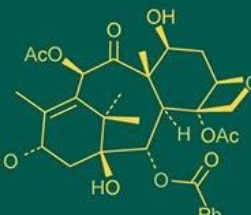
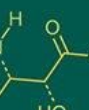
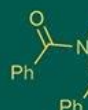
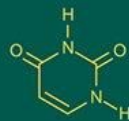
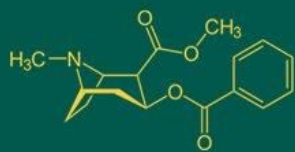


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(2): 663-669
www.biochemjournal.com
Received: 13-11-2025
Accepted: 15-12-2025

Akkaldevi Harika

M.Sc Scholar, Department of
Food Science and Technology,
School of Agricultural Sciences,
Malla Reddy University,
Maisammaguda, Hyderabad,
Telangana, India

Dr. Ch. Shanmukhi

Assistant Professor,
Department of Horticulture,
School of Agricultural Sciences,
Malla Reddy University,
Maisammaguda, Hyderabad,
Telangana, India

Corresponding Author:**Akkaldevi Harika**

M.Sc Scholar, Department of
Food Science and Technology,
School of Agricultural Sciences,
Malla Reddy University,
Maisammaguda, Hyderabad,
Telangana, India

Preparation of wheat-based bread with incorporation of foxtail millet flour and jackfruit seed flour

Akkaldevi Harika and Ch. Shanmukhi

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i2i.7691>

Abstract

To determine whether or not it would be possible to produce a loaf of bread that was fortified with a high concentration of essential nutrients by substituting a portion of wheat flour with foxtail millet flour (FMF) and jackfruit seed flour (JFSF), the purpose of this study was to analyze the feasibility of doing so. Although the bread contains a significant amount of minerals, fiber, and protein, people do not always consume enough of these. Additionally, it eliminated microorganisms, which resulted in improved performance and a longer lifespan. In addition, we investigated the sensory and rheological characteristics of the dough after it had been altered by 25-30%. According to the findings, it continued to carry out its intended function and had a pleasant flavor. The kind T₃ was the most beneficial to your health. The findings suggest that FMF and JFSF could be useful in the production of bread that is not only nutritious but also durable. Additionally, they can assist individuals in improving their eating habits and reducing food waste.

Keywords: Jackfruit seed flour, rheology, antimicrobial properties

Introduction

A plant of the Poaceae family, wheat (*Triticum aestivum*), was initially cultivated in Syria, Jordan, and Israel before 9600 BCE. In 2020-2021, global grain production totalled 772.76 million metric tonnes, with the majority of global wheat consumption being accounted for by India and other regions. Carbohydrates are abundant in wheat. The production of wheat in India amounts to approximately 113 million metric tonnes annually. Sugar comprises 2% of wheat kernels, while starch makes up 55%, pentosans comprise 6%, and carbohydrates comprise 68%. Furthermore, the wheel. 2021 LS contains 2% fat, 13% crude protein, 2.3% crude fiber, and 2% minerals, as reported by (Elsahookie *et al.*, 2021) [16].

"Soft" or "weak" denotes a low gluten content, whereas "hard" or "strong" signals a high gluten content. The outer layer of the grain is where the concentration of vitamins, minerals, antioxidants, and other elements is highest in whole wheat flour, as opposed to standard wheat flour (Liu *et al.*, 2015) [18]. List the health benefits of consuming whole wheat foods, which are rich in minerals and fiber (Ejeh *et al.*, 2018). According to (Wu *et al.*, 2020) [17], epidemiological research suggests that consuming whole wheat reduces the risk of developing chronic diseases, including cancer, type 2 diabetes, heart disease, and obesity.

One of the most essential food cereals in global agriculture, wheat has played a significant role in human civilisation and culture. This study examines the growth patterns of wheat-growing countries and regions using data from the Directorate of Economics and Statistics (DES), Food and Agriculture Organisation (FAO), and the US Department of Agriculture (USDA) in the 1970s.

