enzymes. This process improves the nutritional quality of the food by enhancing the bioavailability of essential micronutrients and making it a super food (Hotz and Gibson, 2007; Nkhata et al., 2018).

Furthermore, fermentation improves antioxidant properties of the food by increasing its vitamin C content and enhances the release of beneficial promoting bioactive compounds, which is achieved through the weakening of the grain matrix. The disruption in food matrices, which is embedded with various minerals, helps to increase bioavailability of minerals. As a result, fermentation and germination are crucial in enhancing the nutritional value of weaning and complementary foods, especially for children (Nkhata et al., 2018).

LAB are also known for producing a range of antimicrobial compounds, including lactic acid, propionic acid, and diacetyl. These compounds contribute to lowering the pH of the environment, which inhibits the growth of numerous microorganisms, including fungi (Schnürer et al., 2005). In addition, bacteria in fermented foods produce essential antimicrobial bioactive molecules like hydrogen peroxide, organic acids, and bacteriocins (Ananou et al., 2007; O'Sullivan et al., 2010). These bioactive substances serve as powerful natural preservatives and harnessed in the development of functional foods, which ultimately leads to an enhanced bioavailability of the nutrients (Toma & Pokrotnieks, 2006; Beena Divya et al., 2012).

Over 100 species of Lactobacillus, including Lactobacillus acidophilus, Lactobacillus salivarius, Lactobacillus rhamnosus, Lactobacillus brevis, and Lactobacillus casei, have been identified and characterized to have a crucial role in enhancing both innate and acquired immunity, while also inhibiting pro-inflammatory mediators (Grover & Luthra, 2011). Furthermore, bacteriocins produced by LAB strains have a self-protection mechanism by expressing a specific immunity protein encoded within the bacteriocin operon. Bacteriocins have demonstrated their efficacy in combating gram-positive toxigenic and pathogenic bacteria.

Probiotics, defined as live microorganisms beneficial to the host when ingested in sufficient amounts (Joint and FAO/WHO, 2002), primarily encompass strains like lactic acid bacteria and bifidobacteria (Guarner & Malagelada, 2003). Probiotic bacteria, specifically those of the Lactobacillus genus, are naturally found in fermented foods. These microorganisms play a protective role by impeding pathogens from adhering to the intestinal lining. Consumption of fermented foods can help in preserving healthy intestinal flora and guarding against diseases triggered by invading pathogens in the gastrointestinal tract. The potential benefits of probiotics are extensive, including alleviating intestinal disorders, improving the immune system, optimizing gut ecology, and promoting overall health. These effects are attributed by its ability to compete with pathogens for adhesion sites, counteract pathogenic activity, and regulate the host's immune response (Toma & Pokrotnieks, 2006; Bonifait et al., 2009; Kore et al, 2012).

The present study aligns with these observations that millet:rice blend-based porridges have a true synbiotic potential with scope for increased nutritional value and safety of consumption among vulnerable age groups such as children. These porridges are already part of the traditional food culture and easily acceptable among the community. Hence, they can be used as a valuable tool in combating malnutrition and associated diarrhoeal illnesses due to the beneficial food matrix that enables proliferation of healthy gut bacterial population.

VII. References

1. Alvesalo, J., Vuorela, H., Tammela, P., Leinonen, M., Saikku, P., & Vuorela, P. (2006). Inhibitory effect of dietary phenolic compounds on chlamydia pneumoniae in cell cultures. Biochemical Pharmacology, 71(6), 735–741.
2. Ananou S, Maqueda M, Martinez-Bueno M, Valdivia E. (2007). Biopreservation, an ecological approach to improve the safety and shelf-life of foods. In: Mendez-Vilas A, ed. Communicating current research and education topics and trends in applied microbiology. Madrid.
3. Aparna K. & Ansari ZG., (2017), Evaluation of ragi genotypes on growth parameters and physiological attributes under kharif rainfed conditions. Int J Chem Stud. 2017; 5(6):1899-901.
4. APEDA, (2022). About Millets, Agricultural and Processed Food Products Export Development Authority (APEDA)
5. Beena Divya, J., Kulangara Varsha, K., Madhavan Nampoothiri, K., Ismail, B., & Pandey, A. (2012). Probiotic fermented foods for health benefits. Engineering in Life Sciences, 12(4), 377-390
6. Blandino A, Al-Seeri ME, Pandiellla SS, Cantero D, Webb C. (2003). Cereal-based fermented foods and beverages. Food Res Int. 36: 527–43. Publisher Full Text
7. Bonifait, L., Chandad, F., & Grenier, D. (2009). Probiotics for oral health: myth or reality?. Journal of the Canadian Dental Association, 75(8)
8. Borresen EC, Henderson AJ, Kumar A, Weir TL, Ryan EP. (2012). Fermented foods: approaches and formulations for nutritional supplementation and health promotion. Recent Patents on Food. Nutrition & Agriculture; 4: 134–4.

