Processing and health benefits ofunderutilized foxtail and barnyard millet for development of functional bakery products

Abstract

The bread sector in India holds the distinction of being the largest food industry in terms of yearly turnover, amounting to almost 3000 crores. Formerly considered a dietary choice limited to individuals with health ailments, bakery products have evolved into essential nutrition for a significant portion of the population. The majority of countries exhibit a notable increase in per capita consumption of bread goods. It is anticipated that there will be a sustained increase in the demand for bakery goods in the future. The anticipated growth rate of 9.8% appears to be quite modest when considering the existing market potential of bakery products among populations with lower and middle incomes. This suggests that there is significant opportunity for the promotion and consumption of bakery products as a means of enhancing dietary enrichment. Bakery products are among the most affordable processed food items available for consumption within the country. Over 70% of the overall production has historically been contributed by the industry, which is still mainly from the unorganized sector.

Keywords: Bakery products, Barnyard, Foxtail Functional, Health benefits, Millets, Underutilized

1. Introduction

The demand for healthier bakery items has led to adjustments in ingredients, focusing on enhancing fibre, controlling calories, adding omega and essential fatty acids, and reducing saturated and trans fats. Natural sweeteners are favoured over artificial ones, and low-calorie options are explored, resulting in gluten-free baked goods. Millets, ancient grains cultivated in diverse climates, have been a staple for millennia in Asia and Africa, with China being an early grower around 2700 B.C., predating rice as a staple cereal.

Millets, considered nutraceuticals, are used to create functional foods due to their superior nutritional profile compared to main cereals, being rich in protein, vitamins, minerals, phytochemicals, and dietary fibre. Recognized as edible Chinese drugs, millets release sugar slowly, making them suitable for therapeutic diets (Chandrashekhar, 2003; Desikachar, 1977; Xu, 2001). They also contain inaccessible carbohydrates.

Millets are grown in India, producing 17.26 million metric tonnes. India produces 4.77 million tonnes of sorghum, ranking fifth worldwide. India produces the most pearl, finger, tiny, kodo, and barnyard millet, 12.46 million metric tonnes per year on 8.87 million hectares. With 7.29 million tonnes, Rajasthan produces the most millet followed by Karnataka, Madhya Pradesh, Maharashtra, Uttar Pradesh, Tamil Nadu, and Telangana(Ashoka et al., 2020).

Foxtail millet (*Setariaitalica*) is grown mostly in India, Bangladesh, and China. The names are kangni, korra, navana, tenai, kakun, and rala. It thrives in harsh climates and weather extremes. Practically devoid of grain storage pests, it has indefinite storage life (Malleshi, 1989). It is essentially grown in the foothills of Himalayas. Foxtail millet is grown on 90% of India's land, especially in Andhra Pradesh, Karnataka, and Tamil Nadu's lowlands and highlands. Per hectare, grains yield was 400-800 kg and straw 1000-2000 kg.

Barnyard millet (*Echinochloa frumentacea*), also known as banti, madira, and sanwa, is a key coarse cereal in dryland agriculture. According to Kumar *et al.* (1997), it is primarily grown in the hills of Uttaranchal and tribal areas of Orissa, Maharashtra, Gujarat, Madhya Pradesh, Tamil Nadu, and Bihar. Despite being used as animal feed, it is mainly cultivated for human consumption. Due to its short length and rapid growth, it is possible to cultivate and harvest multiple crops within a single growing season (Mandelbaum *et al.*, 1995). Known for its short growth period and resilience to drought, heat, and waterlogging, barnyard millet yields 700-800 kg of grains and 1-1.5 tonnes of straw per acre (Hegde and Linge Gowda, 1989).

Traditional barnyard millet,*Echinochloa species*, grows in warm and temperate locations including India, China, Japan, and Korea. It is the fourth most cultivated millet, feeding many impoverished people. India has the most barnyard millet acreage and produces the most, averaging 1034 kg/ha over the past three years(Renganathan *et al.*, 2020).

Muffins, a popular bakery item, are not quick bread and do not contain yeast. Unlike cupcakes, muffins may have a glazed surface. They are typically consumed in one sitting and fit comfortably in an adult hand, often enjoyed as breakfast or snacks. Common ingredients include wheat flour, sugar, milk, butter, salt, baking soda, and baking powder. Whole grains, traditionally grown in India, have varied productivity, and new varieties have shown potential medicinal and functional benefits. Research worldwide highlights the nutritional and medicinal benefits of whole grains in managing non-communicable diseases and promoting health.