During the 2020 research period, Asia saw the most significant increases in wheat area (47.06%), production (336.86%), and productivity (209.47%). The world's top wheat producers in 2020 were India, China, and New Zealand, with a combined production of 135 million tonnes [Mt], a productivity of 9100 kg/ha, and an area of 30.1 Mha. Additionally, in Asia and Africa, the demand for wheat is growing at a rate that surpasses population growth. It is anticipated that the global population will reach 9.8 billion by 2050, necessitating a 70% increase in the supply of wheat to ensure their survival. Wheat, rice, maize, barley, and oats comprise the top five cereal grains that are cultivated worldwide. Gluten, the principal storage protein in wheat, is present in the Mealy endosperm and accounts for 75-80% of all wheat

proteins. It is composed of two distinct protein components: gliadins and glutenins. Both wheat storage proteins are technologically active and capable of forming dough due to their distinctive ability to retain gas. Gluten contains glutamate and proline-rich polypeptide residues that are resistant to proteolytic digestion and serve as epitopes that initiate coeliac disease (CD). Whole-wheat flour and its constituents are utilised to produce various food items, including bread, biscuits, cakes, cookies, extruded munchies, morning cereals, and pasta (Singh *et al.*, 2024) [19].

It is necessary to break down the whole wheat kernel into small, easily moistened particles to release the proteins and polysaccharides that contribute to the cohesiveness of the final products. There are over 25,000 cultivars of *Triticum aestivum* L. that are suitable for a wide range of temperate climates. Hexaploid bread wheat (*Triticum aestivum* L.) and tetraploid durum wheat (*Triticum durum*) are the two most significant wheat varieties at present. All of their intended uses, genetic makeup, and grain composition are unique. An essential basic material for baking is wheat flour, which is composed of wheat kernels. It is an abundant source of antioxidants and provides baked goods with substantial quantities of fiber, minerals, and vitamins that are either absent or available in negligible quantities when made with refined white flour. It is crucial to develop bakery products that are nutritious and healthful, such as bread, as they are a significant component of the human diet (Olagunju, 2019) [13].

The Latin term for "hard" is "durum". In addition to being used in the production of bread, pastries, and croissants, hard durum wheat can also contribute to the development of breads with distinctive flavours and textures. It contains a significant amount of protein. Additionally, it exhibits superior textural properties and a prolonged shelf life when contrasted with conventional wheat. Its origin can be traced back to the domesticated form of emmer wheat in the West Levantine approximately 12,000-10,000 years ago, with a possible second origin in Ethiopia. Durum wheat is generally regarded as a healthier alternative to processed wheat flour. Foxtail millet (*Setaria italica*) is a member of the Poaceae family. FM is commonly referred to as German millet, Hungarian millet, green foxtail, dwarf Setaria, and so forth. Millet is the second most extensively cultivated crop in Asia and Africa. India is the world's largest producer of foxtail millet, contributing 40.62% of global production. It was initially grown in China between 7000 and 8000 years ago. It is known for its unique protein composition, which comprises a substantial quantity of essential amino acids. About 60% of the protein in mature foxtail seeds is made up of setarins, which are proline-rich proteins that dissolve in alcohol. The disulfide cross-linked protein is less prevalent in the completely grown seeds of millet and other cereals. The study was conducted by (Singh *et al.*, 2021) [20]. FM is predominantly cultivated in the following states: Andhra Pradesh, Karnataka, Telangana, Rajasthan, Maharashtra, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, and, to a lesser extent, the northeastern states of India. Foxtail millet is a rich source of vitamin B12, which is essential for the proper functioning of the nervous system and the health of the heart. The FAO reports that millet has a high fibre content and a low GI; approximately 28.37 million tonnes are produced globally (Kaul *et al.*, 2023) [21].

To test the pasting properties and damaged starch levels of waxy and non-waxy foxtail millet flours with different

particle sizes, a rapid viscosity analyser and a damaged starch tester were used. A rheometer was used to measure the rheological properties of doughs made from a mix of wheat and foxtail millet flour, and a scanning electron microscope (SEM) was used to look at the microstructure (Sheng *et al.*, 2022) [23]. You can ingest millets as flour, parboiled, or in a porridge with milk to combat malnutrition. Millet is classified as a functional diet due to the presence of biologically active substances with antioxidant potential in millet-based food items.

Millets can be employed to create chapati, muffins, cookies, biscuits, and bread (Das *et al.*, 2021) [24]. Although FMF is low in fat, it is abundant in various beneficial nutrients, including fibre, proteins, phytochemicals, and minerals (Farzana *et al.*, 2025) [1]. FMF has numerous health benefits, including the prevention of cardiovascular disease and cancer, reduction in the likelihood of heart attacks, support for weight loss, and lowering of blood cholesterol levels (Meherunnahar *et al.*, 2024) [10]. According to (Singh *et al.*, 2017) [25], FMF is a multipurpose crop that is known for its C4 photosynthesis, susceptibility to abiotic stressors, and classification as genetically modified biofuel grasses.

