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Study on the effect of germination on the nutritive value of finger millet-cum-wheat for developing bread

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ABSTRACT

Background: Germinated breads are highly valued for their nutritional benefits, gluten-free properties, digestive advantages, weight management potential, ability to prevent cardiovascular diseases, sustainability, and versatility in cooking.

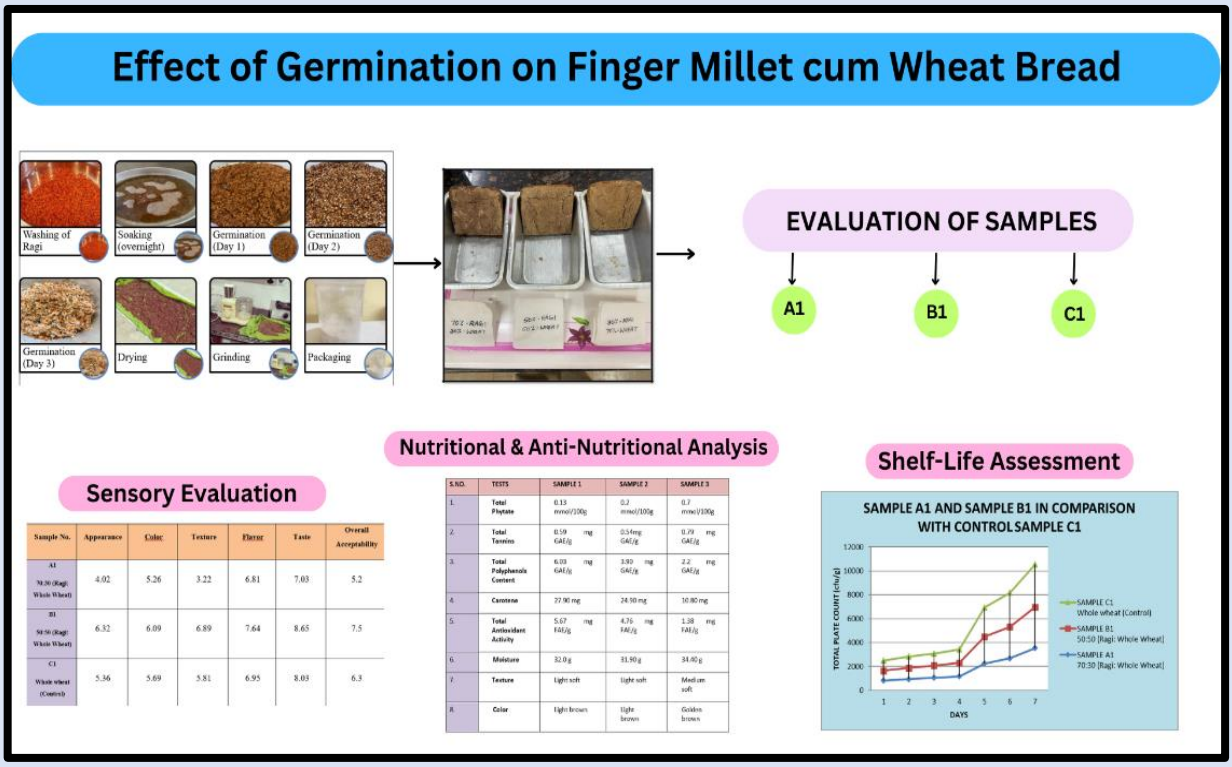
Objective: This study aims to determine how germination affects the nutritional value, consumer acceptability, and shelf-life of finger millet and wheat-based bread.

Methods: The study developed and analyzed various germinated finger millet-based bread compositions through sensory evaluation, nutritional and anti-nutritional analysis, and shelf-life assessment.

Results: Sample A1, which had a ratio of 70% ragi and 30% wheat flour, had the highest levels of calcium (72 g), protein (14.5 g), carbohydrates (58 g), iron (3.3 mg), zinc (29 mg), dietary fiber (11.4 g), potassium (156 mg), carotene (27.9 mg), total antioxidant activity (5.67 mg FAE/g), and total polyphenols content (6.03 mg GAE/g) but sample B1 contained the highest percentage of fat (4.5g). Sample A1 also contained lower levels of anti-nutritional factors like total phytate content (0.7 mmol/100g) and total tannin content (0.79 mg GAE/g) compared to sample B1 and the control sample. The control sample had the highest amount of anti-nutrients. The study also assessed the microbial shelf life of the bread at different temperatures and found that the developed finger millet-based bread had a shelf life of eight days at 15°C.

Conclusion: This study shows the significant impact of germination on the nutritional composition of finger millet, a novel and promising finding. Germination leads to reduced antinutritional content due to the leaching out of tannins and degradation of phytic acid, thereby enhancing the nutritional value of the bread.

Keywords: Germination, Finger Millet, Bread, Finger millet-cum-wheat-based, Wheat, Shelf life, Consumer acceptability, gluten free



INTRODUCTION

The general word "millets" refers to a stray group of forage grasses distinguished by its tiny grains. Since millets are C4 photosynthetic plants, they are primarily grown in semi-arid regions of Asia and Africa. Because of their ability to thrive in low moisture, high temperatures, and nutrient-poor soils, millets are believed to be resistant to the effects of climate change [1]. Millets, a functional food, also have various notable qualities in improving human health, including excellent nutritional value [2-3] (Refer Table 1), low susceptibility to diseases, and tolerance to salinity and drought. Millets are the perfect staple crop for an expanding population because they have a shorter life cycle than other types of crops species. Of these, most important millets such as pearl millet (Pennisetumglaucum), finger millet (Eleusinecoracana), proso millet (Panicummiliaceum), and foxtail millet (Setariaitalica) belong to the Eragrostideae tribe. In contrast, other minor millets namely fonio (Digitariaexilis), kodo millet (Paspalumscrobiculatum) and tef (Eragrostistef) belong to the Paniceae tribe [4]. Millets are among the earliest foods consumed by humans and may have been the first cereal grain used in a domestic setting. Small-seeded millets are hardy, rain-fed crops that thrive in dry regions

and grow well in harsh conditions of low soil fertility and moisture. Millets are distinctive in part because of their brief growing season. They can grow from seeds planted to fully grown, harvestable plants in as little as 65 days. Particularly in densely populated areas, this is crucial. Whole millets can be kept for two or more years when properly stored. Along with the staples of wheat, rice, and maize, millet is a type of cereal. Millions of people worldwide, particularly those who live in hot, dry climates, rely heavily on millets as a food source. They are primarily grown in rural, marginal areas where major cereals don't produce significant yields [5]. According to Yang et al. (2012) [6], millets are classified in the grass subfamily Panicoideae along with maize, sorghum, and Coix. Millets are a staple food in many developing nations due to their resilience to challenging environmental factors like little rainfall. For millions of people in Africa, on the other hand, millet serves as their primary source of protein and energy. Millet has a variety of nutritive and therapeutic uses, according to reports [6-7]. Millets are a special type of biodiversity that millions of subsistence farmers in places like Sub-Saharan Africa depend on for their agriculture and food security. Although India is the world's largest producer of pearl millet, it is a staple food throughout the Sahel [8]. Millets are frequently made into flour, formed into large balls, parboiled, and then served with milk. Millets are also occasionally made into drinks. The primary food of farmers in Gujarat, India, has been roti made from pearl millet [9]. It is crucial to investigate plants like millets that are grown locally and consumed by low-income households in regions like India and the Sahel zone because there is an emerging need for the world to feed its expanding population [10]. Most African countries still include cereals, particularly millet-based foods and beverages, in their staple diets [7,11].