Recently the word ‘nutraceuticals’ has gained more importance in the field of nutrition. Nutraceutical is the food which can used as preventing drug or food supplement. Millets are the underutilized food having nutraceutical value.

The dietary value of bakery products needs enhancement due to growing consumer awareness about nutrition and ideal health. There's an increasing demand for healthier bakery options as people become more conscious of food-related health issues like obesity, diabetes, and heart problems. This article focuses on the chemical composition, health benefits, and functional bakery products developed by incorporating foxtail and barnyard millet flour.

2. Millets

2.1 Foxtail millet

Foxtail millet (*Setaria italica*) is called Italian, German, Chinese, Hungarian, dwarf, gigantic, and Siberian. The foxtail millet's 2mm-diameter seeds are tiny. They are attached to a thin paper shell that can be easily removed after being threshed off. Pale yellow to orange, crimson, brown, and black were among the seed's many colours. The foxtail millet thousand kernel weighs 2 g. Foxtail millet has a low amino acid score and is lacking in lysine, similar to maize. Leucine and methionine levels can reach 100% in some types. More easily absorbed than maize starch include foxtail, proso and barnyard starches. More amount of ash is found than cereal grains. Significant reduction in ash content was recorded after dehulling.

Starch, protein, vitamins, and minerals make up the majority of the nutrients in foxtail millet. Coarse grains of foxtail millet have 79 % digestible protein and undigestible part contains fibre and antinutritional compounds. High fibre contents induce bowl movement, increasing laxative effect to improve health of digestive system. Therefore, foxtail is a crucial element for preparing noodles, soup, brewed alcoholic beverages, cereal porridges, and pancakes, in addition to its functional and nutritional qualities. Also, it has anti carcinogenic, hypoglycaemic and hypolipidemic effects.

The value-added product obtained by foxtail millet processing significantly contributary economic development of many Asian and African countries. The foxtail and other millet have potential to care malnutrition problems (Sharma *et al.*, 2018).

2.2. Functional properties of foxtail millet

The wide variety of health-promoting functional compounds makes the foxtail millet unique among the cereals. The compounds present in foxtail millet improve the nutritional and organoleptic attributes like as aroma, flavour, and appearance.

Yang *et al.* (2013) studied that the foxtail millet contains 11.85% crude protein, 2.83 - 4.47% of crude fat, 65.59-74.12 g/100 g total starch and 0.25-4.31 g/100 g amino acid.

Over 80% of millet fat is unsaturated. Linoleic, oleic, palmitic, stearic, and linolenic acids were the primary fatty acids. According to Zhang *et al.* (2015), cultivar variety correlated with fatty acid content in different places. Thus, varietal breeding could increase foxtail millet's fatty acid composition.

2.3. Composition of foxtail millet

Foxtail millet contained 12.30g/100g protein, 60.90g/100g carbohydrates, 2.80 mg/100g iron, 250mg/100g potassium, 15mg/100g folic acid and 66.50 mg/100g linoleic acid (Table 1) (Hasan *et al.,* 2019)

Foxtail millet has a number of advantageous nutritional qualities. The thick seed coat of foxtail grains contributes to their high fibre content (8 g/100 g), as well as their high protein (12.30 g/100 g), fat (4.30 g/100 g), and mineral content (calcium 31 mg/100 g, phosphorus 290 mg/100 g, and iron content of around 2.80 mg/100 g). Foxtail grains are coarse and stand out for these qualities. They also have a significant quantity of antinutritional components such phytates and polyphenols, which prevent the absorption of nutrients (Garwadhiremath, 2011).

2.4. Barnyard millet

The family Poaceae, genus Echinochloa, and subfamily Panicoideae are where barnyard millet is classified. The warm and temperate regions of the planet are home to a large number of the 250 annual and perennial species belonging to the genus Echinochloa (Bajwa *et al.,* 2015). Most of the species from genus *Echinochloa* grow as weed in major crop field (Kraehmer*et al.,* 2016).