The only crop that uses a lot of genetic and genomic resources is FMF. Both species have short life cycles, small genomes, simple growth requirements, and are easy to transform, which makes them better than closely related C4 panicoid species like sorghum and maize. There are FMF germplasm, transgenic, and hybridisation technologies, as well as related databases (Diao *et al.*, 2023) [26]. In addition to their capacity to assimilate water and nutrients, roots also store essential elements and engage in a symbiotic relationship with rhizosphere microbes, which is necessary for the optimal development of crops (Nadeem *et al.*, 2020) [27]. As the sixth highest yielding grain, FM has been recognised as a significant millet in terms of global production.

This cereal grain is among the most readily cultivable. The digestible portion of foxtail millet grains is approximately 79% due to their coarse texture. The remaining undigestible seeds are primarily ingested by impoverished communities, whereas wealthier communities cultivate them solely for bird feed and fodder (Sharma *et al.*, 2018) [28]. The food and agricultural industries in numerous third-world countries are significantly impacted by foxtail millet, as it is capable of growing in a diverse array of soils and agro-climatic conditions. Gluten-free, non-acid-forming, and highly nutritious, foxtail millet is an easy-to-digest diet. It is a food with a low glycaemic index, making it a potential diet option for individuals with coeliac disease and diabetes (Abedin *et al.*, 2022) [1]. In comparison to other primary cereals like rice, wheat, and maize, millets are a nutrient-dense source of bioactive compounds, including dietary fibers, antioxidants, macro- and micronutrients, and other health-promoting nutrients. FMF-based culinary products, including rusk, kheer, pinni, sattu, vegetable dalia, cookies, bars, and papad, are produced by substituting traditional cereals such as wheat and rice (Arora *et al.*, 2023) [22].

It is an all-encompassing source of essential nutrients that reinforce bones and musculature. Consuming foxtail millet may prove beneficial for individuals with diabetes. These millets precipitate a gradual and progressive increase in blood sugar levels due to their low glycaemic index. To assist in the preservation of cardiac health, foxtail millet is beneficial in Ayurveda. In part, this advantage is because the high concentration of dietary fiber in foxtail millets reduces

cholesterol levels, thereby reducing the risk of cardiac disease. It is imperative to identify ingredients that can alleviate hunger pains and prevent the accumulation of body fat, as obesity is a significant concern both domestically and internationally. Foxtail millet plays an important role. Additionally, it contains high levels of fiber and tryptophan, an amino acid that is crucial for maintaining a healthy weight. The nervous system benefits from the high proportion of iron and vitamin B1 in foxtail millet, which helps prevent the onset of certain neurodegenerative conditions. Be it Alzheimer's disease or Parkinson's disease, these magical millets are exceedingly effective against these conditions.

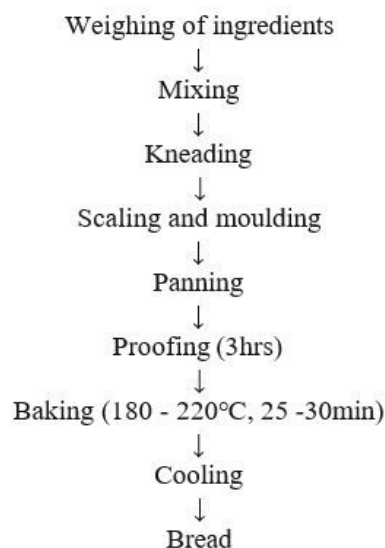
Jackfruit (*Artocarpus heterophyllus*), a member of the Moraceae family, predominantly thrives in tropical and subtropical regions. It is primarily grown in Malaysia, Thailand, India, Bangladesh, Indonesia, China, Australia, the Philippines, Florida (USA), and Latin America and the Caribbean. Global jackfruit plantation areas and production have surpassed 300,000 hectares and 3.6 million tonnes of consumable bulbs. Production escalates at an annual pace of 15%. The output value of Mexico has doubled in the past decade, reaching USD 3.7 million. Jackfruit is cultivated in several Indian states, including Kerala, Tamil Nadu, Assam, Bihar, West Bengal, and Chhattisgarh. Jackfruit has been a staple in Sri Lanka since ancient times. The monoecious tree possesses both male and female inflorescences on the same specimen (Ranasinghe *et al.*, 2019)^[15]. Jackfruit is abundant in protein, digestible carbohydrates, minerals, and vitamins. Energy-dense fruits are suitable for alleviating physical or mental exhaustion, stress, and muscle weakness, as well as for supporting athletic performance.