Table 1 Nutritional composition of finger millet per 100 g edible portion

S. NO.	NUTRIENTS	RAGI MILLET	RICE	WHEAT
1	Carbohydrates (g)	72.6	78.2	71.2
2	Protein (g)	7.7	6.8	11.8
3	Fat (g)	1.5	0.5	1.5
4	Crude fiber (g)	3.6	5.2	12.9
5	Ash (g)	2.7	0.6	1.5
6	Calcium (mg)	344	10	41
7	Phosphorus (mg)	250	160	306
8	Iron (mg)	6.3	0.5	3.9
9	Manganese (mg)	3.5	1.0	13.3
10	Magnesium (mg)	130	32	120

*Source: Chandra et al. (2018) [12]

MATERIALS AND METHODS

Procurement of ingredients: Finger millet grains and other ingredients such as yeast, salt, and black pepper were purchased from the local market of Chandigarh, India.

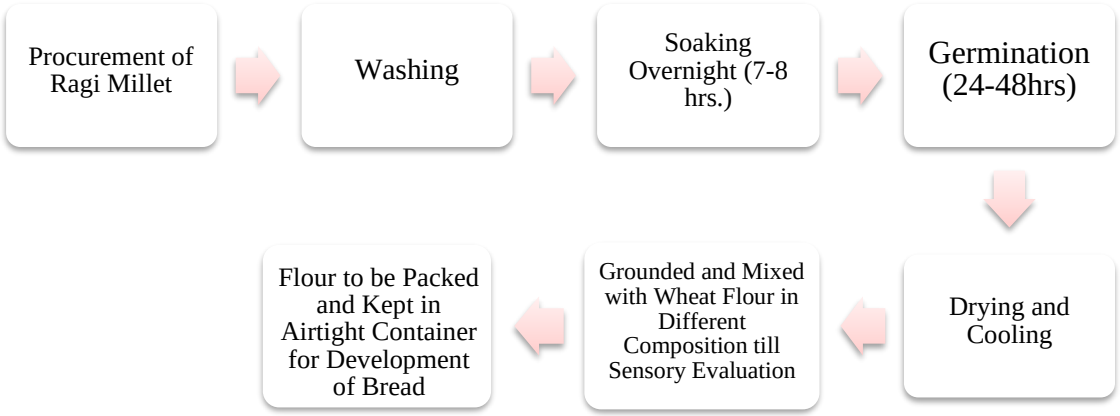


Figure 1 Methodology for preparation of germinated finger millet-based flour for preparation of bread.

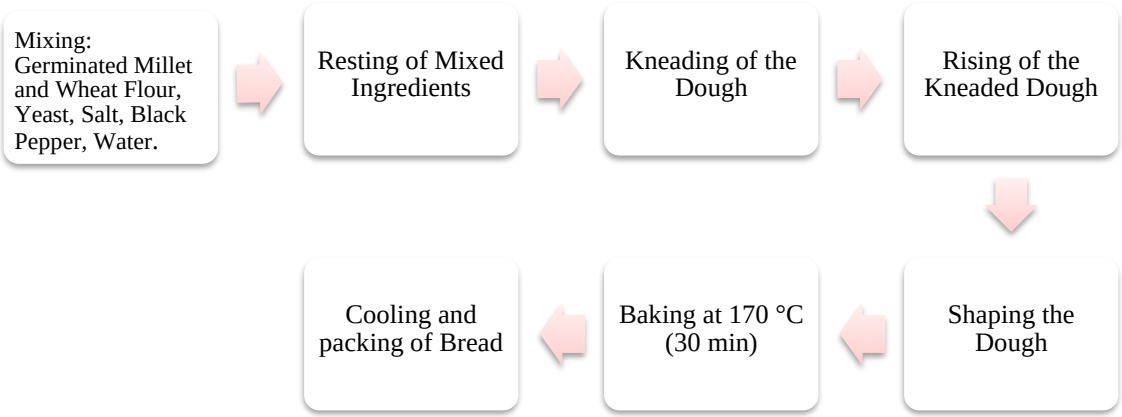


Figure 2 Stepwise process for making germinated finger millet-based bread.

Processing of ingredients: Ingredients such as finger millet were soaked overnight before starting the process of germination. The step-by-step process of germination is shown below:

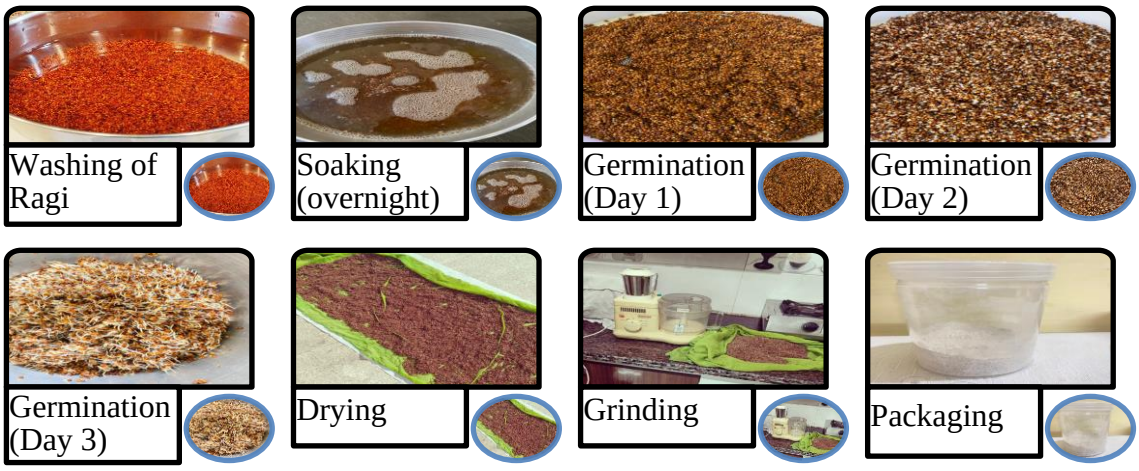


Figure 3 Stepwise processing of ingredients for the preparation of finger millet (ragi) flour.