9. Choi Y.-Y., Osada K., Ito Y., Nagasawa T., Choi M.-R., Nishizawa N., (2005), Effects of Dietary Protein of Korean Foxtail Millet on Plasma Adiponectin, HDL-Cholesterol, and Insulin Levels in Genetically Type 2 Diabetic Mice. *Biosci. Biotechnol. Biochem.* 2005;69:31–37. doi: 10.1271/bbb.69.31. [PubMed] [CrossRef] [Google Scholar]
10. Dhanushkodi , V., Hemavathy , A. T., Shenbagavalli , S., Sangeetha , S., Anitha , R., & UmaMaheshwari , T. (2023). A Review on Nutritional Properties and Health Benefits of Finger Millet. *International Journal of Plant & Soil Science*, *35*(18), 753–761. https://doi.org/10.9734/ijpss/2023/v35i183342
11. FAO/WHO. (2002). Guidelines for the evaluation of probiotics in food. Food and Agricultural Organization of the United Nations and World Health Organization. Working Group Report.
12. Grover, H. S., & Luthra, S. (2011). Probiotics–the nano soldiers of oral health. J Indian Acad Clin Med, 13(1), s48-s54.
13. Guarner, F., & Malagelada, J. R. (2003). Gut flora in health and disease. Lancet (London, England), 361(9356), 512–519. https://doi.org/10.1016/S0140-6736(03)12489-0
14. Gull A, Jan Romee, Nayik GA, Prasad K, Kumar P. (2014), Significance of Finger Millet in Nutrition, Health and Value-added Products: a review. J Environ Sci Comput Sci Eng Technol. 2014;3(3): 1601-8.
15. Hotz C, Gibson RS. (2007). Traditional food-processing and preparation practices to enhance the bioavailability of micronutrients in plant-based diets. The J Nutr 137: 1097–100. PubMed Abstracthttps://doi.org/10.25141/2475-3432-2017-6.0230
16. Hutkins, R.W. (2018). Microbiology and Technology of Fermented Foods, 2nd Edn. Hoboken, NJ:Wiley.
17. ICMR, (2020). Nutrient requirements for Indians. A report of the Expert Group 2020. Published by ICMR-National Institute of Nutrition. Hyderabad. India.
18. Kore, K. B., Pattanaik, A. K., Sharma, K., & Mirajkar, P. P. (2012). Effect of feeding traditionally prepared fermented milk dahi (curd) as a probiotics on nutritional status, hindgut health and haematology in dogs. J Trad Knowl. 11:35–9.
19. Lee Y.-Y., Kim J.-B., Lee H.-S., Jeon Y.-A., Lee S.-Y., Kim C.-K., (2012),. Evaluation of Millet (*Panicum miliaceum* subsp. *miliaceum*) Germplasm For Seed Fatty Acids Using Near-Infrared Reflectance Spectroscopy. . *Korean J. Crop Sci.* 2012;57:29–34. doi: 10.7740/kjcs.2012.57.1.029. [CrossRef] [Google Scholar]
20. Lei V, Friis H, Michaelsen KF., (2006), Spontaneously fermented millet product as a natural probiotic treatment for diarrhoea in young children: an intervention study in Northern Ghana. Int J Food Microbiol. 2006 Aug 1;110(3):246-53. doi: 10.1016/j.ijfoodmicro.2006.04.022. Epub 2006 Jun 30. PMID: 16814890
21. Marco, M. L., Heeney, D., Binda, S., Cifelli, C. J., Cotter, P. D., Foligné, B., et al. (2017). Health benefits of fermented foods: microbiota and beyond. Curr. Opin. Biotechnol. 44, 94–102. doi: 10.1016/j.copbio.2016.11.010
22. Mohapatra, D., Patel, A. S., Kar, A., Deshpande, S. S., & Tripathi, M. K. (2019). Effect of different processing conditions on proximate composition, anti-oxidants, anti-nutrients and amino acid profile of grain sorghum. Food Chemistry, 271, 129–135
23. Mokoena, M. P., Mutanda, T., & Olaniran, A. O. (2016). Perspectives on the probiotic potential of lactic acid bacteria from African traditional fermented foods and beverages. Food & Nutrition Research, 60(1), 29630.
24. Muoki P.N., de Kock H.L., Emmambux M.N., (2012), Effect of soy flour addition and heat-processing method on nutritional quality and consumer acceptability of cassava complementary porridges. *J. Sci. Food Agric.* 2012; 92:1771–1779. doi: 10.1002/jsfa.5545. [PubMed] [CrossRef] [Google Scholar]
25. Muthamilarasan M, Dhaka A, Yadav R, Prasad M., (2016), Exploration of millet models for developing nutrients rich graminaceous crops. Plant Sci. 2016; 242:89-97.
26. Nassar, A. G., Mubarak, A. E., & El-Beltagy, A. E. (2008). Nutritional potential and functional properties of Tempe produced from mixture of different legumes. 1: Chemical composition and nitrogenous constituent. International Journal of Food Science & Technology, 43(10), 1754–1758.
27. Newlove, A.A., Mahunu, G.K., Tahir, H.E. (2022). Fermented Millet for Porridge Production: A Model for Improved Gastrointestinal Health. In: Elhadi Sulieman, A.M., Adam Mariod, A. (eds) African Fermented Food Products- New Trends. Springer, Cham. https://doi.org/10.1007/978-3-030-82902-5_29
28. Nkhata, S. G., Ayua, E., Kamau, E. H., & Shingiro, J. B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. Food science & nutrition, 6(8), 2446-2458.
29. O'Sullivan, L., Murphy, B., McLoughlin, P., Duggan, P., Lawlor, P. G., Hughes, H., & Gardiner, G. E. (2010). Prebiotics from marine macroalgae for human and animal health applications. Marine drugs, 8(7), 2038-2064.
30. Pandhre GR, Satwase AN, Hashmi SI., (2011), Studies on drying characteristics and nutritional composition of sprouted wheat and finger millets. Int J Curr Res. 2011;3(7):218-21.
31. Ramashia SE, Anyasi TA, Gwata ET, Meddows-Taylor S, Jideani AIO., (2019), Processing, nutritional composition and health benefits of finger millet in subSaharan Africa. Food Sci Technol, Campinas. April-June 2019;39(2): 253-66.
32. Saran, S., Gopslsn, S. and Krishna T.P., (2002). Use of fermented foods to combat stunting and 549 failure to thrive. Nutrition 18, 393-396.
33. Schnürer, J., & Magnusson, J. (2005). Antifungal lactic acid bacteria as biopreservatives. Trends in Food Science & Technology, 16(1-3), 70-78