2.5. Composition of barnyard millet

When compared to kodo and foxtail millet, barnyard millet has a lower degree of hardness. There are two layers of epidermis on the seed coat of barnyard millet. The aleurone layer cutinized cell wall had 57-66 % carbohydrates, 6.4-12.2 % fibre, 5-8.5 % protein, 3.5-4.6 % fat, 2.5-4.0 % ash. The shape of simple starch granules is spherical to polygonal with large 1.2-10 m diameter as compared to other millet (Kumari and Thayumanavan., 1998). Different genotypes have grain pericarps that range in colour from straw white to light grey and dark grey (Renganathan *et al.,* 2020).

Singh *et al.* (2022) studied the composition of barnyard millet grain. Data revealed that, barnyard millet contained 6-13g/100g protein, 55-65.50g/100g carbohydrates, 1.15-

19.50mg/100g iron, 280-340mg/100g phosphate, 11-27.10mg/100g calcium and ash 3.8-4.50mg/100g ash (Table 2).

2.6. Nutraceuticals properties of barnyard millet

The nutritive food choice for anaemic women and patients with lifestyle disease is barnyard millet. The barnyard millet had 2 times more polyphenol and carotenoids than finger millet with several health functions (Panwar *et al.,* 2016). The ethnomedical properties include wound healing ability, biliousness, anti-inflammatory, antibacterial, anti-carcinogenic, and easing constipation-related issues (Kim *et al.*, 2011). So, the barnyard millet is most secured and good choice for making nutritional food products.

2.7. Nutritional significance of barnyard millet

Singh *et al.* (2022) studied the amino acid profile of barnyard millet grain. Data revealed that, barnyard millet had very low lysine content ranging from 106 mg to 136 mg/g. The barnyard millet contained 175-219mg/g cystine, 288-372mg/g isoleucine, 725-762mg/g leucine, 35-263mg/g threonine, 131-133mg/g methionine, 119-415mg/g tyrosine, 388-415mg/g valine (Table 3).

Barnyard millet may help type II diabetes. Millet has 10.50 % protein, 68.80 % carbs, 3.60 % fat, and 398 kcal/100 g. Dietary fibre, both soluble (4.20 %) and insoluble (8.40 %), was abundant (12.60 %). Dehulled (50.0) and heat-treated (41.70) grains had low glycemic indexes(Ugare *et al.,* 2014).

Foxtail and barnyard millet are equally nutritious as wheat and rice. They outperform rice and wheat in fibre and minerals. Millets have some potential for therapeutic nutrition, although this potential has not yet been fully realised. The development of millet-based foods that are suitable for diabetics has not been the subject of many studies (Pathak *et al*., 2000).

3.Uses ofnon-wheat flours in bakery products

Donelson *et al.* (1988) replaced the flour starch with starch tailing or water-soluble fractions and gluten fraction. The researcher investigated the impact of including certain substances on the baking characteristics of cake and cookies. The data revealed that loss of volume of cake was observed with incorporation of starch tailing of water solution fraction for cake making. While non-significant changes were observed in baking properties with incorporating of gluten fraction for cake making. The baking quality of cookies improved significantly with replacement of gluten or starch tailing fraction with flour starch.

Gaines et al. (1985) evaluated the effects of cake flour protein alteration on white layer thickness and softness. The air classification method used to charge the protein content of flour by addition of gluten lever from 7 to 16 %. Result revealed that composition of flour did not. Significantly effect on yield and textural properties i.e. softness of cake. The increased flour protein content significantly effects on height and tenderness of angle cake.

Ammar *et al.* (2009) prepared the balady bread with replacement of taro flour of levels of 5, 10, 15 and 20% in wheat flour. Additionally, researchers looked at the farinograph, extensograph, sensory, and chemical characteristics of bread made with taro flour. The findings of the farinograph analysis indicated that the substitution of taro flour showed an increment in water absorption and dough weakening. However, it also led to a decrease in the time required for dough mixing and its overall stability. The energy required for dough markings, resistance to extension of dough and number of cells decreased with increased concentration of taro flour while extensibility of dough increased in case of extensograph. The bread with taro flours up to 10% had similar sensory score with control for all attributes. The elevated concentration of tarp flour in bread leads to a reduction in crude protein and crude fat, while simultaneously resulting in an increment in ash, total carbs, and fiber content.