Figure 4 Germinated finger millet-based breads made final after the experiment.

Table 2 The compositions that were made final after the experiments are as follows.

Compositions	Ragi (gm)	Wheat Flour (gm)	Salt and Sugar (tsp)	Oil (ml)	Dry Yeast (gm)	Observation
1	30	70	1/4	40	5	Light brown in color, Soft in Texture
2	50	50	1/4	40	5	Light brown in color, Soft in Texture
3	60	40	1/4	40	5	Very soft, good in taste. Color totally improved in every factor

Sensory evaluation: According to Sharif et al. (2017) [13], "sensory evaluation of a food product is significant since it represents the sensory characteristics that lead to consumer approval for a specific food product, and it helps in luring target consumers." When sensory qualities are linked to various elements, such as physical, chemical, formulation, and process variables, the creation of food products with the maximum level of customer approval is the outcome of a successful sensory evaluation. (Figure 5)

Developed breads were analyzed for different sensory characteristics like color, texture, odor and taste, and overall acceptability. A panel of 10 semi-trained judges performed the sensory evaluation. The sensory evaluation was conducted at 28-29-degree Celsius with 60% relative humidity. A 9-point Hedonic scale (1= dislike extremely, 9 = like extremely) was used for the sensory evaluation of the breads. The sensory score sheet is given in Figure 5 [13].

Sensory Score Card (Product: Finger-millet cum Wheat-based bread)

Name of panelist:…… **Date:……..**

Instruction: Rate of given sample of cereal bar study in terms of color, texture, odor, taste, and overall acceptance on the basis of nine-point hedonic scale is given below:

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

PARAMETERS	Sample A	Sample B	Sample C	Sample D	**Sample E**
Color					
Texture					
Odor					
Taste					
Overall acceptance					

Remarks: …… Signature: ……..

Figure 5 Sensory Score Card

Nutritional and Antinutritional Analysis

Determination of Moisture content: The moisture content of the formulated granola bar samples was evaluated using the AOAC International method (2005) [14].

Determination of Fat content: Estimation was done by method of AOAC 2000 [15] and carried out in SOCS PLUS SCS 02E (Pelican Equipment) apparatus.

Protein: The protein content in millet-based breads was estimated by the AOAC (2000) method and carried out in a Kjeldhal apparatus.

Digestion: The system was activated, and the digestion unit was preheated to 350 degrees Celsius. A 500mg sample was carefully weighed and placed in triplicate within filter paper, then enclosed in a 250ml macro DTL Tube.

Next, 10ml of concentrated H_2SO_4 was introduced to the samples, followed by the addition of 5gm of a catalyst mixture consisting of a 5:1 ratio of Potassium Sulphate to Copper Sulphate. The sample tubes were then loaded into the digestion unit, equipped with a

manifold and KEL Freeze setup, ensuring tap water pressure was at its maximum for KEL Freeze. The temperature was increased to 420 degrees Celsius, and digestion continued until a clear green color emerged, with ninety samples processed in this manner. The digested mixture was then allowed to cool on a rack for approximately 1 hour.

Distillation: Solutions of 4% boric acid, 40% alkali, and 0.1% NHCL were prepared for distillation. These were loaded into the system through silicon hoses at the rear of the equipment while awaiting the READY signal. In a 250ml conical flask, 25ml of boric acid was combined with an indicator and positioned at the receiving end. The sample was diluted with distilled water (in a 10ml to 20ml ratio) before being loaded into the sample side. Prior to initiating sample testing, water circulated through the system for cooling purposes. Then, 40ml of the 40% alkali solution was added until a dark brown color emerged, signaling the start of the process. Liquid ammonia collected into the boric acid, changing its color according to the indicator used. Upon completion of the process, the conical flask was removed from the receiver end and titrated, while the DTL tube from the sample side was also removed.

Titration: 0.1 N HCL was taken in the burette and titrated first against clank and then against sample. Burette value was noted down.

Calculations:

$$\text{Nitrogen N\%} = \frac{14.01*0.1*(TV-BV)*100}{W*1000}$$

Protein % = %N * 5.7

Where, TV = Titer Value, BV = Blank Value, W = weight of sample

Crude fiber: Crude fiber content was determined by using method of AOAC (1990) [16].

Calcium: The standard technique of analysis, the Titrimetric method, was used to determine the amount of calcium in the sample [15]. 50 ml of clear sample filtrate made from ash was poured into a beaker. 10 ml of saturated ammonium oxalate solution was added.

After bringing to a boil, two drops of methyl red indicator were added. To make a coarse crystalline precipitate, the contents were neutralized with weak ammonium hydroxide and then boiled again.

Using a few drops of weak hydrochloric acid, alter the color to a pale pink. The solution can sit in the refrigerator overnight. The precipitate is filtered using Whatman filter paper and carefully rinsed with hot distilled water until oxalate-free. The precipitate from the filter paper is placed in the original beaker and dissolved in 20 mL of sulphuric acid (10%). The contents are heated to around 70 °C and titrated to a light pink color with 0.1 N potassium permanganate solution. A blank is also run using the same procedure.

Calculations: 1 mL of 0.1 N KMnO, used = 0.002 g calcium Calcium, % = mL of 0.1 N KMnO4 used × 0.002 × A/B× Weight of sample (g)

Iron: The amount of iron in the sample was assessed using the Titrimetric technique, a standard analysis method [15]. The extract obtained after ashing the food sample was measured for iron. 10 mL of aliquot was pipetted into a 25 mL volumetric flask, followed by 1 mL of hydroxyl amine hydrochloric solution. Add 5 mL buffer solution and 1 mL Ortho-phenanthroline solution after a few minutes. The components are blended, and the volume is adjusted to meet the requirements. In a spectrophotometer, the intensity of color produced is

measured at 540 nm. 2 mL of concentrated HCl is diluted to 100 mL, and 10 mL of this solution is used as a blank per sample. Standard: 5,10,20,30,40,50 mL of standard iron solution is transferred to a 100 mL volumetric flask. 2 mL conc. HCl is added to each flask, bringing the total volume to 100 ml. Each flask contains an aliquot of 10 mL, which is heated in the same manner as the sample. With the reading of the standard solution, a calibration curve is created. The concentration of iron in the sample is estimated from the standard curve and multiplied by the dilution factor.

