Acta Scientific NUTRITIONAL HEALTH (ISSN:2582-1423)

Volume 7 Issue 6 June 2023

Review Article

Millets as Super Foods: A Review

Aditya S Bhandari[1], Kundan B Jat[1], Aniruddha A Kanse[1], Prathamesh D Gorde[1], Shweta Suri[2] and Anirudh G Patil[1]*

[1]Department of food technology, Annasaheb Dange College of Engineering and Technology, Ashta, Maharashtra, India

[2]Assistant Professor, Amity Institute of Food Technology, Amity University Uttar Pradesh, Noida, India

***Corresponding Author:** Anirudh G Patil, Department of food technology, Annasaheb Dange College of Engineering and Technology, Ashta, Maharashtra, India.

DOI: 10.31080/ASNH.2023.07.1253

Received: May 05, 2023

Published: May 31, 2023

Abstract

Climate change, water shortages, rising global population, and rising food prices in the twenty-first century, and other socioeconomic effects are anticipated to pose a serious threat to global food security and agriculture, particularly for the poorest residents of arid and sub arid areas. Scientists and dietitians are challenged by these effects to look into the feasibility of growing, preparing, and consuming alternative food sources for eradicating poverty and hunger. The primary food source in the world and an essential component of the human diet are cereal grains over the globe. In the semiarid tropics of Asia and Africa, millet is one of the most significant drought-resistant crops. It is a significant source of proteins and carbs for residents in these places. Additionally, millet grain is currently attracting more interest from food scientists, technologists, and nutritionists due to its significant contribution to national food security and potential health advantages. This study's objective was to analyse recent developments in research done up to that point in order to assess the nutritional value and potential health advantages of millet grains. Utilising processing methods to enhance millet's edible and nutritious qualities also highlighted are difficulties, restrictions, and prospects for promoting millet use as food for a sizable and expanding population.

Keywords: Fermented and Traditional Foods; Baked and Extruded Products; Functional Foods and Beverages

Abbreviations

ha: Hectare; Mha: Million Hectare; MT: Million Tonnes; HTST: High Temperature Short Time; RTE: Ready to Eat; RTC: Ready to Cook; NPU: Net Protein Utilisation; NPR: Net Protein Retention; BV: Biological Value; FAO: Food and Agricultural Organization; WHO: World Health Organisation; UNU: United Nations University; US: United States; GI: Glycaemic Index

Introduction

World millet production

In the developing world, particularly in the arid regions of Africa and Asia, millets are a staple meal. The majority of millets are native to Africa and were domesticated there before spreading to other regions of the world. Only 7 of the 93 countries that farm millets on a global scale have more than 1 million acres of millets. Developing countries produce and consume more than 97% of the world's millets. According to estimates, the amount of land used for millets cultivation decreased across the continents by about 25.71 percent between 1961 and 2018. However, from 1961 to 2018, millet productivity grew globally by 36%, from 575 kg/ha to 900 kg/ha. With the exception of Africa, the average statistics from the previous 58 years showed that millet output decreased globally. West Africa saw the largest increase, about double that of the 1960s. Although millet planting has decreased in Asia, production trends indicated a progressive rise, which increased productivity. In the case of India, millet output peaked in the 1980s and then steadily fell as a result of a substantial fall in the area that was being grown. With 37.5% of the world's output, India leads all other producers of millets, followed by Sudan and Nigeria. The largest millets import and export values ever were reported between 2011 and 2017 (155.26 and 127.60 million US dollars, respectively). The ongoing decline in the world's millets-growing area may be linked to changes in dietary preferences, the relocation of millets for other crops, the assurance of irrigation systems, and the guaranteed returns from important commercial crops [54].

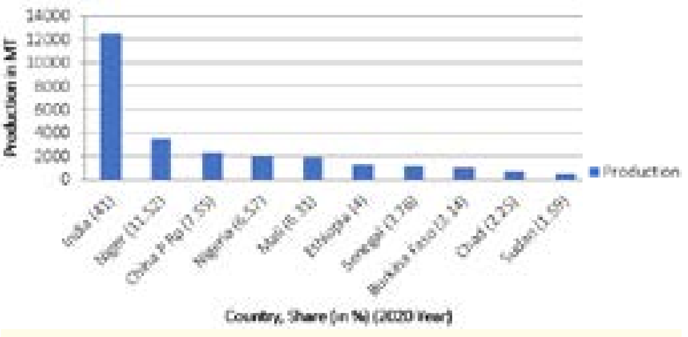

Figure 1: Top 10 countries in millet production (APEDA, 2021) (FAO, 2020).

Indian millet production

The area of all millets taken into consideration during the years (1970-1971)-(2018-2019) decreased steadily. Due to a 2.5 times improvement in productivity, the area planted with pearl millet has decreased by approximately 34% while production has increased by over 63%. Jowar, which had a sizable area share in the 1970s (16.55 Mha), declined to 6.04 Mha, a fall of almost 64 percent, which led to a 44 percent decrease in production despite a 51 percent gain in productivity. The Ragi area has decreased by approximately 50%, which has resulted in an almost 23% loss in production even while productivity has increased by 68%. Small millets experienced the highest area reduction (to the amount of 85%), which led to a 77 percent reduction in production even though the yield increased by 58 percent over the course of the study period. Therefore, it can be inferred that the increase in millets production has not offset the decline in their area, with the exception of pearl millet [95].

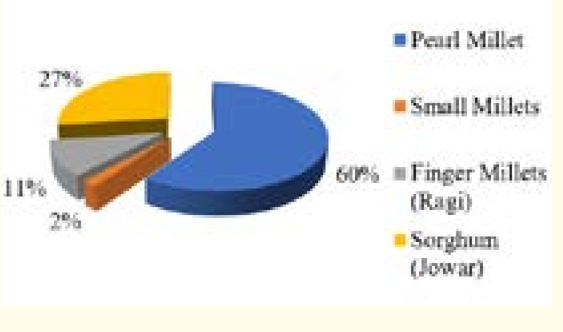

Figure 2: Major millets production in India 2021-22 (APEDA, 2021).

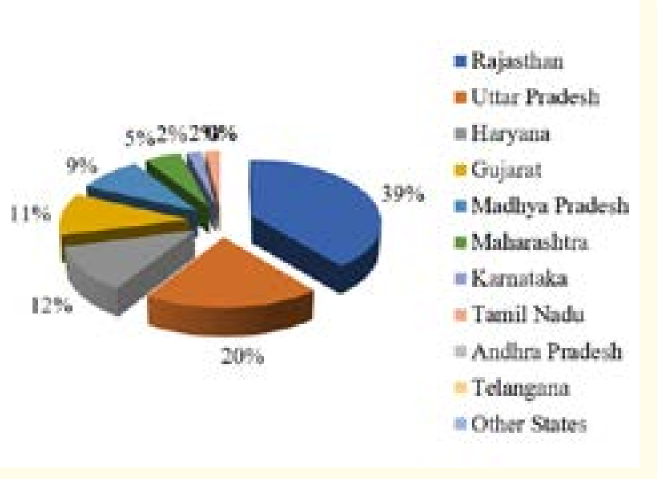

Figure 3: State wise millet production 2021-22 (APEDA, 2021).

Significance of millet

Millets are a group of small-seeded grasses that have been cultivated for thousands of years as a food source for humans and livestock. They are gluten-free and rich in nutrients, making them a popular choice for people with gluten intolerance or those seeking alternative grains to add to their diet. They have been an important part of human diet and culture throughout history, and have significant significance both from the past to recent times [20].

Historical significance

Millets have been cultivated for thousands of years in various parts of the world, especially in Africa and Asia. They were one of the first cereal crops to be domesticated, and were a staple food in many ancient civilizations, such as the Indus Valley Civilization, the Chinese, and the Egyptians. Millets have played a significant role in traditional farming practices, cultural practices, and religious festivals [20].

Nutritional significance

Millets are rich in nutrients such as protein, dietary fiber, vitamins, and minerals, and are gluten-free. They have been recognized as a "superfood" due to their nutritional value, and are an important source of food for many populations, especially in developing countries. Millets are known to have a low glycaemic index, which makes them an excellent food for people with diabetes [20].

Environmental significance

Millets are hardy crops that can grow in poor soil conditions and require minimal water and fertilizer inputs. They are also resistant to pests and diseases, which reduces the need for chemical pesticides. Thus, they have significant environmental significance, and can be an important crop in sustainable agriculture [20].

Economic significance

Millets have been an important source of income for many farmers, especially in developing countries. They are relatively inexpensive to grow and require minimal inputs, which makes them a profitable crop for small-scale farmers. In addition, millets have gained popularity in recent years due to their nutritional value and health benefits, which has led to an increase in demand and prices. In conclusion, millets have significant historical, nutritional, environmental, and economic significance from the past to recent times. They are an important crop that has sustained many populations throughout history, and continue to be an important source of food and income for many people today [20].