Sanful *et al.* (2010) evaluated the effect of addition of soy flour making bread on nutritional value, sensory score, composition of bread. The findings indicate that an elevated concentration of soy flour is associated with an increment of the moisture, ash, and protein levels in bread. The protein level of bread had a notable enhancement, resulting in a substantial improvement in its nutritional worth. The sensory evaluation for soy bread showed that bread with 30% of soybean flour liked more as compared to control while sensory acceptance decreases beyond 30% level of incorporation.

By including pea flour, a protein-rich and fiber-rich ingredient, baked products can be enhanced in terms of their nutritional value. Kamaljit *et al.* (2010) examined pea flour's functional properties for this purpose. The milled dried pea flour was added in bread and cookies at a 5 and 10% level. The baking quality of bread and cookies were studied. Water absorption capacity increased with reduction in stickiness of dough. Increased level of pea flour causes collapse in volume and increase in weight of bread was observed. Pea flour lowered cookie spread ratio. Bread with 5% pea flour had similar of sensory score with control. The inclusion of 5% pea flour improves the baking quality of cookies and bread without affecting on organoleptic quality.

4. Uses of millets in bakery products

The quality assessment of bakery goods made with pearl millet was researched by Singh *et al.* (2006). They used wheat and pearl millet flour to make sponge cake, eggless cake, and rusk. The millet flour replaced with wheat flour at level of 25, 50 and 75%. The product prepared from wheat flour replaced with 25 and 50% of pearl millet flour had overall acceptability between 7.40 and 8.20. The bakery product with a 50% substitution of pearl millet flour with wheat flour was acceptable by the majority of sensory panel assessors. The moisture content, protein content, fat content, ash content, crude fiber content, and carbohydrate content of baked fresh pearl millet items exhibited a range of 3.80-30.20%, 11.20-17.20%, 13.50-36%, 1.1-1.8%, 0.4-0.78%, and 51.0-67.20%, respectively.

Anu *et al.* (2007) prepared the pearl millet-based sponge cake for the survey of dietary assessment. The proportions of blanched pearl millet and green gram meal added to controls with 100% refined wheat meal were 40:50:10 for Type I and 60:30:10 for Type Il. Both varieties of sponge cakes were adored by the panellists. The type I and type II cakes' chemical composition were superior to that of the control cake.

Nazni and Karuna (2016) developed the rusk and muffin incorporated with barnyard millet bran (BMB). In comparison to calcium hydroxide-treated bran, the amount of dietary fibre, protein, and ash was stabilised in hot water-treated bran. The two products with BMB substitution that earned the highest overall acceptability from the panel were the rusk at ratio (85:15) and muffin at ratio (75:25). Increased replacement of BMB at slightly higher levels caused increase in hardness of rusk and muffin. The bran was first filtered and combined with a 20% solution of 1% calcium hydroxide before being dried at 50°C and used to make rusk and muffins. The bran was then steeped in boiling water (125°C) for 15 minutes.

Grigelmo *et al*. (1999) included peach DF at 2, 3, 4, 5, or 10% to make high-fruit, dietary-fibre muffins. Peach DF holds water well, thus adding it to muffins enhanced moisture content. DF enhanced muffins' hardness, chewiness, and gumminess but not their weight (302 g), height (4.50 cm), springiness (0.880 cm), or cohesiveness (0.460). The little dark color came from peach DF. Consumer panellists rated muffins with peach DF levels of 2, 3, 4, and 5% as nice as the control on the hedonic scale.

Khatri *et al.* (2020) developed muffins with Palmyra sprout flour. In comparison to normal whole wheat flour's (0.52%) 5.08% crude fibre content, palmyra sprout flour (SF) had 5.08%. Since palmyra sprout flour had a lower water activity (0.55) than wheat flour, it was used to extend muffin shelf life. The muffin that contained 50% palmyra sprout flour was deemed to be the best. Additionally, palmyra SF muffins had better proximal composition than refined wheat muffins. The chosen muffin, which contained 50% palmyra sprout flour, had a high nutritional value.

Millets are more nutritious than cereals, yet traditional consumers and low-income people still eat them. Food technologist and engineers have developed mechanised methods for numerous food products due to customer health awareness and benefits. Millets and products were used to make traditional and RTE cuisines (Jaybhaye*et al.,* 2014).