Potassium: Flame-photometry was used to determine the potassium concentration. To keep the pH between 4.0 and 4.5, 0.4 mL of NaOH (5 M) was pipetted into the sample solution (2.5 mL). Then, Acetate buffer (0.7 mL, pH 4.5) and 0.5 mL Hydroquinone were added to the mixture (25%). 11 Dipridyl 0.1 percent in 0.5 mL to make up the volume, 0.35 mL of distilled water was used. At 520 nm, the absorbance was measured against a blank.

Carotene: The open-column chromatography combined spectrophotometer (carotenoids) is used in the AOAC technique for determining carotenoids (941.15) in foods. It was first extracted with acetone-hexane, then filtered, and finally rinsed with water to eliminate the acetone. The extracts in hexane were then put into a diatomaceous earth column activated with MgO2 and eluted with acetone and hexane. The carotene component elutes first because it is less polar than xanthophylls.

Total phenolic content and antioxidant activity of developed breads

Total phenolic content determination: The total phenolic content in developed breads was estimated by the following method given by Lin *et. al* (2018) [17]

Procedure: To assess the total phenolic content of the bread with different compositions, a method reported by Lin et al. (2018) [17] was followed, where the methanolic extract of bread was reacted with a Folin-Ciocalteau reagent (0.1 mL) and deionized water (1.58 mL) for 6 min and then mixed with 2 M of sodium carbonate (0.3 mL). The mixture was then stirred and incubated for 2 h while the absorbance was recorded in a spectrophotometer at 765 nm.

Calculation: The total phenolic content was calculated as gallic acid equivalent GAE/g of bread sample based on a standard curve of gallic acid.

Radical scavenging activity (DPPH inhibition): The radical scavenging activity in the cereal bar was estimated as DPPH inhibition activity by the following protocol:

Procedure: DPPH free radical scavenging activity of the bars was measured by adding different concentrations of extracts to 60 µM methanolic solution of DPPH and recording the absorbance at 517 nm.

The IC_{50} value was determined from the plotted graph of scavenging activity against the different concentrations of extracts, which is defined as the total antioxidant necessary to decrease the initial DPPH radical concentration by 50%. The measurements were done in triplicates and their scavenging effects were calculated based on the percentage of DPPH scavenged.

Calculation: The antioxidant activity was expressed as ascorbic acid equivalent (mg AAE/g extract) which served as a positive control.

Statistical Analysis: All the obtained data of chemical analysis and sensory evaluation were statistically analyzed using the mean. Also, graphical representations of the mean scores were done.

RESULTS AND DISCUSSION

The various parameters were used to assess the acceptability as well as the variations in the overall quality of the developed samples of three different compositions of finger millet-based bread (prepared compositions of finger millet-based bread (prepared from germinated flour).

Sensory Evaluation of Breads: (Table 3) A1- 70:30 Germinated finger millet (ragi) flour: Whole Wheat flour); B1- 50:50 (Germinated finger millet (ragi) flour: Whole Wheat flour); C1- Whole wheat (Control).

Table 3 Sensory Evaluation of Breads

Sample No.	Appearance	Color	Texture	Flavor	Taste	Overall Acceptability
A1 70:30 (Ragi: Whole Wheat)	4.02	5.26	3.22	6.81	7.03	5.2
B1 50:50 (Ragi: Whole Wheat)	6.32	6.09	6.89	7.64	8.65	7.5
C1 Whole wheat (Control)	5.36	5.69	5.81	6.95	8.03	6.3

The following categories have been used to characterize the findings of this investigation:

1. The sensory evaluation of the three different compositions of finger millet-based bread developed.
2. The estimation of nutrients analysis of three different compositions of finger millet-based bread developed.
3. The estimation of anti-nutrient analysis of different compositions of finger millet-based bread developed.
4. The estimation of shelf life of different compositions of finger millet-based bread developed.

Nutritional and Anti-Nutritional Analysis

Protein: The highest protein content (14 g) was found in the sample of A1 70:30 (Ragi: Whole Wheat), in which the proportion was 70:30 of ragi and wheat flour, respectively. The protein content in the sample of B1 was 12.8 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. However, the protein content of the non-germinated control sample of ragi bread was found to be less than that of bread made from germinated ragi.

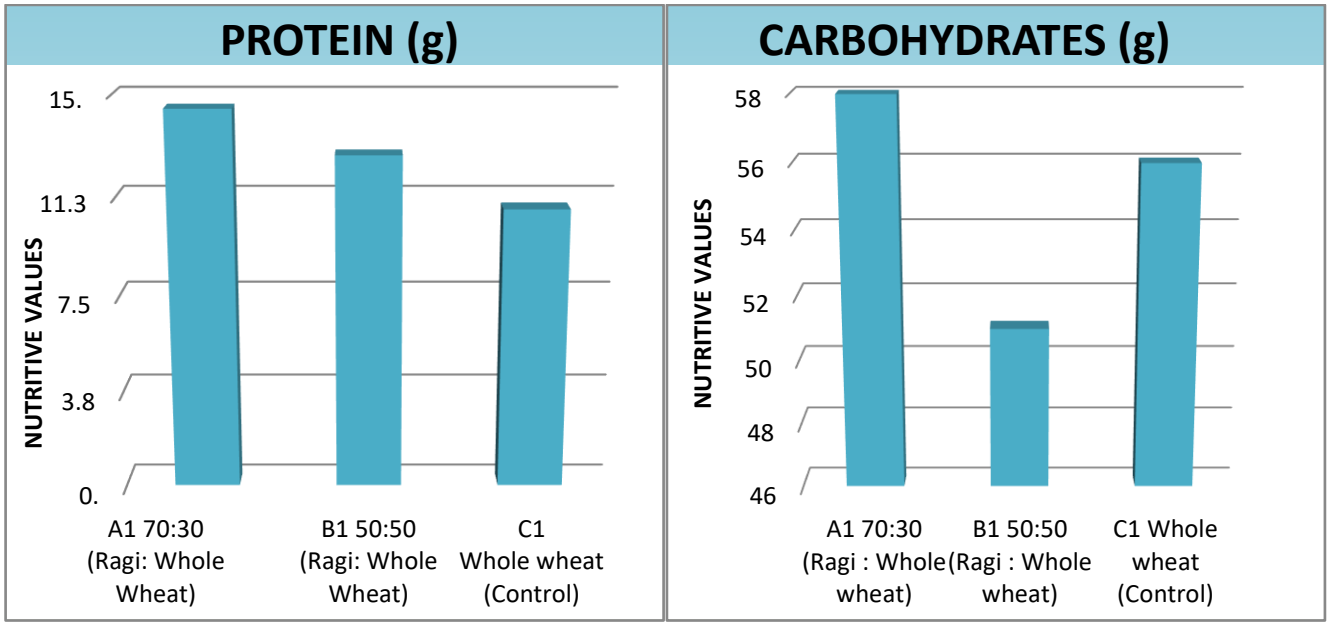


Figure 6 Graphical Representation of Protein and Carbohydrate content in the three bread samples