Types of millets

There are several types of millets, including Pearl millet also known as Bajra, it is one of the most widely grown types of millet in India and Africa. It is a good source of protein and fiber. Foxtail millet also known as Kangni or Thinai, it is a popular type of millet in India and China. It is high in antioxidants and has a low glycemic index, making it a good choice for people with diabetes. Finger millet also known as Ragi or Nachni, it is a staple food in South India and Africa. It is rich in calcium, iron, and protein, making it a good choice for vegetarians and vegans. Proso millet also known as White millet or Barri, it is a popular type of millet in China and Russia. It is high in protein and has a low glycaemic index. Little millet also known as Kutki or Samai, it is a popular type of millet in India. It is a good source of fiber and minerals such as iron and magnesium [1].

Benefits of millets

Millets are easy to cook and can be used in a variety of dishes, including porridges, salads, bread, and even alcoholic beverages. They are also often used to make flour for baking. Millets are a sustainable crop, as they require less water and fertilizers than other grains and can be grown in a variety of climates. Millets are highly nutritious and offer a range of health benefits, including Millets are rich in nutrients like fiber, protein, vitamins, and minerals like iron, calcium, and magnesium. They are also gluten-free, making them an excellent option for people with celiac disease or gluten intolerance. Millets are high in fiber, which helps to improve digestion and prevent constipation. The high fiber content also helps to regulate blood sugar levels and reduce the risk of diabetes. Millets are a good source of magnesium, which is essential for maintaining heart health. Magnesium helps to regulate blood pressure and reduce the risk of heart disease. Millets are low in calories and high in fiber, which makes them an ideal food for weight management. They also have a low glycaemic index, which means they are absorbed slowly by the body and help to keep you feeling full for longer. Millets are a good source of antioxidants, which help to protect the body against damage from free radicals. This can help to reduce the risk of chronic diseases like cancer, Alzheimer's, and Parkinson's disease [25].

Here are some of the advantages of consuming millets, Millets are easy to digest and can help improve digestive health by preventing constipation, reducing bloating, and improving bowel movements. Millets have a low glycaemic index, which means they release glucose slowly into the bloodstream, preventing sudden spikes in blood sugar levels. This makes millets an excellent food choice for people with diabetes. Millets are low in calories and high in fiber, which helps in keeping you full for longer periods, thereby reducing cravings and promoting weight loss. Millets are naturally gluten-free, making them an excellent food option for people with celiac disease or gluten intolerance [25]. Millets are drought-resistant, require less water than other grains, and can be grown in poor soil conditions. This makes them a sustainable crop that can be grown without harming the environment. Millets can be used in a variety of dishes, including porridges, bread, cakes, and even alcoholic beverages, making them a versatile ingredient in the kitchen. Overall, millets are an excellent food choice for their nutritional value, health benefits, and environmental sustainability [25].

Challenges for millet cultivation

But from recent years millets are disappearing from local market as well as millet based foods are also fading away. There are several reasons responsible for declining availability of millets such as: Millets are ancient grains that have been cultivated for thousands of years. However many peoples are not aware of their health benefits and nutritional value. Due to green revolution in India, many farmers have shifted from traditional crop cultivation to high yielding crop varieties, which are less level intensive and required fewer inputs. As a result the cultivation of millets has declined. The demand for rice and wheat has increased over the years and farmers are more employed to grow these crops due to their high demand and profitability. The government has not provided enough support to the cultivation of the millets. These include subsidies, research and development and infrastructure support. Millets are considered a low profit crop compared to other crops like rice and wheat and this has discouraged farmers to growing the minutes. There are a lack of marketing initiative and campaigns to promote millet and their nutritional benefit, leading to lack of awareness and demand. Millets cultivation is more labour intensive than other crops and this can discourage farmers from growing them. Millets require proper storage facilities which are not readily available in many areas. This has led to a decline in cultivation. Millets cultivation is affected by climate change, with unpredictable rainfall patterns affecting crop yield and quality [79].

Millet based products

Puffed/popped and flaked millets

An ancient custom of heating grains for use as a snack or morning cereal, either plain or with some spices, salt, or sweeteners, is known as puffing or popping. The primary source of carbohydrates in human nutrition, starch also has a number of useful technological qualities. The structure of the starch and how it is processed have a significant impact on the nutritional quality [45,58]. The millet grain or preconditioned pasta undergoes structural changes during the puffing or popping process that cause the grain or pasta pieces to expand and result in a puffed product with a high level of crisp and other tactile qualities. Utilising the thermo-physical characteristics of starch, the high temperature short time (HTST) treatment creates enlarged grains or flakes. During this process, the Millard reaction occurs, in which the sugars in the aleurone layer combine with the millet's amino acids to give the puffed product a delightful and much desired aroma. Additionally, it decreases antinutrients like phytates and tannins, increases the bioavailability of minerals, gives the product a nice texture, and improves the digestion of protein and carbohydrates [65,70]. Popping volume and ratio are influenced by engineering characteristics such as moisture content, porosity, bulk density, kernel size, and ingredients utilised in popping, such as salt or sugar. Ushakumari [96]. Utilising HTST, enlarged finger millet was created as a ready-to-eat next generation product. The important elements for achieving the maximum expansion ratio are flattening the grains to the correct form factor and moisture content. A moisture content of roughly 40%, a form factor of 0.52 to 0.58, and a drying period of 136 to 150 minutes are the ideal circumstances for expansion. The enlarged millet had a 4.6 expansion ratio, 5.0 N of hardness, and a 7.2 overall acceptance rating. By exposing native grains (12% mc) to HTST treatment at 230+/- 5°C, the cereal processing technologies can be successfully applied to foxtail millet to produce ready-to-eat or RTE products in the form of flaked, extruded, roller dried, decorticated, and popped grains [96,109]. Roller-dried millet had the highest level of starch gelatinization, followed by products that were popped, flaked, and extruded the microstructure of puffed starch granules becomes spherical, while that of popped and extruded products has a structure resembling a honeycomb [29,78]. Expanded flakes can be made by heating finger millet and foxtail millet flour at 80-100°C with varying amounts of water (100-130 ml) and time (1-3 min) to produce dough, extruding using a hand extruder, flaking to a thickness of 0.6 mm, and roasted at 90-110°C for 5-15 min [37,59].

Puffed grains of various varieties of finger millet were made by conditioning the grains for two hours with 20% moisture content and puffing the grains using hot sand at a temperature of 220-230°C. The changes in fatty acid composition were found to be non-significant. However, during inhalation, phospholipids increased by 33.3% and glycolipids by 21.92%, while neutral lipids decreased by 9.3%. When heated sand (250°C) was used to pop conditioned pearl millet, the yield and expansion ratio of the popped grains ranged from 8.3-77.1% and 2.3-11.3%, respectively. Popping greatly increases the bio-accessibility of Zn (18 g/100 g) in native millet whereas puffing significantly decreases phytic acid (21-50%) and tannins (3-18%) [105]. The finger millet variety effect on puffing quality revealed that white seeded varieties produced organoleptically superior puff while brown seeded varieties are more appropriate for puffing. The brown seeded variety "PR 202" produced the highest puffing yield, followed by the medium expansion variety "JNR 852" [87]. A ready-to-eat (RTE) snack food made from barnyard millet (*Echinochloa frumentacea*) was created by shaping thin, rectangular-shaped cold extrudate (cut pieces of dough) samples, steam cooking them, and puffed them with the HTST puffing process [43]. It was found that using a dolly pasta machine to form and cut the dough into the right shape required the proper amount of ingredients and moisture content. In order to produce puffed products with an expansion ratio of 2.05 and moisture content of 0.09 kg/kg dry matter, the samples made from dough containing tapioca powder, potato mash, and barnyard millet in the ratio of 60:37:3 were steam cooked and puffed in hot air. To get toasted snack food with moisture content (0.0464 kg/kg), colour (L- value - 69.79), crispness (18.45 positive peaks), and hardness (362.64 g), the product was oven toasted after puffing at the ideal toasting temperature and time combination of 116.26°C and 20.23 min, respectively. Popped/puffed grains and products are dried down during the process to an exceptionally low moisture content (3-5%), extending their shelf life. Modern air puffing devices have been created recently that can be used to produce puffed or popped millet grains in large quantities [103].