Microscopy, rheology, and quality of muffin batter were investigated by Rajiv *et al.* (2011) in relation to substituting 0, 20, 40, 60, 80, and 100% finger millet flour (FMF), emulsifiers, and hydrocolloids for wheat flour. Increased FMF replacement decreased amylograph peak, breakdown, and setback viscosity. Microscopy of muffin batter with FMF exceeding 60% in blend showed fewer air cells, indicating inadequate air incorporation during mixing. Muffin batter viscosity, volume, density, and score decreased as FMF increased from 0% to 100%, however crumb hardness increased. Cake quality suffered above 60% FMF. Polysorbate-60, hydroxypropyl-methylcellulose, and 60% FMF enhanced muffin batter viscosity, volume, grain, and texture.

Hernandez *et al.* (2017) examined muffin texture and baking quality with modified cross-linked cassava starch (CCS) as a fat replacer. Based on wheat flour weight, CCS replaced fat at 8, 12, and 16%. CCS and wheat flour were tested for thermal characteristics, and wheat flour-CCS mixes for pasting and farinography. CCS flour lowered dough stability and development time. CCS gelatinized and retrograded faster than wheat flour. Wheat flour-CCS mixes had lower setback and final viscosities. Weight loss, specific volume, crumb moisture content, and colour score of wheat flour-CCS muffins were non-significant. T8 muffins with 8% CCS fat replacer had the closest texture to control muffins without CCS. Thus, this muffin and the control muffins were chosen for a 7-day shelf life research. On 2 and 4 days of storage, the T8 muffins had a higher crumb hardness and were equally acceptable. Despite being firmer during storage, consumers liked T8 muffins.

Gornas*et al.* (2016) tested muffins with 50 g/kg pomace from strawberries, black currants, raspberries, and sour cherries at 140, 180, and 220 °C in conventional and halogen ovens to increase polyphenol stability. Anthocyanins (36-97% lost) were more unstable than flavanol glycosides (0-21%). Thermal degradation of ellagitannins and ellagic acid glycosides increased free ellagic acid in strawberry or raspberry muffins. High-temperature short-baking preserved polyphenols. Enriching bakery items with fruit pomace maximises nutritional value. 50 g/kg apple pomace improved organoleptic quality and nutritional value of muffins compared to controls.

Rupasinghe *et al.* (2008) examined muffin dietary fibre and phenolics after adding apple skin powder (ASP). Apple processing waste contains nutritional fibre and phenolics. 41% total dietary fiber and 52 mg Trolox equivalents g^{-1} dry weight of oxygen radical absorption capacity (ORAC) are found in blanched, dehydrated, and crushed ASP. ASP incorporation increased muffins' dietary fibre, phenolic, and antioxidant content. Bakery recovered 61%, 57%, 53%, 44%, and 20% of quercetin glycosides, catechins, chlorogenic acid, phloridzin, and cyanidin galactoside.

5. Baking characteristics of millets-basedbakery products

Almaski *et al.* (2017) examined the sensory evaluations and in vitro starch digestion of millet muffins high in polyphenols. In lab trials, starch digestion and lowering sugar were measured in millet-based muffins. All three millet muffins released less sugar than a wheat muffin. Kodo millet grain muffins were less appealing than control and finger millet flour muffins. Kodo and finger millet muffin acceptance varied significantly. Current research helped make millet-based bread items to enhance millet use and produce healthful daily-consumption products.

Emmanuel *et al.* (2013) investigated millet sponge cake's nutritional and sensory qualities. The formulation with an overall acceptability scores greater than 6.0 was utilised to optimise levels. The sensory panel liked millet cakes and would buy them regularly. Cake carbohydrate, fat, and ash improved significantly. Ash increased 2.08±0.36% and fat 33.41±3.32% compared to 1.53% and 30.96% in the control sample. Carbohydrate content decreased 71.41±5.38% compared to control sample of 77.43%.

Kulthe*et al.* (2017) developed and tested cookie physical and textural features using pearl millet flour (PMF). For cookies, Shanti, Dhanshakti, and Pioneer 84M64 pearl millet flour was replaced at 0, 10, 20, 30, 40, and 50% with wheat maida. PMF increased cookie thickness but decreased diameter, spread ratio, and spread factor. PMF boosted a* and lowered L* and b* in cookies. PMF enhanced cookie hardness, breaking strength, and cutting strength. Based on cookie texture and appearance, PMF of Dhanshakti was better than Shanti and Pioneer 86M64.