Carbohydrates: The highest carbohydrate content of around 58 g was found in the sample of A1, in which the proportion of ragi and wheat flour was 70% and 30%, respectively. The carbohydrate content in the sample of B1 was 51 g, where the proportion was 50:50 (of ragi and wheat flour, respectively. The carbohydrate content of the control sample was found to be around 56 g. Dharmaraj et al. (2012) [18] studied the physico-chemical composition of decorticated and expanded finger millet and reported the carbohydrates (43 g) as 72.97 ± 0.10 and 72.15 ± 0.10. Similarly, in one of the studies reported by ChangmeiShadang et al. (2018) [19], where barnyard millet-based cakes were developed with a percentage of carbohydrates around 7 g. However, this value is comparatively more than all the breads developed in our study, as the preparation of cakes requires butter and sugar, which are considered rich sources of carbohydrates.

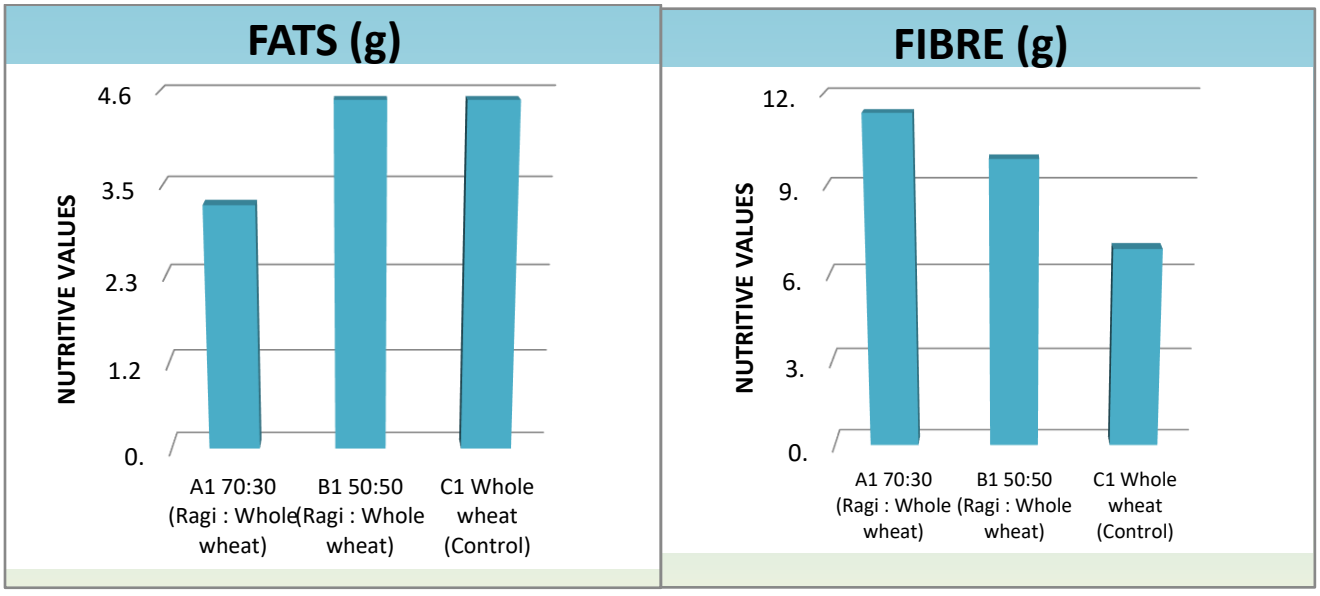


Figure 7. Graphical Representation of Fat and Crude Fiber content in the three bread samples

Fat: The highest fat content (4.5 g) was found in the sample of B1 in which the proportion was 50:50 of ragi: wheat flour, respectively. The fat content in the sample of A1 with a 70:30 proportion of ragi: wheat flour was 3.2 g. The fat content for the control sample was 4.5 g.

Moisture: The moisture content (32.4 g) was found to be the highest in the sample of A1 where proportion was 70:30 of Ragi: Wheat flour, respectively. The moisture content in the sample of B1 was 31.9 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The moisture content of all the breads was significantly lower than that of the control sample (34.4 g).

Crude Fiber: The highest fiber content (11.4 g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The dietary fiber content in the sample of B1 was 9.9 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The dietary fiber content of all the breads was significantly higher than of the control sample (6.9 g). During germination, the fiber content in seeds can increase due to several factors. The breakdown of cell wall components, activated by enzymes like cellulases and pectinases, leads to the release of fiber and thus, an increase in fiber content. Enzymes involved in fiber metabolism, such as β-glucosidases and β-galactosidases, are also activated during germination, breaking down complex fiber compounds into simpler forms.

Calcium: The highest calcium content (72 mg) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The calcium content in the sample of B1 was 59 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The calcium content of all the breads was significantly higher than that of the control sample (43 mg). A few studies were done regarding the consumer acceptability of millet-based baked products.