Pasta and other millet - based Products

Pasta or papad are prepared using dried goods as the RTC and flour from grains or legumes as the primary ingredient. Noodles are pasta items commonly referred to as convenience foods that are produced using a cold extrusion technology and dry out to become hard and brittle. These noodles are easy to prepare and just take a few minutes. There are many different combinations of noodles that can be made entirely made from finger millet, finger millet and wheat blended 1:1, and finger millet mixed 5:4:1 with wheat and soy flour. Finger millet, refined wheat, and soy flour/whey protein concentrate composite flour that has been manufactured (50, 40, and 10%) can all be used to make pasta combination of proso millet and wheat flour with a respectable shelf life [27,48]. In a dolly pasta machine, pasta was extracted. Noodles are a favourite food among people of all ages due to their longer shelf life and significant commercial value. Barnyard millet has a sluggish digestion of 25.88% and a comparatively low carbohydrate content of 58.56% [2,102]. The value added low glycaemic index noodles made from barnyard millet flour were prepared by adding sago flour, pulse flour, and bengal gram leaf powder at various quantities to create plain, pulse, and vegetable noodles, respectively [102]. The results showed a considerable improvement in the nutritional composition of vegetable and pulse noodles. Vegetable noodles (38.02) and pulse noodles (35.65) both had a considerably lower glycaemic index than plain noodles (42.07). Punia., *et al*. (2003) Making ladoo (sweet balls) and shankarpara (dough made into flakes) from kanagini or foxtail millet (*Setaria italica*), we found that the latter's ladoo had 13.13 percent protein, 4.92% ash, and 13.83 and 2.35 mg of iron and zinc per 100 g, respectively. It was also discovered that both prepared items were satisfactory and that the product's appearance, texture, and flavour all fell under the category of "liked very much" [10,93]. Barnyard, foxtail, and tiny millet were processed as popped grains using common salt as the heating medium in an open iron pan with sample and salt in the ratio 1:20 at 240-260°C for 15-25 s. Two different kinds of ladoos (5 cm in diameter), the first made with individually popped millet grains and jaggery, and the second with millets, roasted groundnuts, and coconut powder, were made. First and second type ladoo received sensory scores on nine point hedonic scales of 5.0-6.9 and 7.2-8.1, respectively. The protein and calcium content of foxtail millet-based products was higher than that of barnyard millet-based products. In the formulation, groundnut and coconut were included, which doubled the amount of protein (7.27-8.39 g/100 g), calories, calcium, and iron compared to the previous type of ladoo, which only contained millets and jaggery (a sweetener produced from sugarcane juice). Geervani and Eggum [33] Minor millets were made fortified by adding lysine to make up for an amino acid shortage during heat treatment. After being autoclaved and subsequently supplemented with lysine at a rate of 0.6 g/100 g dry matter, the biological value (BV) and net protein utilisation (NPU) of the Italian, French, Barnyard, Kodo, and Little Millet grains increased. Ifon (1980) observed considerable increases in NPR, NPU, and BV, as well as a significant improvement in the nutritional value of millet porridge after it had been fortified with soy proteins in a rat bioassay. Jowar crunch, a snack meal with a delicate crunch, is made by deep-frying dried sorghum kernels (pellets) that have been alkaline-cooked. For sorghum, the best procedure was an autoclave for 60 minutes at 120°C, followed by a rinse, drying to 9% moisture content at ambient temperature and then at 50°C, and deep fat frying at 220°C.

Baked products

The popularity of bakery items around the world has led to a massive increase in production since they are inexpensive, have a wide range of tastes and textures, come in attractive packaging, and have a long shelf life for convenient marketing [75,89]. Millets will be superior in terms of fibre content and micronutrients when used in bakery products, and they will also create a strong opportunity for millets to enter the baking industry for a variety of value-added products [103]. These are mostly prepared from the wheat flour but efforts are being made to replace few portion of it with millets in order to provide an alternative and reduce over dependence on wheat and make gluten free bread. It is possible to use finger millet and foxtail millet flour in baked goods including cookies, nankhatai, chocolate, cheese cakes, muffins, and more. According to research, it is possible to replace 40% of the wheat flour in baked goods like cake and biscuits with finger millet flour [3,19,110]. The finger millet-based muffins, soup sticks, rusks, masala cake, carrot cake, and chocolate cup-cakes all received high marks for look, texture, flavour, and general appeal. Malted finger millet flour has been added in an effort to boost the nutritional value of cakes in terms of the minerals and fibre content [26,64]. Sehgal and Kawatra [12] Pearl millet flour (40-80%), refined wheat flour (10-50%), and green gram flour (10%) were used to make sweet, salty, and cheese biscuit and the results were determined to be highly satisfactory with no discernible difference. When packaged in a double pack of polypropylene/pearlized BOPP and metalized polyester/polylaminate packaging, biscuits made from a blend of maida and finger millet (80:20) can last 120 days at 65% RH at 27°C [57,83]. Biscuits made with refined wheat flour, blanched pearl millet, and green gram in the proportions of 50:40:10 (Type I) and 30:60:10 (Type II) are healthier than those made with just refined wheat flour, however Type II biscuits include more anti-nutrients (polyphenol and phytic acid) than Type I biscuits [12,90]. Saha., *et al*. (2010) Biscuits were made using flour composites including 60:40 and 70:30 (w/w) finger millet: wheat flour and it was discovered that the 60:40 combinations had harder biscuit dough than the 70:30 levels. Although the expansion of the biscuit and its breaking strength after baking were greater in the composite 70:30 than the 60:40, the adhesiveness and resistance of the biscuit dough increased with the increasing amounts of wheat flour. The water absorption capacity of wheat composite flour (40 g/100 g) was higher than that of composite flour (30 g/100 g). Krishnan., *et al*. [52] a study was conducted to investigate if finger seed coat matter (SCM) might be used Making biscuits with millet and a composite flour that has a similar crisp texture and breaking strength (1480-1690 g), more calcium, dietary fibre, and protein than the control biscuits (1560 g). According to the sensory analysis of the biscuits, composite biscuit flour might contain 10% of SCM from native and hydrothermally processed millet and 20% from malted millet. Making sorghum- or millet-based bread without wheat continues to be difficult [80,97]. Some researchers have also experimented with baking cookies made entirely of sorghum or pearl millet. These cookies could be made, but they tasted and felt mealy, hard, gritty, and harsh. These items also lacked top surface cracks and spread, two characteristics that are viewed as desirable. It's possible that this quality is caused in part by the lipid content [80,97].

Extruded products

The majority of people on earth experience qualitative and quantitative dietary protein and calorie deficiencies. In every one of these situations, physiologic upkeep and growth are compromised, and malnutrition follows. In this situation, extrusion is a useful method. Extrusion cooking is an HTST cooking technique that can be used to prepare both proteinous and starchy materials. Extrusion cooking offers a variety of benefits including adaptability, high output, good product quality, and increased in-vitro protein digestibility [4,24] and the creation of fresh meals without the use of waste. Extrusion Cooking is achieved by applying heat, either directly by the infusion of steam, indirectly through the jacket, or by releasing mechanical energy through shearing that takes place within the blend. Lactic and citric acids were employed by Onyango., *et al*. [74] to make extruded uji (a thin porridge made of maize finger millet from eastern Africa) instead of backslop fermentation. Before extrusion, the blends' acidity was successively lowered by fermentation or by adding 0.1, 0.5, and 1.0 mol/l of lactic or citric acids. Starch is dissolved during extrusion without maltodextrins being produced. After extrusion, the *in vitro* starch digestibility rose from 20 mg maltose/g in the raw blend to roughly 200 mg/g. In-vitro protein digestibility and the nitrogen solubility index were both 20% higher after fermentation of lactic/citric acid-treated blends before extrusion. In the extrudates, the tannin level dropped from 1677 mg/100 g in the raw mix to between 551 and 1093 mg/100 g; however the phytate content (248-286 mg/100 g) was unaltered by extrusion [111]. When compared to similar roasted weaning meals, the extrusion procedure improves the iron availability of the extruded weaning foods based on pearl millet, cowpea, peanut, or milk powder by 3.5 to 6.5 times [23,50]. Millet based extruded snack foods are prepared using twin-screw extruder from kodo millet-chickpea flour blend (70:30) [35]; pearl millet, finger millet and soybean flour blend [17] or ragi, sorghum, soy and rice (42.03,14.95,12.97 and 30%) flour blend with desired quality. For feed rate and screw speed combination of 9.5 kg/h and 250 rpm, expansion index (2.31) and sectional expansion index (5.39) were found to be at their highest for pearl millet (81.68%), finger millet (7.02%), and decorticated soy bean (11.29%) composite flour. All product characteristics, including the expansion ratio, bulk density, hardness, and crispiness, are greatly influenced by the barrel temperature. At a higher screw speed of 280 rpm, a lower feeder speed of 20 rpm, and a medium to high temperature of 123°C, the Kodo-chickpea flour blend produces desired crispy extrudates. The millet-pulse or millet-soy feed's around 15% moisture content at a blend ratio of 10% to 15% seems to be an appropriate level [93]. Dhumal., *et al*. [28] created microwave-cold extruded puffed barnyard millet-based ready-to-eat fasting snacks with equal sensory quality. By extrusion heating at 130°C and 200 g/kg of water, Pelembe., *et al*. [76] created a protein-rich composite sorghum-cowpea porridge that, in terms of functional qualities, was comparable to commercial quick maize-soy porridge. Protein content, the water absorption index (WAI), and the expansion ratio (ER) all increased as cowpea production increased [108]. Sumathi., *et al*. [96] developed healthy extruded ready-to-eat meal by combining pearl millet with grain legumes (30%) and separately with defatted soy (15%).The protein content of the millet-based foods and the millet-soy mixture was 14.5% and 16%, respectively, with protein efficiency ratio values of 2.0 and 2.1. In order to create an RTC extruded product from a composite of millet powder and maida (50:50), Devi and Narayanasamy (2013) investigated the possibility of creating composite millets milk powder using the combination of finger millet and pearl millet. The results were within the acceptable range in terms of nutrient content, colour, texture, cooking quality, and sensory characteristics.