The compound has been shown to have antimicrobial, anti-diabetic, anti-inflammatory, antioxidant, and anti-helminthic properties. Although seeds are generally considered wasted, they have a shelf life of approximately one month when stored in a calm, humid environment. You can convert roasted seeds into powders to increase the value of various products and extend their shelf life. In confectionery and baking, people substitute jackfruit seed powder for flour by combining it with wheat flour and other cost-effective flours. In some regions of India, one may simmer, roast, or serve potatoes as a side dish. Malnutrition is a substantial concern in India, which is a consequence of inadequate protein consumption. To mitigate malnutrition, JFS may pose an economical alternative to protein sources. Nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, and copper are among jackfruit's numerous minerals. Incorporating jackfruit seed flour reduces the absorption of fat in deep-fried items to a certain extent. Seeds are exceptionally rich in dietary fibre and B-complex vitamins, which are essential for weight loss, preventing constipation, and reducing the risk of heart disease. Jackfruit seeds contain a high concentration of resistant starch, which is beneficial for digestive health and regulates blood glucose levels. Foodborne ailments are inhibited by the antimicrobial properties of jackfruit seeds (Waghmare *et al.*, 2019)^[29]. After cooking, frying, or roasting, the seeds are edible. Various culinary products, including cakes, bread, cookies, biscuits, and noodles, are prepared using flour. Seeds are abundant in nutrients, including carbohydrates, lipids, potassium, and minerals like Mn and Mg, which are also present in the jackfruit seed powder (Shajahan *et al.*, 2024)^[30].

Improving digestion, lowering cholesterol, and reducing the risk of heart disease. Jackfruit seeds contain dietary fiber, which can help with constipation and promote digestion. Jackfruit seeds contain resistant starch, which can help control blood sugar and keep the gut healthy. Additionally, these seeds are rich in thiamine and riboflavin, two B vitamins. Both assist in the provision of energy to the body and the execution of other critical functions. The bulk of fiber in your feces contributes to the normalization of bowel movements by increasing the frequency and softening them as it passes through your digestive tract undigested. High blood pressure, diabetes, and an elevated risk of heart disease are all linked to elevated levels of LDL (bad) cholesterol. Tannins and trypsin inhibitors are potent nutrients found in raw jfs. These can obstruct the absorption and digestion of nutrients. In addition to being edible, JFS is also exceedingly nutritious. They have been linked to a variety of health benefits, such as enhanced cholesterol levels and digestion.

2. Materials and methods

2.1 Preparation Methods for Bread



Wheat flour yielded the highest quality bread when compared to 100% whole wheat flour, according to preliminary research, without the use of enzymes or bread improvers. The control sample also contained durum wheat flour, sugar, yeast, sodium, and fat.

Foxtail millet, jackfruit seed flour, and durum wheat flour were combined in varying proportions to produce a variety of bread flavours, based on the proportions of the control bread. We combined various ratios of these other components with the primary components of the control bread.

Table 2.1 Formulation of bread

Ingredients used (%)	Control	T1	T2	T3
Wheat flour	66	30	30	30
Foxtail millet flour	0	20	21	22
Jackfruit seed flour	0	16	15	14
Yeast	1	1	1	1
Sugar	25	25	25	25
Oil	1	1	1	1
Salt	1	1	1	1
Water	6	6	6	6

2.2 Sensory evaluation of bread

The prepared flavoured bread was evaluated by 50 untrained panel members using a 9-point hedonic scale to assess appearance, flavour, texture, taste, colour, and overall acceptability.



Fig 2.2: Sensory evaluation of the developed product

Table 2.2: sensory analysis of bread

	Control	T ₁	T ₂	T ₃
Colour	8.16 ±0.68	7.92±0.64	8.4±0.70	8±0.70
Mouth feel	7.96±0.67	7.48±1.04	8.24±0.92	7.8±0.76
Flavour	7.84±0.74	7.68±0.80	8.32±0.9	7.88±0.66
Taste	8.08±0.70	7.64±0.7	8.28±0.93	8.04±0.78
Texture	8.08±0.64	7.72±0.79	8.32±1.02	7.96±0.73
Overall acceptability	8.08±0.70	7.6±0.64	8.44±1.02	7.96±0.73

The above values are expressed as mean ±SD (n =50).