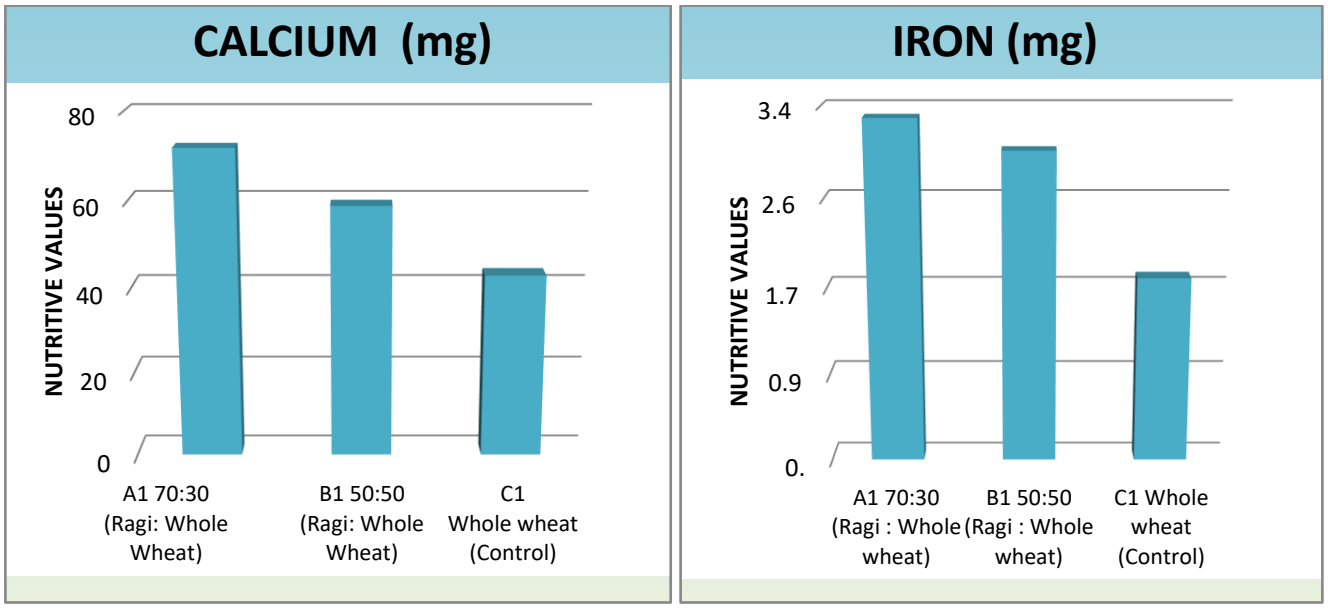


Figure 8 Graphical Representation of Calcium and Iron content in the three bread samples

Iron: The iron content (3.3 mg) was almost the same as found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively, and B1 (3 g), in which the proportion was 50:50 of Ragi: Wheat flour, respectively. The iron content for the control sample was 1.8 mg.

Zinc: Inadequate levels of zinc (Zn), one of the most important trace elements for human nutrition, pose serious risks to global public health. Fe and Zn deficiencies are among the micronutrient malnutrition conditions that affect the human population. They are particularly concerning due to the number of people affected globally, particularly in China, as well as the potentially serious health consequences they may have.

The highest zinc content (29 g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The zinc content in the sample of B1 was 23 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The zinc content of all the breads was significantly higher than that of the control sample (4.9 g).

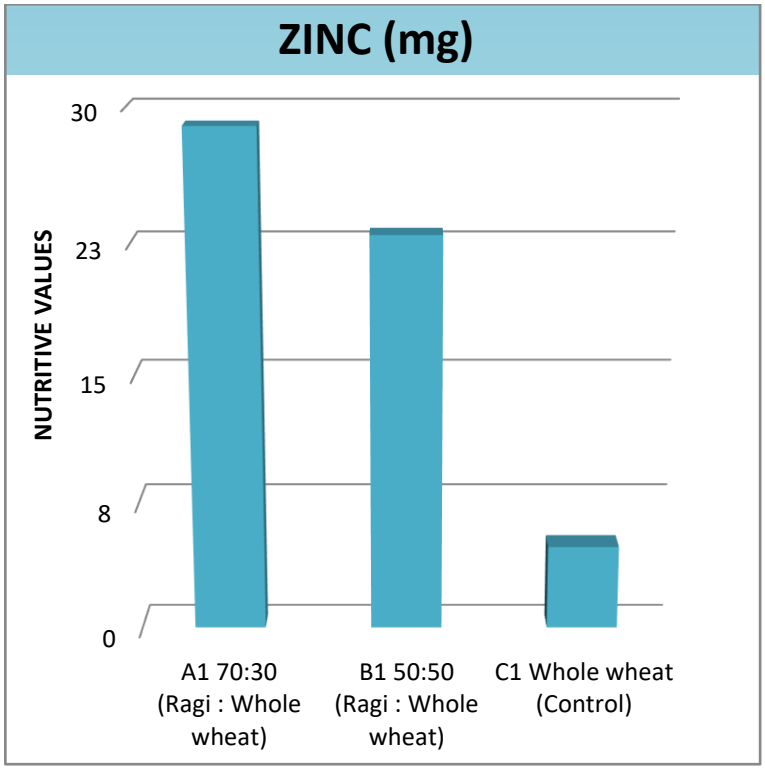


Figure 9 Graphical Representation of Zinc content in the three bread samples

Sodium: The sodium content (245 mg) was found in the sample of A1 70:30 (Ragi: Whole Wheat), in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The sodium content in the sample of B1 was 234 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The sodium content of all the breads was significantly lower than that of the control sample (310 mg). During germination, the sodium content in seeds tends to decrease due to various factors. Water absorption during germination can lead to the leaching of soluble sodium ions, reducing their concentration. Metabolic processes and the incorporation or redistribution of sodium within the seed can further contribute to its decrease.

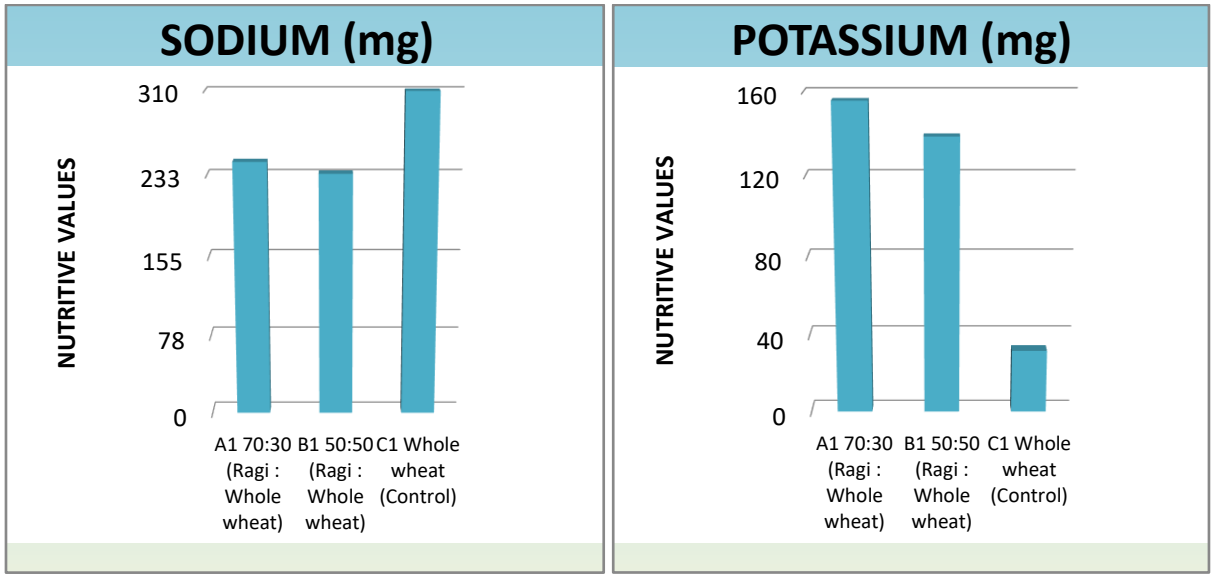


Figure 10 Graphical Representation of Sodium and Potassium content in the three bread samples

Potassium: The highest potassium content (156 mg) was found in the sample of A1 70:30 (Ragi: Whole Wheat), in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The potassium content in the sample of B1 was 139 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The potassium content of all the breads was significantly higher than that of the control sample (32 mg).