Fermented products

In many regions of India, fermented dishes like dosa and idli are widespread and popular breakfast options as well as evening meals. Millets are a strong source of protein, but because of their low lysine and tryptophan concentration, the protein quality is something that is being focused on more and more. In addition to enhancing flavour, fermentation also increases the nutritional content of food in terms of protein, calcium, fibre, B vitamins, and *in vitro* protein increases food grain digestibility and lowers antinutrient levels [8,22,41,103]. The protein digestibility of the ground, germinated pearl millet grains after fermentation is higher (>90%). By inoculating *S. diastaticus, S. cerevisiae, L. brevis, and L. fermentation,* [14,46] fermented pearl millet in single culture, mixed culture, and sequential culture fermentations for 72 hours at 30°C. The samples were oven dried and ground into fine flour, and it was discovered that controlled pure culture fermentation considerably improved the starch digestibility of the flour while leaving the protein and ash content of pearl millet (both sprouted and ground) unchanged. Zinc-Ca-phytate or Zn-phytate complexes limit zinc bioavailability when dietary calcium and phytic acid levels are high. One of the most economical and efficient ways to dramatically reduce phytic acid and polyphenols is by fermentation increases zinc's HCL extraction capacity [6,92] iron, copper, calcium, and manganese, but successive fermentation produces the greatest reduction. The mineral availability of pearl millet is also greatly increased by dry heating and acid treatment [13,44]. The levels of thiamine, niacin, total lysine, protein fractions, carbohydrates, soluble dietary fibre, and *in vitro* availability of Ca, Fe, and Zn in food blends significantly enhance after germination and probiotic fermentation [14,100]. An increase in the percent mineral availability of calcium (20%), phosphorous (26%), iron (27%) and zinc (26%), as well as phytates, tannins, and trypsin inhibitor activity, were observed after 24 hours of fermentation of finger millet flour using endogenous grain microflora [11,21]. Cutlets, weaning mixes, vermicelli, and biscuits were among the many recipes made from naturally and artificially fermented pearl millet flour that were well regarded. The results showed that pure culture fermented products might be safely added to people's diets to increase protein and mineral bioavailability and improve starch digestion. It was discovered that the availability of zinc during pure culture fermentation was more efficient than spontaneous fermentation. If fermented for 14 hours, pearl millet genotypes *in vitro* protein digestibility will improve in a very significant ($p \leq 0.05$) way [8]. Onyango., *et al*. [74] Using various combinations of maize, finger millet, sorghum, and cassava, high energy density fermented uji was made-extrusion and amylase. It was found that extrusion of the fermented and dried flour at 150-180°C and a screw speed of 200 rpm reduced the viscosity of uji from 6000-7000 to 1000-2000 cp with acceptable energy densities (0.6-0.8 kcal/g) for child feeding. It was found that fermentation alone was not able to reduce the viscosity of uji.

Malting and weaning foods

Millet malt has historically been used for newborn feeding. Finger millet has excellent malting qualities, and Tamil Nadu and Karnataka both have a thriving malting industry. Malting greatly improves the composition of nutrients, fibre, crude fat, vitamins B and C and their availability, and minerals [82], increase the grain's sensory qualities and nutrient bioavailability. Weaning foods with low dietary bulk and a high caloric content, supplementary foods, health foods, and foods high in amylase all use millet malt as a cereal base. Compared to many other heat treatments, malting reduces the viscosity of flour paste [61]. According to Serna-Saldivar and Rooney, finger millet (ragi) and pearl millet (*Pennisetum glaucum (L.)*) both exhibit high-starch gelatinization temperatures [84]. As a result, they are subject to the same restrictions regarding the preservation of enzyme activity during brewing. The brewing of millets has not been thoroughly studied. Similar to sorghum, arabinoxylans appear to be the primary element of the cell walls of finger millet and pearl millet [70]. The arabinoxylans in pearl millet are likewise changed with uronic acids, just like they are in sorghum. However, an examination of the non-starch polysaccharides found in finger millet did not reveal uronic acid [70]. The ideal malting conditions for sorghum and pearl millet appear to be very similar. Malt germination is a process a crucial unit operation that requires more focus. The typical recommendation for germination temperature is higher than 22°C. Pelembe., *et al.* [76] observed that a germination period of 3-5 days at a temperature of 25-30°C was ideal. Malting little millet increases the nutraceutical and antioxidant properties in terms of total phenolic, flavonoid, and tannin contents, while malting finger millet decreases tannin (brown millet) and phytic acid content and improves ionisable iron and soluble zinc [77,86]. Malt flour made from brown finger millet seed had a higher amylase activity than white seed variants. The protein content of malted pearl and finger millet is reduced, while the protein efficiency ratio (PER) and bioavailability are improved of all minerals and significantly reduces anti-nutrients [26,52].

Asma., *et al.* [15] created weaning mixes that contain 42% sorghum, 20% legumes, 10% oil seeds, and 28% additives (vanillin, sugar, oil, and skim milk powder) as per FAO/WHO/UNU recommendations and processed in a twin-roller drum dryer. The blends had a decent amount of protein (16.6% to 19.3%), a fair amount of fibre (0.9% to 1.3%), a satisfactory amount of energy (405.8 to 413.2 kcal/100 g), and a healthy amount of iron (5.3 to 9.1 mg/100 g). The lysine concentration increased significantly ($p \leq 0.05$) for all blends, whereas the calcium content varied from 150 to 220 mg/100 g. The paste made from this mixture had a water-holding capacity, wettability, and bulk density that were on par with conventional weaning foods [9]. Malleshi and Klopfenstein [60] made an effort to use seed germination as a method to increase millets' nutritional potential. Sorghum, pearl millet, and finger millet fractions that had been germinated, dried, and milled were used to create the malted flour. It has been suggested that moist-conditioning the malt and grinding it in a roller mill will yield low-fiber malt flour. Low fibre malt flour made from sorghum and millets had an amino acid profile similar to that of barley malt flour. Therefore, finger millet malt flour's essential amino acid profile is superior, and the bran fraction is a rich source of proteins and minerals and may be used in the formulation of high-fiber health foods and feed. Therefore, finger millet malt flour's essential amino acid profile is superior, and the bran fraction is a rich source of proteins and minerals and may be used in the formulation of high-fiber health foods and feed. Sorghum, pearl, and finger millet produced 86, 85, and 78% of the refined malt flour, respectively, with respective protein and crude fibre levels of 10.4, 15.5, and 4.5% and 1.2, 1.0, and 1.8%. Compared to sorghum (1.45%) and pearl millet (2.16%), finger millet (3.4%) has a greater lysine level in its malt flour protein [65,70]. It was discovered that the finger millet variety Indaf-15 produces significant amounts of amylases during germination, and that its malt form is a rich source of reducing sugar, increasing from 1.44 to 8.36% at 96 hours of germination. Adewale., *et al.* [5] extracted Starch-digesting enzymes from finger millet, sorghum, and malted maize. It was shown that the extracted -amylases were heat sensitive, but that the sorghum amylases were slightly more resistant, making them more appropriate for commercial malt production. Progressive germination was accompanied by a significant increase in amylase activity in the case of malted weaning food (MWF) made by combining refined malted ragi with malted green gram flour in a ratio of 70:30 [61,94]. MWF's hot paste viscosity was significantly lower than that of numerous exclusive brands of weaning foods. Cold paste viscosity was higher while heated paste viscosity was lower. The sorghum, pearl millet, and finger millet flour (60%) combined with roasted mung bean flour (30%) and nonfat dry milk (10%) to create the extruded precooked RTE weaning food's viscosity [62]. Foods included 10% more soluble dietary fibre than the similar blends, and in-vitro protein digestibility increased while there was little discernible variation in carbohydrate digestibility. Compared to pearl millet meals, the NPR, PER, and BV were higher for finger millet flour. Thathola and Srivastava [101] made a comparable effort to make weaning meal based on malted foxtail (30%), barnyard (30%), roasted soybean (25%) and skim milk powder (15%) flours. The sensory quality of the commercial weaning mix and the unweaned mix was quite similar and acceptable.