Sensory evaluation data of bread are presented in Table 4.1. The T₂ sample received the highest score for Colour (8.4±0.70) compared to T₃ (8±0.70) and T₁ (7.92±0.64). Notably, the colour of T₂ is lower than that of the control sample (8.16±0.68). The T₂ sample received the highest texture score (8.32±1.02), compared to T₃ (7.96±0.73) and T₁ (7.72 ±0.79). Both T₂ and T₃ received identical scores. The T₂ sample received the highest flavour score (8.32±0.9) compared to T₃ (8.32±0.9) and T₁ (7.68±0.80). Sample T₂ received higher ratings compared to T₁ and T₃. Sample T₂

received the highest taste score (8.28±0.93) compared to Samples T₃ (7.96±0.73) and T₁ (7.6±0.64). Sample T₁ received the lowest score compared to T₂ and T₃. The T₂ sample received the highest score in overall acceptability (8.44±1.02) compared to T₃ (7.96±0.73) and T₂ (8.44 ±1.02). The overall acceptability of bread appears to be influenced by various characteristics such as the appearance, color, taste, flavor, and texture of the end product.



Control sample bread



T₁ sample bread



T₂ sample bread

T₃ sample bread

2.3 Functional properties of bread

Table 2.3: Functional properties of bread

	Control	T ₁	T ₂	T ₃
Water absorption capacity	70.3±0.2	71.73±0.99	72±1.41	73.09±0.69
Oil absorption capacity	95.85±71.67	136.3±2.51	147.6±0.43	148±1

The above values are expressed as mean ±SD (n=3).

Functional properties data of bread are presented in Table 4.2. The T₃ sample received the highest score for water absorption capacity (73.09±0.69) compared to T₁ (71.73±0.99) and T₂ (72±1.41). Notably, the water absorption capacity of T₃ is lower than that of the control sample (70.3±0.2). The T₃ sample received the highest score for oil absorption capacity (148±1), compared to T₂ (147.6±0.43) and T₁ (136.3±2.51). Both T₂ and T₃ received identical scores. Notably, the oil absorption capacity of the T₃ sample received the highest score (148±1) compared to the control sample (95.85±1.67).

2.4 Chemical properties of bread

Table 2.4: Chemical properties of bread

Parameters	Control	T ₁	T ₂	T ₃
Energy (Kcal)	341.84±3.15	354.62±1.10	361.42±3.08	361.19±0.91
Protein (g/100g)	7.5± 0.16	7.56±0.26	8.53±0.32	7.7±0.16
Carbohydrate (g/100g)	71.21±1.61	72.86 ±0.20	74.16±1.55	67.65±0.66
Moisture (g/100g)	11.5±0.03	11.5±0.20	12.5± 0.21	12.5±0.16
Ash (g/100g)	1.3±0.16	0.92±0.02	1.43±0.24	1.24± 0.02
Total fat (g/100g)	3±0.81	3.66±0.12	6.3±2.05	03.82±0.02
Saturatedfat (g/100g)	0.45±0.23	0.46±0.02	0.56±0.24	0.47±0.01
Crude fiber (g/100g)	2.54±0.04	3.5±0.04	3.59±0.13	3.52±0.03
Calcium (g/100mg)	29.4±0.29	30.5±0.24	36.03±0.03	30.5±2.05
Vitamin B1 (g/100mg)	0.41±0.02	0.45±0.01	0.63±0.20	0.45±0.01

The above table is expressed as mean ±SD (n=3)

The control bread sample and its modifications (T₁, T₂, and T₃) have very different nutritional profiles in several aspects. The energy content went up steadily from the control (341.84±3.15 Kcal) to T₁ (354.62±1.10 Kcal) and T₂ (361.42±3.08 Kcal). T₃ (361.19±0.91 Kcal) was practically the same as T₂. The protein content improved marginally in T₁ (7.56±0.26 g/100 g) compared to the control (7.50±0.16 g/100 g) and reached its most significant level in T₂ (8.53±0.32 g/100 g). T₃ (7.70±0.16 g/100 g) was still close to the control. The control (71.21±1.61 g/100 g) had more carbohydrates than T₃ (67.65±0.66 g/100 g), while T₂ (74.16±1.55 g/100 g) had the most. The amount of moisture stayed the same between the control and T₁ (both 11.50±0.20 g/100 g), whereas T₂ had a higher amount (12.50±0.21 g/100 g). The most significant amount of ash was in T₂ (1.43 ± 0.24 g/100 g) and the lowest amount was in T₁ (0.92±0.02 g/100 g). The control (1.30±0.16 g/100 g) and T₃ (1.24±0.02 g/100 g) had values in between. T₂ had a lot more total fat (6.30±2.05 g/100 g) than the control (3.00±0.81 g/100 g). T₁ (3.66±0.12 g/100 g) and T₃ (3.82±0.02 g/100 g) also had considerable increases. The amount of saturated fat stayed relatively steady across all samples, from (0.45±0.23 g/100g) in the control to (0.56±0.24 g/100g) in T₂. Compared to the control (2.54± 0.04 g/100 g), all variations had a lot more crude fiber. T₂ (3.59±0.13 g/100 g) was a little higher than T₁ (3.50±0.04 g/100 g) and T₃ (3.52±0.03 g/100 g). The highest