Shiny *et al.* (2014) produced a high-fibre millet-based biscuit and studied its nutritional and sensory properties. Consumers now prioritise health benefits when eating properly. The high-fibre biscuit recipe used millets, whole grains, flax seed, and spices after several experiments. The newly created high-fiber biscuit was well-accepted during sensory examination, scoring 4.5 out of 5. The new high-fibre cookie contains the most fibre (19.21 g/100 g), the fewest calories (424.6 Kcal/100 g), and the least fat (13.10 g/100 g).

Jyotsna *et al.* (2016) examined millet-based gluten-free muffin rheology, texture, quality, and immunochemical validation. The project aimed to produce gluten-free (GF) wheat flour muffins. WP:FM blends were 100:0, 95:5, 90:10, and 85:15. Peak, hot, and cold paste viscosities decreased from 0 to 15% mix WP concentration. The 90:10 muffin blend had the highest volume and quality ratings. Thus, the 90:10 blend was optimised. Additives improved muffin texture profiles by lowering hardness and increasing springiness. FM: WP 90:10, distilled glycerol monostearate, and hydroxypropyl methylcellulose enhanced muffin quality. Celiac disease patients can eat the GF muffins after immunochemical testing.

Jadhav *et al.* (2021) examined the physico-sensory and textural properties of composite millet palm jaggery (CMPJ) muffins produced by replacing all-purpose flour with CM (0:100, 50:50, 30:70) and cane sugar. Physico-sensory and texture profile analysis (TPA) was performed on CMPJ and cane sugar (APFS) muffins. Millet flour and wheat flour mixed 70:30 produced a muffin with good sponginess. Palm jaggery muffins had more moisture (21.84±0.01%) than sugar muffins (19.58±0.01%). Due to palm jaggery's brown colour, CMPJ muffins had more redness (9.18±0.07, 12.12±0.22) than APFS muffins (6.56±0.15, 10.61±0.15). Jaggery muffins showed higher water activity (aw) and lower pH and sensory score than sugar muffins. TPA revealed CMPJ (6270±7.2 g) was tougher than APFS (4729±4.7). CMPJ muffins were safe for 12 days without preservative after microbial investigation (Total plate count, Yeast and mould count). CMPJ muffins without preservative could replace APFS without impacting quality.

A promising bio-compound-rich fruit waste, raspberry and cranberry pomace powder, was tested in muffins by Bajerska *et al.* (2016).Quality was tested with raspberry and cranberry pomaces in American-style muffins baked under various conditions. Baking didn't affect control muffin texture or microstructure. Baking obtained 156, 53, 48, 43, and 22% ellagic acid, flavanols, tocopherols, tocotrienols, and anthocyanins. More than flavanols, tocopherols, and anthocyanins, elagic acid and tocotrienols held up at lower temperatures Improved samples result from muffins baked at 180°C for 20 min with optimal microstructure, texture, and phytochemical retention.

Mrabet *et al.* (2016) evaluated date fruit (Phoenix dactylifera l.) fibre concentration (DFC) muffins for quality and antioxidants. Due to poor commercial quality, Tunisian date varietals were underutilised. Steam pre-treatment yields DFC from these fruits. Bakery items used DFCs as antioxidant dietary fibre. 2.5 and 5% flour replacement muffins were made with DFCs from 165 and 180C treatments. DFC-doughs yielded muffins with a lower volume than the control. Despite lesser cohesion and springiness, DFC-165 muffins were softest. Samples shared proximal composition. DFC-muffins scored well in sensory evaluation and had more antioxidant capacity than the control. DFC-165 improves baked foods, however its effects on fat rancidity and staling delays need testing.

6. Shelf life studies of millet-based bakery products

To increase muffin quality and shelf life, Bhise and Kaur (2015) added psyllium husk, oat, and barley fibre. After adding 5, 10, 15, and 20% oat, psyllium, and barley fibres, muffins were stored at room and refrigerated conditions. With increasing fibre addition, muffin weight increased significantly. Sensory scores were higher for muffins with 10% oat, 10% psyllium, and 15% barley fibres. Under refrigeration, product flavour did not change when free fatty acid concentration (% oleic acid) rose. Control muffins stored under ambient conditions grew faster and showed higher growth than fibre-incorporated muffins. The highest acceptability scores were for muffins made with 10% psyllium fibre (8.37), 15% barley fibre (8.34), and 10% oat fibre (7.95). After fibre integration, muffins lasted 28 days at ambient conditions and 35 days in LLDPE packed refrigerated conditions, however sensory qualities changed after 35 days. Fibres improved muffin shelf life from 21 to 35 days.