Carotene: The highest carotene content (27.9 mg) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The carotene content in the sample of B1 was 24.9 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The carotene content of all the breads was significantly higher than that of the control sample (10.8 mg).

Total Antioxidant Activity: The highest total antioxidant content (5.67 mg FAE/g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The total antioxidant content in the sample of B1 was 4.76 mg FAE/g, where the proportion was 50:50 of Ragi: Wheat flour. respectively. The total antioxidant activity content of all the breads was significantly higher than that of the control sample (1.38 mg FAE/g). The biochemical and antioxidant properties of millet products could be significantly changed by germination or malting, which also activated dormant enzymes that triggered intricate biochemical reactions. When using germinated millet as the raw material, the antioxidant activity was the highest (91.34%) after a 13.81-hour soaking period and 35.82-hours of germination at 38.75°C, which were the ideal conditions for making flour [20].

Total Polyphenols Content: The highest total polyphenols content (6.03 mg GAE/g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The total polyphenols content in the sample of B1 was 3.9 mg GAE/g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The total polyphenols content of all the breads was significantly higher than that of the control sample (2.2 mg GAE/g). Germination can have diverse effects on the polyphenol content of seeds or grains. It may lead to decreases and increases in polyphenol levels, depending on factors such as the activation of enzymes, changes in

polyphenol composition, the release of bound forms, and environmental influences.

Total Phytate: The phytate content (0.13mmol/100g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The total phytate content in the sample of B1 was 0.2 mmol/100g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The phytate content of all the breads was significantly lower than that of the control sample (0.7 mmol/100g). Processing of the millets, such as in the process of germination, assists in reducing the bioavailability of anti-nutritional compounds such as phytates, which increases the bioavailability of minerals like zinc [21].

Total Tannins: The total tannins content of 0.59 mg GAE/g was found in the sample of A1, in which the proportion was 70:30 of ragi: wheat flour, respectively. The total tannins content in the sample of B1 was 0.54 mg GAE/g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The total tannins content of all the breads was significantly lower than that of the control sample (0.79 mg GAE/g).

Table 4 Summary table of results obtained from various tests on different samples of bread.

S.NO.	TEST	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	Total Phytate (mml/100 gm)	0.13	0.2	0.7
2.	Total Tannins (mg GAE/g)	0.59	0.54	0.79
3.	Total Polyphenols Content (mg GAE/g)	6.03	3.90	2.2
4.	Carotene (mg)	27.90	24.90	10.80
5.	Total Antioxidant Activity (mg FAE/g)	5.67	4.76	1.38
6.	Moisture (g)	32.0	31.90	34.40
7.	Texture	Light soft	Light soft	Medium soft
8.	Color	Light brown	Light brown	Golden brown

Shelf-life Evaluation: The demand for consistently high-quality food is rising, and consumers expect this quality to remain high between purchase and consumption. These expectations result from the primary need for the food to remain safe and the requirement to minimize unwelcome changes in sensory quality. The labeling requirements that food manufacturers must follow reflect the need for quality. In India, the appropriate date

coding depends on how long the product will be on the market: microbiologically, highly perishable foods require a "use by" date. Meanwhile, foods with a shelf life of more than 18 months require a "best before" or "best before end" date. In general, chemical and sensory changes are more significant for products with a medium to long shelf life than microbiological changes are for those with a short shelf life [22]. However, all three types of changes can be significant for products with a short to medium shelf life.

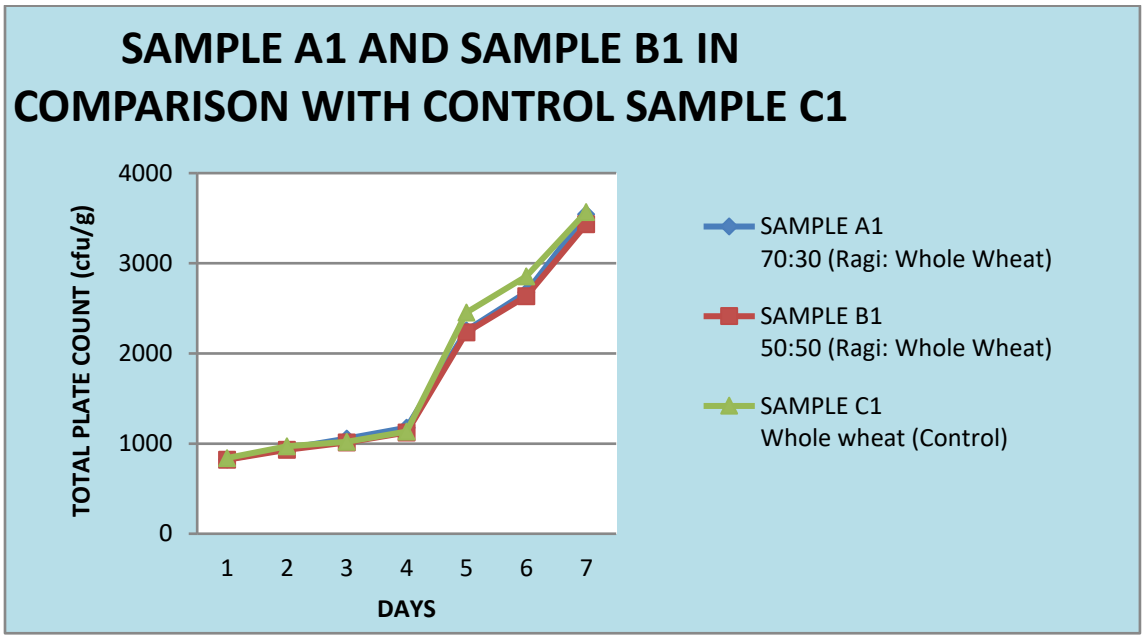


Figure 15 Graphical Representation of Evaluation of Shelf Life in the three bread samples