Health and functional foods

Important coarse grains and a great source of nutrition are small millets. Due to the impact of health-promoting and bioactive phytochemicals in plant meals, the term "functional foods" has been widely used to describe foods that enhance health through the prevention of certain degenerative diseases including diabetes, cancer, Parkinson's disease, cataract, etc. The term "nutraceuticals" (like "pharmaceuticals") refers to such bioactive components as vitamins, minerals, and essential fatty acids that, when taken in isolated form, have a preventive impact against degenerative diseases [25]. According to epidemiological research, those who eat a diet high in millet experience less degenerative illnesses including heart disease, diabetes, hypertension, etc. Due to their potential as functional foods and the presence of health-promoting phytochemicals, millets have drawn interest. People with celiac disease and gluten allergies can safely consume millets. They don't generate acids and aren't allergic, so they're simple to digest [39,81]. Potential sources of antioxidant chemicals that can snuff out free radicals include finger millet, foxtail millet, pearl millet, and sorghum [92]. Our diets can benefit from the total phenolics and tannin content of finger millet that is coloured, as well as the moderate reducing capacity and strong free radical scavenging activity of pearl millet [40,73,91,107]. Traditional recipes contain flavonoids such tricin, acacetin, 3, 4 Di-OMe luteolin, and 4-OMe tricin, which suggests that pearl millet has chemo-preventive properties [55,68]. In the pearl millet-consuming belts of the world, they may be inversely connected to coronary heart disease mortality and the incidence of heart attacks, much like the reduced prevalence of diabetes documented in millet-consuming communities [39,81]. Millets ability to prevent diabetes is mostly related to their high fibre content. Millets include several anti-oxidant phenols that also frequently have an anti-diabetic impact. Foxtail and barnyard millet are minor millets with low glycaemic indexes (40-50). These little millets have been converted into ready-to-eat foods by University of Agriculture Sciences, Dharwad (and others) and have proven to have anti-diabetic properties. The glycaemic index, or GI, of biscuits made by replacing 50% of refined wheat flour with barnyard millet flour was lower (50.17) than that of wheat biscuits, which had a higher GI (73.58), with little to no variation in the nutritional composition [93]. The burfi was made by subbing foxtail millet flour for Bengal gram flour up to 57% of the time, along with a control. Both varieties of burfi were found to have equal sensory scores (8.2), but millet burfi had a lower GI score (51) than control [68]. Additionally, it was noted that foxtail millet crackers and burfi significantly reduced serum glucose and serum cholesterol. In a 2007 study, Shobana., *et al.* [88] prepared diabetic food formulations using finger millet, popped rice, and expanded rice, each blended separately with legumes, non-fat dry milk, oil, spices, and a few hypoglycaemic ingredients. They discovered that rice-based formulations (109+/-8) have a higher glycaemic index (GI) than millet-based formulations (93.4+/-7), which have a lower GI [34]. Using a mixture of finger millet flour (45%), wheat flour (40-45%), defatted soy flour (10%), and the hypoglycaemic agent amruth balli (5%), finger millet vermicelli is made ashwagandha demonstrated superior sensory score for various storage periods, and reported lowest cooking loss [57,63]. Millets high fibre and antioxidant content benefits not just blood sugar but also the serum lipid profile. Roti, upma, and idli are traditional Indian breakfast dishes. According to Thakkar and Kapoor [99], these dishes have the lowest glycaemic index (41-48%) [67]. Similar to this, Arora., *et al*. [13] discovered that preparations of finger and barnyard millet with legumes and fenugreek seeds [32,85] lower the GI with no discernible difference between them. Gopalan [36] and Kamath and Belavady [47] both noted the hypoglycaemic effect of millet-based diets. When subjected to five autoclaving and cooling (4°C) cycles, the native starch (NS) isolated from rice and minor millets contains more resistant starch (RS) than NS. In comparison to rice and other minor millets, rats fed with NS and RS from barnyard millet had the lowest levels of blood sugar, serum cholesterol, and triglycerides [49,56]. Newly marketed slowly dissolving carbohydrates (SDC), such as isomaltulose/palmitinose, assert a gradual and sustained blood glucose level after consumption. However, there is no information about any such commercial millet-based product.

Traditional foods and beverages

In millet-growing regions of South India, it has become customary to include finger millet as one of the basic ingredients at a rate of 15-20% (w/w), along with other necessary ingredients like rice and spices [103]. In some areas of Karnataka, finger millet can be used up to 60% more in papad. To make millet papad (rolled, circular, and thin sheets), simply replace 50% of the mixture of black gram dhal and sago flour with finger millet flour and compare the results to black gram (*Phaseolus mungo*) dhal papad [18,104]. In comparison to black gram dhal papad (82 mg% in roasted and 99.6 mg% in fried), the finger millet flour papad had a higher sensory score of 4.7 on a five point hedonic scale and was rich in calcium (102 mg% in roasted and 109 mg% in fried). The nutrient content was slightly altered, but millet and pulse proteins had a supplemental effect that increased the protein quality. Acceptability of finger millet among consumers Finger millet can be a good substitute for traditional papad because papad was still quite tasty after being stored for a while. The preparation of papad using malted sorghum and finger millet flour as well as composite flours in varied ratios of 80:20, 60:40, and 40:60 required a similar amount of labour. On a five-point hedonic scale, the finger millet papad received the highest rank and received an acceptance score of 4.6 for its crisp, appealing flavour, and good appearance [66]. The finger millet papad received the highest ranking on a five-point hedonic scale, receiving an acceptance score of 4.6 for its crisp, appealing taste and excellent presentation. The protein content of sorghum and other small millets can be improved by adding pulses or cereals. Chickpeas and peanuts were added to Kisra, a staple food in the Sudan, to increase its quality [2,16]. For infants older than a year old, this kind of kisra can be utilised as a nutritious sorghum and millet-based baby meal. Sorghum/millet-based baby food can be produced commercially using this composition and processing method. Brown bread shouldn't contain more than 10% wheat or sorghum bran for newborns because doing so negatively affects the bread's digestibility. The main component of millet and sorghum flours is starch. In actuality, the structure of a starch granule is quite complex and is based on changes in the components content and structure [7,98]. In an effort to shorten the cooking time for rolled flour products, hydrothermal treatments (soaking up to moisture 30 2%, steaming 1.05 kg cm^{-2}, 20 min) considerably reduced anti-nutritional components and inactivated lipase activity. From 37 minutes without any treatment to 9 minutes, Arraw used individually germinated millet and sorghum flours. After 3-4 days of grain germination, malt is manufactured, dried at 50 °C, and processed to make flour [17,31,69].

Traditional dishes in the German, Chinese, and Russian cuisines include millets porridge. Mudde is a thick finger millet porridge that is consumed by both the rural and urban populations. For large portions of the tribal population in Central India, kodo millet is a crucial food crop. Millet is a whole grain that is used by the inhabitants of the Himalayan foothills to make the dense bread known as Chapatti, as well as a cereal and soup. Sorghum/millet flour is frequently used to make flat, thin cakes known as Roti in the state of Maharashtra, which are then used as the foundation for meals. Making rotis, idlies, dosas, and chakli with barnyard millet flour might include between 50 and 75 percent of this grain [102]. From finger millet, traditional dishes include idli, pakora, vedai, adai, and sweet halwa or kolukattai; from foxtail millet, Navane sampali, huggi, burfi, or kabab; and from small millet, Samai dosa, porridge, paddu, and paysam. The most popular fermented alcoholic beverage made from dried finger millet seeds is called and "kodo ko jaanr" and is produced in the Eastern Himalayan regions of India's Darjeeling hills and Sikkim. In the Ladakh area of India, chhang, a fermented finger millet beverage, is also well-liked. Koozh is another fermented beverage used by ethnic communities in Tamil Nadu that is made with rice and pearl or finger millet flour [42,53]. Ambali is the name of the conventional, organically fermented finger millet product. In India, finger millet is the cereal of choice for making porridges for kids, the elderly, and those who are ill. Since quite a while ago, millet malt has also been used to make beverages, either with milk or lukewarm water and the addition of sugar. Mahewu is a traditional non-alcoholic beverage made in Zimbabwe from finger millet (1/3) and sorghum (2/3) malt [30,106]. India consumes a few liquid dishes made from millets that go by several local names. Another well-known dish is ragi soup, which is produced by combining ragi flour with water (one part ragi flour to 2.5 parts water) [38]. Researchers worked diligently to create finger millet-based ethnic popular cuisines. In a sensory evaluation, two beverage types—Ambli and malt—received favourable ratings for their look, texture, and flavour, with total acceptability values ranging from 4.0 to 4.5. All of the sensory attribute metrics showed a non-significant difference between the experimental and control products. There are currently modern goods on the market that contain finger millet, such as the ragi health drink (baby vita). When malted pearl millet grains are extruded, the peak viscosity of the starches is dramatically reduced ($p \leq 0.05$), allowing for the production of instant beverage powder from pearl millet [71,72]. Naikare., *et al*. [66] indicated that the best sweet sorghum millet cultivars for making syrup, jaggery, and khandsari. Additionally, it was said that the SSV-84 variety generated good quality jaggery with non-reducing sugars making up 65.4% and reducing sugars making up 12.5% (3.5-4.0 tonnes per hectare).