Kaur *et al.* (2018) examined wheat flour and wheat atta germinated and ungerminated flaxseed muffins. This study baked muffins with germinated and ungerminated flaxseed flour. Wheat atta muffins and flour were made with 5, 10, 15, 20, 25, and 30% flaxseed meal. Flaxseed increased muffin volume and texture. Organoleptic and textural evaluations favour 15% ungerminated and 10% germinated flaxseed meal. To evaluate the best shelf life, muffins were packed in LLDPE and stored in room and refrigerated conditions for one month. Muffins lasted 15 days at 30±1°C and 1 month at 4-6°C.

7. Conclusions

Millets like foxtail and barnyard millet are valuable bread ingredients due to their nutritional content and functional characteristics. Foxtail millet had 12.3g/100g protein, 60.9g carbs, 2.8 mg/100g iron, 250mg/100g potassium, 15mg/100g folic acid, 66.5 mg/100g linoleic acid, vitamins, and minerals, and may have anti-carcinogenic, hypoglycaemic, and hypolipidemic properties. However, barnyard millet's high polyphenol and carotenoid content helps treat anaemia and lifestyle disorders. Barnyard millet has 6-13g protein, 55-65.5g carbs, 1.15-19.5mg iron, 280-340mg phosphate, 11-27.1mg calcium, and 3.8-4.5mg ash. Foxtail and barnyard millet flours can replace wheat flour in baking recipes to make healthier products. Millet flours increase protein, fibre, and antioxidant content in baked goods, as well as sensory qualities and customer acceptability.

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Table 1. Compositionof foxtail millet (values/100 g)

Parameter	Composition (per 100g)
Energy	331 (kcal)
Carbohydrates	60.9g
Crude fibre	8g
Fat	4.3g
Protein	12.3g
Thiamine	0.59mg
Niacin	3.2mg
Riboflavin	0.11mg
Vitamin A	32mg
Folic acid	15mg
Vitamin Bs	0.82mg
Vitamin E	31mg
Iron	2.8mg
Zinc	2.4mg
Magnesium	81mg
Sodium	4.6mg
Potassium	250mg
Cupper	I .4mg
Manganese	0.6mg
Palmitic	6.4mg
Stearic	6.3mg
Oleic	13mg
Linoleic	66.5mg
	Hasan *et al.* (2019**)**

Table 2. Composition of barnyard millet (values/100 g)

Nutrient	Composition (per 100g)
Protein	6 - 13 g
Carbohydrates	55 - 65.5 g
Fat	2 - 4 g
Crude fibre	9.5 - 14 g
Thiamine	0.30 mg
Riboflavin	0.09 mg
Calcium	11 - 27.1 mg
Iron	1.15 – 19.5 mg
Ash	3.8 -4.5 mg
Phosphate	280 - 340 mg
Zinc	2.6 – 4.75 mg
Manganese	1.33 – 3.13mg
Magnesium	82 mg

Singh *et al.* (2022)

Table 3. Amino acid composition of barnyard millet

Amino acid	Composition (mg / g)
Cystine	175 - 210 mg
Isoleucine	288 - 372 mg
Leucine	725 - 762 mg
Lysine	106 - 136 mg
Methionine	131 - 133 mg
Phenylalanine	175 - 210 mg
Threonine	35 – 263 mg
Tryptophan	63 mg
Tyrosine	119 - 150 mg
Valine	388 - 415 mg

Singh *et al.* (2022)

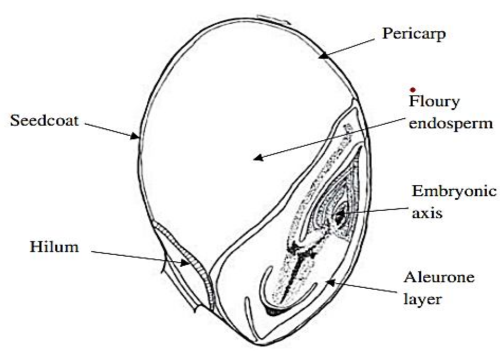

Figure 1. Longitudinal section of a foxtail millet grain

Figure 2: Barnyard millet (A) straw white, medium (B) light gray, bold (C) gray, medium, and