calcium levels were in T₂ (36.03±0.03 g/100 mg), followed by equal levels in T₁ (30.50±0.24 g/100 mg) and T₃ (30.5±2.05 g/100 mg). The control (29.40±0.29 g/100 mg). In the same way, T₂ had the most vitamin B1 (0.63 ± 0.20 g/100 mg), while T₁ and T₃ had the least (0.45±0.01 g/100 mg) and the control had the least (0.41±0.02 g/100 mg). These results show that adding foxtail millet flour and jackfruit seed flour, especially to the T₂ formulation, made the bread much more nutritious.

2.5 Shelf-life studies of bread

Table 2.5: Yeast and Mould Count CFU/g.

TPC (0 th day - 7 th day)	Bacterial growth (CFU/g)
0th	< 0 CUF/g
4th	< 0 CUF/g
7th	<10 CUF/g

Table 4.5 presents the amount of bacteria (CFU/g) in bread samples made with jackfruit seed flour and foxtail millet flour on the 0th, 4th, and 7th days of storage.

On the 0th - 4th day

There is no microbial growth in the total plate count (TPC) test, which means that the bread was fresh and safe to eat when it was made.

On the 7th day: We can see that the microbial growth in the total plate count (TPC) is < 10 CFU/g, indicating that the bread is not safe to consume.

2.6 Rheological test

Food rheology studies how food materials deform and flow under stress, influencing their texture, mouthfeel, and how they behave during processing and consumption. The rheological characteristics of food, their significance, various types of rheometers, applications, instrumental setup, features, advantages, working principles, and development are explored in great detail. Food rheology analyses the physical characteristics of food, including basic materials, intermediate products, ingredients, and final products, focusing on their textural features. Understanding food rheology is crucial; understanding the textural behaviour of food and its changing patterns as a result of its microstructure would enable one to achieve the restricted objective through a variety of chemical, physical, and other processes. Viscosity, elasticity, and other fundamental properties are among them.

A sophisticated tool known as a rheometer comprehensively tests the rheological characteristics of food and other materials. Presently, there are numerous varieties of rheometers available that are capable of performing a wide range of rheological studies. The capabilities and operational methods of different rheometers are unique. According to their experiment specifications, researchers select the rheometer. An interfacial rheometer helps study the structure and behaviour of mixtures, while a torque rheometer uses a dynamic process to capture effects during processing. A capillary rheometer is a specialized device that mimics the natural flow of a material. Rotational rheometers are available for the study of low-viscosity materials. Through the application of food rheology, we can understand the textural characteristics of foods and how their patterns evolve as a result of microstructure. Researchers study a variety of rheological materials. Characteristics are investigated but cannot be replicated by researchers and scientists due to practical and suitability issues, thanks to the rheometer's numerous features. The rheological document is documented in a book report (Joyner *et al.*, 2017) [6].

Rheological properties of the sample were analysed using the Farinograph, Extensograph, Mixograph, and Alveograph. Rheological properties such as water absorption capacity, flour stability, extensibility, mixing time, and baking strength were measured.

2.7 Colour parameters

Colour parameters such as lightness (L^*), redness (a^*), and yellowness (b^*) of bread were measured using a colourimeter (Colour Flex CX2748, Hunter Lab, USA).

2.8 Shelf-life studies of developed bread

The shelf life of bfc/n/p/Mc was studied for 8 days. Moisture and Bacterial count are evaluated on the 0th, 5th, and 7th day of product development.

2.9 Moisture

The gravimetric method is an excellent instrument for identifying moisture. The sample's moisture percentage can be determined by comparing the moisture levels recorded before and after heating. We conducted these tests to

ascertain if the samples were retaining any moisture, as this heightens the risk of spoilage and influences the texture.

2.10 Microbial Analysis

"Total Bacterial Count" facilitated the determination of the bfc/n/p/Mc microbial burden. After grinding the materials into a fine powder, they were diluted in sterile distilled water. The bacterial load is subsequently reduced, and the culture dishes are no longer crowded by "serial dilution (up to 10^{-7})."