CONCLUSION

Germinated finger millet cum wheat-based breads were developed with different compositions of finger millet and wheat. A sample containing non-germinated Finger millet cum wheat-based bread acts as a control. This study mainly focuses on the results of various parameters used to assess the acceptability and variations in the overall quality of three different types of breads with different compositions. It was found that an increased concentration of ragi flour led to negative consumer acceptability and dark color, while an increased concentration of wheat flour resulted in positive acceptability. The sample, containing 70:30 ratio of ragi and wheat, was recorded with the highest protein percentage due to the germination of millets. The highest carbohydrate content was found in sample A1, with ragi and wheat flour proportions of 70% and 30%, respectively, due to the higher content of millets. Regarding fat content, the sample of B1 with a 50:50 proportion of ragi: wheat flour contains the highest amount. Results showed that iron levels ranged from 2 mg/100 g to 8 mg/100 g, depending on the type and variety. Finger millet-based bread showed the highest iron content in sample A1 (70:30), i.e., 3.3 g, and Sample B1 (50:50), i.e., 3 g, while the control sample had an iron content of 1.8 g. The highest zinc content (29 g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The zinc content in the sample of B1 was 23 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The zinc content of all the breads was significantly higher than with respect to the control sample (4.9 g). Germination is the

process by which a seed undergoes initial growth and development into a new plant, which can lead to an increase in the content of certain nutrients, including zinc. Germination reduces the availability of antinutritional compounds such as phytic acid, which increases the bioavailability of minerals like zinc. The moisture content (32.4 g) was found the highest in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The moisture content in the sample of B1 was 31.9 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The moisture content of all the breads was significantly lower than that of the control sample (34.4 g). The fiber content of finger millet increased significantly with increased germination time due to modification of the structure of cell wall polysaccharides of the seeds. This involved extensive cell wall biosynthesis and the production of new dietary fiber. Finger millet has the highest concentration of calcium, iron, zinc, dietary fiber, polyphenols, and phytates and is typically eaten as a whole meal. Enzymes involved in fiber metabolism are also activated during germination, breaking down complex fiber compounds into simpler forms. The highest fiber content (11.4 g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The dietary fiber content in the sample of B1 was 9.9 g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The dietary fiber content of all the breads was significantly higher than that of the control sample (6.9 g).

Sodium is essential for maintaining osmotic balance and nerve impulse transmission and can lead to dehydration or muscle cramps. During germination, the sodium content in seeds tends to decrease due to the leaching of soluble sodium ions. Metabolic processes and the incorporation or redistribution of sodium within the seed can contribute to its decrease. The sodium content (245 mg) was found in the sample of A1 70:30 (Ragi: Whole Wheat), in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The sodium content in the sample of B1 was 234 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The sodium content of all the breads was significantly lower than that of the control sample (310 mg). Adults' recommended daily potassium intake is 2,600-4,700 mg per day, but individual requirements may vary. The highest potassium content (156 mg) was found in the sample of A1 70:30 (Ragi: Whole Wheat), in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The potassium content in the sample of B1 was 139 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The potassium content of all the breads was significantly higher than that of the control sample (32 mg). Germination increases the nutrient content of cereals and legumes, leading to reduced potassium content in gluten-free cookies and pearl millet flour. Cereals contain a variety of carotenoids, including beta-carotene, cryptoxanthin, trans-or cis-lutein, and zeaxanthin. Millet contains significant amounts of lutein, zeaxanthin, and traces of carotene. Germination can have variable effects on carotene content, depending on the seed or grain type, environmental factors, and other variables. The highest carotene content (27.9 mg) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The carotene content in the sample of B1 was 24.9 mg, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The carotene content of all the breads was significantly higher than that of the control sample (10.8 mg).

Millet has antioxidant properties, including phytochemicals, dietary fiber, and micronutrients. It can be fermented and germinated to add antioxidants. The highest total antioxidant content was found in samples A1 (5.67 mg FAE/g) and B1 (4.76 mg FAE/g), and the total antioxidant activity content of all breads was significantly higher than the control sample. Germination and malting can also significantly alter the biochemical and

antioxidant properties of millet products. Germination can have diverse effects on the polyphenol content of seeds or grains, such as activation of enzymes, changes in polyphenol composition, release of bound forms, and environmental influences. The highest total polyphenols content (6.03 mg GAE/g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The total polyphenols content in the sample of B1 was 3.9 mg GAE/g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The total polyphenols content of all the breads was significantly higher than that of the control sample (2.2 mg GAE/g).

Phytate is the salt of phytic acid, myo-inositol-1,2,3,4,5,6 hexakisphosphate, which is widely distributed in the plant kingdom and serves as the major form of stored phosphorus and minerals. The phytate content (0.13mmol/100g) was found in the sample of A1, in which the proportion was 70:30 of Ragi: Wheat flour, respectively. The total phytate content in the sample of B1 was 0.2 mmol/100g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The phytate content of all the bread was significantly lower than that of the control sample (0.7 mmol/100g).

Tannins are astringent, bitter plant polyphenols that reduce the ability of humans and animals to digest protein. Processing methods like germination, soaking, roasting, fermentation, and dehulling can eliminate these antinutrients. The total tannins content of 0.59 mg GAE/g was found in the sample of A1 in which proportion was 70:30 of ragi: wheat flour respectively. The total tannins content in the sample of B1 was 0.54 mg GAE/g, where the proportion was 50:50 of Ragi: Wheat flour, respectively. The total tannins content of all the breads was significantly lower than that of the control sample (0.79 mg GAE/g).

Demand for consistently high food quality is rising, and consumers expect it to remain high between purchase and consumption. Labeling requirements reflect this need, with "use by" and "best before" dates depending on shelf life. Chemical and sensory changes are more significant for products with a medium to long shelf life, while microbiological changes are more significant for those with a short shelf life. The shelf life of the control sample was eight days, while the other 2 proportions of breads, i.e., 70:30 and 50:50 breads, had a shelf life of up to 6 days. Sample A1 had the maximum amount of microbial population at the end of day 8, while Sample B1 had a comparatively less microbial population.

Overall, the result indicated that germination plays a crucial role in enhancing nutritional quality, reducing anti-nutrients, and improving the functional properties of finger millet. Incorporating germinated finger millet into the diet can provide a more nutrient-rich and easily digestible food option, promoting better health and nutritional outcomes.

Conflict of Interest Statement: The authors declare that they have no conflicts of interest related to this research. This includes any financial, personal, or professional interests that could be construed as influencing the research or the interpretation of its results.

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Abbreviations: GAE: Gallic Acid Equivalents, AOAC: Association of Official Agricultural Chemists, DTL: Drift Tube Linac, DPHH: 2,2-Diphenyl-1-picrylhydrazyl, AAE: Ascorbic Acid Equivalent, FAE: Ferulic Acid Equivalent

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