Future prospects and challenges

Although growing millet can be difficult, it is definitely possible with the right methods and circumstances. The lack of consumer knowledge with millet is one of the biggest obstacles to raising awareness of it. It's possible that many individuals are unaware of millet's existence or its culinary applications. To boost awareness and the demand for millet, marketing and educational initiatives are therefore required. In general, promoting millet involves a multifaceted strategy that combines advocacy, marketing, collaboration, and educational initiatives. In this way, more people will be able to recognise millet's many advantages and its contribution to sustainable food systems and healthy diet promotion. By working with area farmers or grocery stores to supply millet-related products, we can expand the availability of millet. To distribute millet to impoverished communities, we can also work with neighbourhood organisations or food cooperatives. Give millet a unique brand identity to draw in more clients. We might create a logo, packaging, and marketing materials that highlight millet's benefits and versatility. Educate the public on the environmental benefits of millet. It is an environmentally favourable choice for both farmers and consumers because it is a hardy crop with lower water and fertilizer requirements than other grains.

The future of millet is promising as more people become aware of its benefits for their health and its ability to improve food security. Millet is the ideal grain for anyone with celiac disease, gluten intolerance, or who simply want to enhance their general health because it is gluten-free and high in protein, fibre, and minerals. Millet is a climate-smart crop that can help with water conservation, crop diversity, and other sustainable agricultural practices. Millet is a vital crop for smallholder farmers in developing countries because it increases their income, increases their food security, and makes them more resilient to climate change. Millet is anticipated to gain popularity in the next years as consumers' need for more nutritious and environmentally friendly food options rises.

As more research is done on millet's health benefits, its potential as a functional food, and its use in cutting-edge food items, the market for millet-based products is predicted to rise. Overall, millet has a promising future because it is a sustainable crop that could contribute to the development of a more varied and robust food system.

Conclusion

Technologies for value addition and post-harvest processing have advanced, making it possible to process and create things with value that will be accepted by the boss both urban and rural consumers. Wider utilisation of millets and sorghum is quite likely. The potential of finger millet is greatly utilised. Minor millets in particular are not currently studied, and their potential is unrealized in many different ways. Processing millets have been used in product development, and positive trends in terms of quality and nutrition Its health advantages, as well as a cereal substitute Its entire extent and application, however, have not yet been determined. More investigations utilising cutting-edge methods and various to investigate the bioavailability of micronutrients, such as minerals, cooking techniques are required to evaluate their nutritional value *in vivo*, particularly B-vitamins. Despite the fact that several of the aforementioned research it seems that knowledge on scientific procedures did address the benefits of minor millets for health. For these millets to be used widely, more research is required on their justifications, beneficial properties, and potential for the creation of health foods.

Acknowledgement

Authors would like to thank Dr. V.D.Talnikar (HoD, Department of Food Technology) and all faculties of Department of Food Technology, Annasaheb Dange College of Engineering and Technology, Ashta for their constant support and guidance.

Conflict of Interest

The author declares no conflict of interest.

Bibliography

1. Abah C R., *et al*. "Nutritional composition, functional properties and food applications of millet grains". *Asian Food Science Journal* 14.2 (2020): 9-19.

2. Abah C R., *et al*. "Sorghum grains: nutritional composition, functional properties and its food applications". *European Journal of Nutrition and Food Safety* 12.5 (2020): 101-111.

3. Abioye V F., *et al*. "Varietal and processing influence on nutritional and phytochemical properties of finger millet: A review". *Heliyon* (2022): e12310.

4. Adeleye Oluwafunmilayo O., *et al*. "Effect of high-temperature, short-time cooking conditions on *in vitro* protein digestibility, enzyme inhibitor activity and amino acid profile of selected legume grains". *Heliyon* 6.11 (2020): e05419.

5. Adewale Isaac Olusanjo., *et al*. "Comparative studies on α-amylases from malted maize (Zea mays), millet (Eleusine coracana) and Sorghum (Sorghum bicolor)". *Carbohydrate Polymers* 66.1 (2006): 71-74.

6. Agrawal Himani., *et al*. "Purification, identification and characterization of two novel antioxidant peptides from finger millet (Eleusine coracana) protein hydrolysate". *Food Research International* 120 (2019): 697-707.

7. Ai Yongfeng and Jay-lin Jane. "Understanding starch structure and functionality". Starch in food. *Woodhead Publishing*, (2018): 151-178.

8. Ali Maha AM., *et al*. "Effect of fermentation on the *in vitro* protein digestibility of pearl millet". *Food Chemistry* 80.1 (2003): 51-54.

9. Aluge Opeyemi O., *et al*. "Effect of malted sorghum on quality characteristics of wheat-sorghum-soybean flour for potential use in confectionaries". *Food and Nutrition Sciences* 7.13 (2016): 1241-1252.

10. Anggraini Putri Dwi Kasih and Abdul Salam. "Acceptance, nutritional content, and shelf life of cookies based on millet flour as a functional food". *Technium Social Sciences Journal* 21 (2021): 795.

11. Antony Usha and T S Chandra. "Antinutrient reduction and enhancement in protein, starch, and mineral availability in fermented flour of finger millet (Eleusine coracana)". *Journal of Agricultural and Food Chemistry* 46.7 (1998): 2578-2582.

12. Anu S Sehgal and A Kawatra. "Use of pearl millet and green gram flours in biscuits and their sensory and nutritional quality". *Journal of Food Science and Technology-Mysore* 44.5 (2007): 536-538.

13. Arora P., *et al*. "Content and HCl-extractability of minerals as affected by acid treatment of pearl millet". *Food Chemistry* 80.1 (2003): 141-144.

14. Arora Sonia., *et al*. "Effect of germination and probiotic fermentation on nutrient profile of pearl millet based food blends". *British Food Journal* 113.4 (2011): 470-481.

15. Asma M Ali., *et al*. "Development of weaning food from sorghum supplemented with legumes and oil seeds". *Food and Nutrition Bulletin* 27.1 (2006): 26-34.

16. Badi S., *et al*. "The nutritive value of new and traditional sorghum and millet foods from Sudan". *Plant Foods for Human Nutrition* 40 (1990): 5-19.

17. Balasubramanian S., *et al*. "Development and shelf-life evaluation of pearl millet based upma dry mix". *Journal of Food Science and Technology* 51 (2014): 1110-1117.

18. Begum, J M. "Refined processing and Products for commercial use and health benefits from finger millet". Food Uses of Small Millets and Avenues for Further Processing and Value Addition, Project Coordination Cell, All India Coordinated Small Millets Improvement Project, ICAR, UAS, GKVK, Banglore, India (2007).

19. Begum J M., *et al*. "Nutritional composition and sensory profile of baked products from finger millet". *Recent Trends in Millet Processing and Utilization, CCS Hisar Agricultural University, Hisar, India* (2003): 82-87.

20. Bhat Sujata., *et al*. "Significance of small millets in nutrition and health-A review". *Asian Journal of Dairy and Food Research* 37.1 (2018): 35-40.

21. Chauhan Ekta Singh. "Effects of processing (germination and popping) on the nutritional and anti-nutritional properties of finger millet (Eleusine coracana)". *Current Research in Nutrition and Food Science Journal* 6.2 (2018): 566-572.

22. Chavan J K., *et al*. "Nutritional improvement of cereals by fermentation". *Critical Reviews in Food Science and Nutrition* 28.5 (1989): 349-400.

23. Cisse D., *et al*. "Effect of food processing on iron availability of African pearl millet weaning foods". *International Journal of Food Sciences and Nutrition* 49.5 (1998): 375-381.

24. Dahlin K and K Lorenz. "Protein digestibility of extruded cereal grains". *Food Chemistry* 48.1 (1993): 13-18.

25. Dayakar Rao B., *et al*. "Nutritional and health benefits of millets". *ICAR_Indian Institute of Millets Research (IIMR), Rajendranagar, Hyderabad* 112 (2017): 33.