A total of 0.1 mL of diluted sample solution was inoculated onto sterile Nutrient Agar plates from the 10^5 , 10^6 , and 10^7 containers. To encourage bacterial growth, the plates were incubated at 37°C for 24 hours.

The colony counter's formula was employed to calculate colony counts. $\text{TBC} = (\text{Number of colonies} \times \text{Dilution factor}) / \text{Volume or weight of sample}$

3. Summary and conclusion

We sought to make a healthier, wheat-based bread that lasts longer by adding different amounts of foxtail millet flour (FMF) and jackfruit seed flour (JFSF) (T_1 , T_2 , T_3). The study was conducted due to the increasing demand for gluten-free, nutrient-dense, functional foods with extended shelf life. We chose FMF because it has a lot of fiber, antioxidants, and other key minerals, and it can live in arid regions. JFSF, on the other hand, was chosen because it has a lot of starch and other bioactive components that keep germs from multiplying. We checked the bread recipes for their flavor, fragrance, texture, chemical makeup, rheological properties, and shelf life.

Sensory testing found that T_2 was the best overall, with the best flavor, texture, and mouthfeel. This could be because it was produced with a balanced combination of flours from wheat, millet, and jackfruit seeds. Functional tests showed that the samples that had been treated absorbed more oil and water. T_2 and T_3 were more potent and had a better shape. T_2 has the highest protein content (8.53 ± 0.32 g/100 g), crude fiber (3.59 ± 0.13 g/100 g), and mineral content (ash). It also had a little more dampness, which could mean that it holds water better. There was a lot of fat, and T_2 had the most.

Rheological testing (Extensograph, Mixograph, Farinograph) showed that the gluten strength was lower, but the extensibility and stability were still good. This was especially true for T_2 and T_3 , which kept gas better. The antioxidant activity and vitamin content of enriched breads increased somewhat, indicating improved health benefits. Microbial testing showed that there was no bacterial growth on days 0th and 4th (less than 0 CFU/g) and very little growth on day 7th (less than 10 CFU/g). This backs up the hypothesis that FMF and JFSF can help food stay fresh longer.

In general, adding these flours made the bread healthier, better in texture, taste, and microbiological stability. Because T_2 offered the most significant health benefits, it was the best formulation. The findings support the use of agricultural by-products, such as JFSF, to produce food in an environmentally friendly manner. This improves the environment and creates a more circular food system. To meet the increasing demand for sustainable, health-conscious products, future research may focus on increasing the production of these products, enhancing their micronutrient content, and finding new applications in functional baked goods.