34. Semwal, J., Kamani, M.H., Meera, M.S. (2021). Fermented Millet Technology and Products. In: Kumar, A., Tripathi, M.K., Joshi, D., Kumar, V. (eds) Millets and Millet Technology. Springer, Singapore. https://doi.org/10.1007/978-981-16-0676-2_12
35. Slashinski, M. J., McCurdy, S. A., Achenbaum, L. S., Whitney, S. N., and McGuire, A. L. (2012). "Snake-oil," "quack medicine," and "industrially cultured organisms:" biovalue and the commercialization of human microbiome research. BMC Med. Ethics 13:28. doi: 10.1186/1472-6939-13-28
36. Srivastava K. & Sharma AK., (2012), Nutraceutical Importance of Finger Millet (Eleusine coracana) for Improved Human Health. The Eur J Plant Sci Biotechnol. 2012; 2:91- 5.
37. Subastri, A., Ramamurthy, C., Suyavaran, A. et al. (2015). Nutrient profile of porridge made from Eleusine coracana (L.) grains: effect of germination and fermentation. J Food Sci Technol 52, 6024–6030.
38. Tetteh G.L., Sefa-Dedeh S.K., Phillips R.D., Beuchat L.R., (2004), Survival and growth of acid-adapted and unadapted Shigella flexneri in a traditional fermented Ghanaian weaning food as affected by fortification with cowpea, International Journal of Food Microbiology, 90:2, Pp189-195
39. Toma, M. M., & Pokrotnieks, J. (2006). Probiotics as functional food: microbiological and medical aspects. Acta Universitatis Latviensis, 710, 117-129.
40. Wu K., Gan R.-Y., Dai S., Cai Y., Corke H., Zhu F., (2016), Buckwheat and Millet Affect Thermal, Rheological, and Gelling Properties of Wheat Flour. *J. Food Sci.* 2016;81:E627–E636. doi: 10.1111/1750-3841.13240.