26. Desai Anuradha D., *et al*. "Effect of supplementation of malted ragi flour on the nutritional and sensorial quality characteristics of cake". *Advance Journal of Food Science and Technology* 2.1 (2010): 67-71.

27. Devaraju B., *et al*. "Effect of temperature on physical properties of pasta from finger millet composite flour". *Journal of Food Science and Technology-Mysore* 43.4 (2006): 341-343.

28. Dhumal CV., *et al*. "Development of potato and barnyard millet based ready to eat (RTE) fasting food". *Journal of Ready to Eat Food* 1.1 (2014): 11-17.

29. Fujita S., *et al*. "Physicochemical studies of starch from millet (Setaria italica Beauv.)". *Food Chemistry* 55.3 (1996): 209-213.

30. Gadaga T H., *et al*. "A review of traditional fermented foods and beverages of Zimbabwe". *International Journal of Food Microbiology* 53.1 (1999): 1-11.

31. Gawande AV and K P Babar. "Effect of malting and fermentation on the functional and rheological properties of sorghum flour". *Asian Food Science Journal* 1.1 (2018): 1-4.

32. Geberemeskel Gen*et al*em., *et al*. "Antidiabetic effect of fenugreek seed powder solution (Trigonella foenum-graecum L.) on hyperlipidemia in diabetic patients". *Journal of diabetes research* 2019 (2019).

33. Geervani P and Bjorn O Eggum. "Effect of heating and fortification with lysine on protein quality of minor millets". *Plant Foods for Human Nutrition* 39 (1989): 349-357.

34. Geetha K., *et al*. "Glycemic index of millet based food mix and its effect on pre diabetic subjects". *Journal of Food Science and Technology* 57 (2020): 2732-2738.

35. Geetha R., *et al*. "Twin screw extrusion of kodo millet-chickpea blend: process parameter optimization, physico-chemical and functional properties". *Journal of Food Science and Technology* 51 (2014): 3144-3153.

36. Gopalan C. "Carbohydrates in diabetic diet". *Bull. Nutr. Found* 3 (1981).

37. Govindappa M., *et al*. "Response of finger millet (Eluesine coracana L.) to organic and inorganic sources of nutrients under rainfed condition". *Journal of Crop and Weed* 5.1 (2009): 291-293.

38. Hama-Ba Fatoumata., *et al*. "Study of the nutritional quality and acceptability of millet biscuits (*Pennissetum glaucum* L.) supplemented with cowpea (*Vigna unguiculata* L.) and Bambara groundnut (*Vigna subterranea* L.)". *Journal of Agricultural Science and Food Research* 9.1 (2018): 1-4.

39. Hassan ZM., *et al*. "The nutritional use of millet grain for food and feed: a review". *Agriculture and Food Security* 10 (2021): 1-14.

40. Ibidapo Olubunmi., *et al*. "Bioactive components of malted millet (Pennisetum glaucum), Soy Residue "okara" and wheat flour and their antioxidant properties". *International Journal of Food Properties* 22.1 (2019): 1886-1898.

41. Ikram Ali., *et al*. "Nutritional and end-use perspectives of sprouted grains: A comprehensive review". *Food Science and Nutrition* 9.8 (2021): 4617-4628.

42. Ilango Shankar and Usha Antony. "Assessment of the microbiological quality of koozh, a fermented millet beverage". *African Journal of Microbiology Research* 8.3 (2014): 308-312.

43. Jaybhaye R V., *et al*. "Processing and technology for millet based food products: a review". *Journal of ready to Eat Food* 1.2 (2014): 32-48.

44. Jha Neha., *et al*. "Effect of different soaking conditions on inhibitory factors and bio accessibility of iron and zinc in pearl millet". *Journal of Cereal Science* 66 (2015): 46-52.

45. Junejo Shahid Ahmed., *et al*. "Starch structure and nutritional functionality–Past revelations and future prospects". *Carbohydrate Polymers* 277 (2022): 118837.

46. Kajla Priyanka., *et al*. "Biofortification and medicinal value of pearl millet flour". *Pearl Millet. CRC Press,* (2020): 139-157.

47. Kamath M Vitaladasa and Bhavani Belavady. "Unavailable carbohydrates of commonly consumed Indian foods". *Journal of the Science of Food and Agriculture* 31.2 (1980): 194-202.

48. Kamble Dinkar B., *et al*. "Evaluation of structural, chemical and digestibility properties of multigrain pasta". *Journal of Food Science and Technology* 58 (2021): 1014-1026.

49. Kanagaraj Sasi Praba., *et al*. "Effect of dry heat treatment on the development of resistant starch in rice (Oryza sativa) and barnyard millet (*Echinochloa furmantacea*)". *Journal of Food Processing and Preservation* 43.7 (2019): e13965.

50. Kaur Arshdeep., *et al*. "Physico-chemical characterization and utilization of finger millet (Eleusine coracana L.) cultivars for the preparation of biscuits". *Journal of Food Processing and Preservation* 44.9 (2020): e14672.

51. Khetarpaul Neelam. "Improvement of nutritional value of pearl millet by fermentation and utilisation of the fermented product". *Diss. Foods and Nutrition, CCSHAU, HIsar*, (1988).

52. Krishnan Rateesh., *et al*. "Quality characteristics of biscuits prepared from finger millet seed coat based composite flour". *Food chemistry* 129.2 (2011): 499-506.

53. Kuma Amistu., *et al*. "Assessment of raw milk microbial quality at different critical points of oromia to milk retail centers in Addis Ababa". *Food Science and Quality Management* 38 (2015).

54. Kumar Anil., *et al*. eds. "Millets and Millet Technology". Springer Singapore, (2021).

55. Kumari Disna., *et al*. "Comparison of phenolic content and antioxidant activities of millet varieties grown in different locations in Sri Lanka". *Food Science and Nutrition* 5.3 (2017): 474-485.

56. Kumari S Krishna and B Thayumanavan. "Comparative study of resistant starch from minor millets on intestinal responses, blood glucose, serum cholesterol and triglycerides in rats". *Journal of the Science of Food and Agriculture* 75.3 (1997): 296-302.

57. Ladkat KS., *et al*. "Physicochemical properties of finger millet and malted finger millet muffins". *BIOINFOLET-A Quarterly Journal of Life Sciences* 16.1and2 (2019): 31-34.

58. Lehmann U and F Robin. "Slowly digestible starch–its structure and health implications: a review". *Trends in Food Science and Technology* 18.7 (2007): 346-355.

59. Maitra Sagar M., *et al*. "Nutrient management in finger millet (*Eleusine coracana* L. Gaertn) in India". *International Journal of Agriculture, Environment and Biotechnology* 13.1 (2020): 13-21.

60. Malleshi N G and CF Klopfenstein. "Nutrient composition, amino acid and vitamin contents of malted sorghum, pearl millet, finger millet and their rootlets". *International Journal of Food Sciences and Nutrition* 49.6 (1998): 415-422.

61. Malleshi N G and H S R Desikachar. "Studies on the suitability of roller flour mill, hammer mill and plate grinder for obtaining a refined flour from malted ragi (*Eleusine coracana*)". *Journal of Food Science and Technology* 18.2 (1981): 37-39.

62. Malleshi Nagappa G., *et al*. "Physical and nutritional qualities of extruded weaning foods containing sorghum, pearl millet, or finger millet blended with mung beans and nonfat dried milk". *Plant Foods for Human Nutrition* 49 (1996): 181-189.

63. Mamatha H S., *et al*. "Effect of storage on cooking and sensory quality of diabetic vermicelli from finger millet with hypoglycemice foods". *Recent Trends in Millet Processing and Utilization, CCS Hisar Agril. Univ., Hisar, India* (2003): 51-55.

64. Mir Shabir Ahmad., *et al*. "Technological and nutritional properties of gluten-free snacks based on brown rice and chestnut flour". *Journal of the Saudi Society of Agricultural Sciences* 18.1 (2019): 89-94.

65. Mitharwal Swati., *et al*. "Nutritional, polyphenolic composition and *in vitro* digestibility of finger millet (Eleusine coracana L.) with its potential food applications: A review". *Food Bioscience* 44 (2021): 101382.

66. Naikare SM., *et al*. "Processing of papad from malted sorghum flour". *Recent Trends in Millet Processing and Utilization, CCS Haryana Agril. Univ., Hisar, India* (2003): 32-37.

67. Nambiar Vanisha S and Tanvee Patwardhan. "Assessment of glycemic index (GI) and glycemic load (GL) for selected traditional millet-based Indian recipes". *International Journal of Diabetes in Developing Countries* 35 (2015): 157-162.

68. Nambiar Vanisha S., *et al*. "Flavonoids and phenolic acids from pearl millet (*Pennisetum glaucum*) based foods and their functional implications". *Functional Foods in Health and Disease* 2.7 (2012): 251-264.