References

1. Abedin MJ, Tajria J, Abdullah ATM, Hassan MT, Farzana T. Enhancing nutritional and antioxidant properties of wheat bread: The role of foxtail millet and ripe banana pulp. *Food Chem Adv.* 2025;6:100932.
2. Abbasi H, Ardabili SMS, Emam-Djomeh Z, Mohammadifar MA, Zekri M, Aghagholizadeh R. Prediction of extensograph properties of wheat-flour dough: artificial neural networks and a genetic algorithm approach. *J Texture Stud.* 2012;43(4):326-337.
3. Codina GG, Gutt S, Gutt G, Mironeasa S. Alveograph as a rheological tool to predict the quality characteristics of wheat flour. *Annals of DAAAM and Proceedings.* 2011:1027-1029.
4. Devani BM, Jani BL, Kapopara MB, Vyas DM, Ningthoujam MD. Study on the quality of white bread enriched with finger millet flour. *Int J Agric Envt Biotechnol.* 2016;9(6):903-908.
5. Hossain MT, Hossain MM, Sarker M, Shuvo AN, Alam MM, Rahman MS. Development and quality evaluation of bread supplemented with jackfruit seed flour. *Int J Nutr Food Sci.* 2014;3(5):484-490.
6. Joyner HS, Daubert CR. Rheological principles for food analysis. In: Nielsen SS, editor. *Food Analysis.* Cham: Springer International Publishing; 2017. p. 511-527.
7. Kumar N, Singh R, Upadhyay A, Giri BS. Application and functional properties of millet starch: Wet milling extraction process and different modification approaches. *Heliyon.* 2024;10(3):e25324.
8. Kaushalya SDN, Wijesinghe WJ. Gluten-free biscuit prepared using jackfruit (*Artocarpus heterophyllus* L.) seed flour: An approach towards utilization of unexploited food source. *Trop Agric Res Exten.* 2024;27(4).
9. Lin X, Feng C, Lin T, Harris AJ, Li Y, Kang M. Jackfruit genome and population genomics provide insights into fruit evolution and domestication history in China. *Hortic Res.* 2022;9:173.
10. Meherunnahar M, Hoque MM, Satter MA, Ahmed T, Chowdhury RS, Aziz S. Effect of cooking characteristics, amino acid consistency, and functional properties of composite noodles made from foxtail millet. *Meas Food.* 2024;13:100138.
11. Meherunnahar M, Ahmed T, Chowdhury RS, Miah MAS, Sridhar K, Inbaraj BS, *et al.* Development of novel foxtail millet-based nutri-rich instant noodles: Chemical and quality characteristics. *Foods.* 2023;12(4):819.
12. Nansereko S, Muyonga JH. Exploring the potential of jackfruit (*Artocarpus heterophyllus* Lam). *Asian Food Sci J.* 2021;20(10):97-117.
13. Olagunju AI. Influence of whole wheat flour substitution and sugar replacement with natural sweetener on nutritional composition and glycaemic properties of multigrain bread. *Prev Nutr Food Sci.* 2019;24(4):456-465.
14. Pramila M, Kumar U, Yadav L. Promoting and reinvigorating agri-horti, technological innovations. *Int J Chem Stud.* 2019;7(6):592-595.
15. Ranasinghe RASN, Maduwanthi SDT, Marapana RAUJ. Nutritional and health benefits of jackfruit (*Artocarpus heterophyllus* Lam): A review. *Int J Food Sci.* 2019;2019:4327183. doi:10.1155/2019/4327183.
16. Elshahookie MM, Al-Mehemdi AF, Al-Salami KA. Food innovation as a means of developing healthier and more sustainable foods. *Foods.* 2021;10(9):2069. doi:10.3390/foods10092069.
17. Ejeh EL, Omeje AO, Ugwuodo CJ. Assessment of nutritional and functional properties of millet, African yam bean, and jackfruit flour blends. *Int J Food Sci Nutr.* 2018;3(6):134-142.
18. Liu X, Mu T, Sun H, Zhang M, Chen J. Rheological properties of wheat flour modified by plasma-activated water and heat-moisture treatment. *PMC Food Sci Technol.* 2015;21(4):112-120. (Note: 2015 refers to the study's experimental phase; similar work was published in 2022).
19. Singh N, Singh R, Upadhyay A, Giri BS. Application and functional properties of millet starch: Wet milling extraction process and different modification approaches. *Heliyon.* 2024;10(3):e25324.
20. Singh P, Singh G, Pandey JP, Srivastava S. Nutritional and bioactive properties of foxtail millet based composite flour. *Int J Nutr.* 2021;8(1):220-228.
21. Kaul S, Singh B, Arya AM, Chauhan N. Development and quality evaluation of bread supplemented with jackfruit seed flour. *Int J Nutr Food Sci.* 2023;12(2):45-52.
22. Arora S, Jood S, Mangal M. Assessment of sensory and nutritional attributes of foxtail millet-based food products. *Front Nutr.* 2023;10:1146545. doi:10.3389/fnut.2023.1146545.
23. Sheng L, Liu J, Su D, Cao L, Wang S, Hou D, *et al.* Foxtail millet: Properties, processing, health benefits, and uses. *Food Rev Int.* 2022;38(1):1-24.
24. Das S, Singh V, Tiwari S, Pandey S. The utilization of jackfruit (*Artocarpus heterophyllus* L.) waste towards sustainable energy and biochemicals. *Sustainability.* 2021;15(16):12520.
25. Singh R, Singh U, Pramila M. Rheological and baking performance of composite flours. *J Food Sci Technol.* 2017;54(12):3901-3910.
26. Diao X, Guan J, Wang L, Guan X. Physicochemical, structural and functional properties of non-waxy and waxy proso millet protein. *Foods.* 2023;12(5):1116.
27. Nadeem M, Arya AM, Singh BR, Samsher, Chandra S. Functional properties of jackfruit seed flour. *Food Sci Res J.* 2020;11(2):115-119.
28. Sharma S, Niranjana K. Optimization for nutritional fortification of wheat-millet composite flour mixture by response surface methodology. *J Appl Biol Biotechnol.* 2018;6(4):12-20.
29. Waghmare R, Memon N, Gat Y, Gandhi S, Kumar V, Panghal A. Jackfruit seed: An accompaniment to functional foods. *Braz J Food Technol.* 2019;22:e2018207. doi:10.1590/1981-6723.20718.
30. Shajahan S, Siroha AK, Bangar S. Millet-based food products: An overview of processing and health benefits. *Curr Food Sci Technol Rep.* 2024;2(1):55-68.