69. Ndiaye Cheikh., *et al*. "Malting germination effect on rheological properties and cooking time of millet (P. typhoïdes) and sorghum (S. bicolor) flours and rolled flour products (arraw)". *American Journal of Food Technology* 3.6 (2008): 373-383.

70. Nirmala M., *et al*. "Carbohydrates and their degrading enzymes from native and malted finger millet (Ragi, Eleusine coracana, Indaf-15)". *Food Chemistry* 69.2 (2000): 175-180.

71. Obilana Anthony O., *et al*. "Functional and physical properties of instant beverage powder made from two different varieties of pearl millet" (2014).

72. Obilana Anthony O., *et al*. "Nutritional, biochemical and sensory properties of instant beverage powder made from two different varieties of pearl millet". *Food and Nutrition Research* 62 (2018).

73. Odusola KB., *et al*. "Assessment of nutritional composition and antioxidant ability of pearl millet (Pennisetum glaucum)". *American Journal of Research Communication* 1.6 (2013): 262-272.

74. Onyango Calvin., *et al*. "Proximate composition and digestibility of fermented and extruded uji from maize–finger millet blend". *LWT-Food science and Technology* 37.8 (2004): 827-832.

75. Patel M M and G Venkateswara Rao. "Influence of untreated, heat-treated and germinated blackgram flours on biscuit making quality of wheat flour". *Journal of Food Science and Technology* 33.1 (1996): 53-56.

76. Pelembe LAM., *et al*. "Development of a protein-rich composite sorghum–cowpea instant porridge by extrusion cooking process". *LWT-Food Science and Technology* 35.2 (2002): 120-127.

77. Pradeep S R and Manisha Guha. "Effect of processing methods on the nutraceutical and antioxidant properties of little millet (Panicum sumatrense) extracts". *Food Chemistry* 126.4 (2011): 1643-1647.

78. Qi Yanyu., *et al*. "Insights into structure-function relationships of starch from foxtail millet cultivars grown in China". *International Journal of Biological Macromolecules* 155 (2020): 1176-1183.

79. Rao Cherukumalli Srinivasa., *et al*. "Potential and challenges of rainfed farming in India". *Advances in Agronomy* 133 (2015): 113-181.

80. Rashwan Ahmed K., *et al*. "Potential processing technologies for developing sorghum-based food products: An update and comprehensive review". *Trends in Food Science and Technology* 110 (2021): 168-182.

81. Saleh Ahmed SM., *et al*. "Millet grains: nutritional quality, processing, and potential health benefits". *Comprehensive Reviews in Food Science and Food Safety* 12.3 (2013): 281-295.

82. Sangita Kumari and Srivastava Sarita. "Nutritive value of malted flours of finger millet genotypes and their use in the preparation of burfi". *Journal of Food Science and Technology (Mysore)* 37.4 (2000): 419-422.

83. Selvaraj A., *et al*. "Packaging and storage studies on biscuits containing finger millet (ragi) flour". *Journal of Food Science and Technology* 39.1 (2002): 66-68.

84. Serna-Saldivar S O., *et al*. "Effects of parboiling and decortication on the nutritional value of sorghum (*Sorghum bicolor* L. Moench) and pearl millet (*Pennisetum glaucum* L.)". *Journal of Cereal Science* 19.1 (1994): 83-89.

85. Sharma RD and TC Raghuram. "Hypoglycaemic effect of fenugreek seeds in non-insulin dependent diabetic subjects". *Nutrition Research* 10.7 (1990): 731-739.

86. Sharma Seema., *et al*. "Changes in the GABA and polyphenols contents of foxtail millet on germination and their relationship with *in vitro* antioxidant activity". *Food Chemistry* 245 (2018): 863-870.

87. Shigihalli Sneha., *et al*. "Effect of processing methods on phytic acid content in selected white finger millet varieties". *International Journal of Current Microbiology and Applied Sciences* 7.2 (2018): 1829-1835.

88. Shobana Shanmugam, *et al*. "Glycemic response of rice, wheat and finger millet based diabetic food formulations in normoglycemic subjects". *International Journal of Food Sciences and Nutrition* 58.5 (2007): 363-372.

89. Silva Daisy Jacqueline Sousa., *et al*. "Correlation between the rheological and technological properties of biscuits with different levels of replacement of wheat flour by rice and azuki bean flour". *International Journal of Food Science and Technology* 56.10 (2021): 5190-5200.

90. Singh Ritu and M S Nain. "Nutrient analysis and acceptability of different ratio pearl millet (*Pennisetum glaccum* (L.) R. Br.) based biscuits". (2020).

91. Siwela Muthulisi., *et al*. "Occurrence and location of tannins in finger millet grain and antioxidant activity of different grain types". *Cereal Chemistry* 84.2 (2007): 169-174.

92. Sripriya G., *et al*. "ESR spectroscopic studies on free radical quenching action of finger millet (Eleusine coracana)". *Food Chemistry* 57.4 (1996): 537-540.

93. Srivastava S., *et al*. "Popping characteristics of Barnyard and foxtail millet and their use in preparation of sweets". *Recent Trends Millet Process Util Hisar, India Chaudhary Charan Singh Hisar Agril Univ* (2003): 38-40.

94. Sudan Sarabjeet Kour., *et al*. "Production, purification and characterization of raw starch hydrolyzing thermostable acidic α-amylase from hot springs, India". *International Journal of Biological Macromolecules* 117 (2018): 831-839.

95. Sukumaran Sreekala Asha Devi., *et al*. "Millet Production and Consumption in India: Where Do We Stand and Where Do We Go?". *National Academy Science Letters* 46.1 (2023): 65-70.

96. Sumathi A., *et al*. "Physico-chemical characteristics, nutritional quality and shelf-life of pearl millet based extrusion cooked supplementary foods". *International Journal of Food Sciences and Nutrition* 58.5 (2007): 350-362.

97. Taylor John RN., *et al*. "Novel food and non-food uses for sorghum and millets". *Journal of Cereal Science* 44.3 (2006): 252-271.

98. Tester Richard F., *et al*. "Starch—composition, fine structure and architecture". *Journal of Cereal Science* 39.2 (2004): 151-165.

99. Thakkar Rasika and Rashmi Kapoor. "Enrichment of rice and finger millet based preparations with gum acacia and their effects on glycemic response in non-insulin dependent diabetic subjects". *Journal of Food Science and Technology-Mysore* 44.2 (2007): 183-185.

100. Thapliyal Vinita and Karuna Singh. "Finger millet: potential millet for food security and power house of nutrients". *International or Research in Agriculture and Forestry* 2.2 (2015).

101. Thathola Anju and Sarita Srivastava. "Physicochemical properties and nutritional traits of millet-based weaning food suitable for infants of the Kumaon hills, Northern India". *Asia Pacific Journal of Clinical Nutrition* 11.1 (2002): 28-32.

102. Veena B., *et al*. "Development of barnyard millet based traditional foods". *Karnataka Journal of Agricultural Sciences* 17.3 (2010).

103. Verma Veenu and S Patel. "Value added products from nutri-cereals: Finger millet (Eleusine coracana)". *Emirates Journal of Food and Agriculture* (2013): 169-176.

104. Vidyavati H G., *et al*. "Utilization of finger millet in the preparation of papad". *Journal of Food Science and Technology-Mysore* 41.4 (2004): 379-382.

105. Wadikar D D., *et al*. "Lipid profile of finger millet (Eleusine coracana) varieties". *Journal of Food Science and Technology-Mysore* 44.1 (2007): 79-81.

106. Wedajo Lemi Bikila. "Microbiology of Ethiopian traditionally fermented beverages and condiments". *International Journal of Microbiology* 2020 (2020).

107. Xiang Jinle., *et al*. "Profile of phenolic compounds and antioxidant activity of finger millet varieties". *Food Chemistry* 275 (2019): 361-368.

108. Xing Qinhui., *et al*. "Enhanced nutritional value of chickpea protein concentrate by dry separation and solid state fermentation". *Innovative Food Science and Emerging Technologies* 59 (2020): 102269.

109. Yadav Gorenand Prasad., *et al*. "Effects of extrusion process parameters on cooking characteristics and physicochemical, textural, thermal, pasting, microstructure, and nutritional properties of millet-based extruded products: A review". *Journal of Food Process Engineering* 45.9 (2022): e14106.

110. Yenagi Nirmala., *et al*. "Hand book for school children: importance of millets in daily diets for food and nutrition security [appendix 11 of the joint technical final report (October 2010-March 2013)]". (2013).

111. Zheng Mingzhu., *et al*. "Effect of adding zein, soy protein isolate and whey protein isolate on the physicochemical and *in vitro* digestion of proso millet starch". *International Journal of Food Science and Technology* 55.2 (2020): 776-784.