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DEVELOPMENT OF FOXTAIL AND BARNYARD MILLET FLOUR BASED FUNCTIONAL MULTIGRAIN MUFFINS

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ABSTRACT

Multigrain muffins were made with foxtail (*Setaria italica*) and barnyard millet (*Echinochloa frumentacea*) flours to improve nutritional value, physicochemical, sensory, and shelf life. With wheat flour as the base, foxtail millet flour was added at 5%, 10%, and 15% and barnyard at 10%, 20%, and 30%. The enhanced formulation of 5% foxtail millet, 20% barnyard millet, and 75% wheat flour was well-accepted (8.27). Lipid oxidation and moderate microbial growth were detected, with peroxide values of 3.43 meq O₂/kg oil and water activity (aw) of 0.673 compared to 0.647 for the control. Optimized muffins had 38.43 g weight, 53.65 cm³ volume, and 2.57 cm³/g specific volume. The moisture of muffins packaged in LDPE reduced from 22.76% to 17.15% and PP to 20.10% after 8 days. Texture analysis showed that muffins packed in LDPE hardened from 3459.56 N to 5035.46 N and PP from 2998.98 N to 5577.16 N, increasing gumminess. Chewiness and resilience varied, especially in PP packaging, while cohesion and springiness persisted. Average acceptability scores dropped during storage but remained acceptable. Foxtail and barnyard millet make nutritionally superior multigrain muffins with outstanding sensory qualities and an 8-day shelf life in LDPE and PP packaging, according to the study.

Key words: Millets, foxtail, barnyard, multigrain muffins, sensory quality, textural properties, nutritional benefits, baking characteristics

Introduction

India is the second-largest food grain producer after China and may lead the food and agriculture sector. Pearl millet, finger millet, kodo millet, proso millet, foxtail millet, little millet, sorghum, oats, and barley are small-seeded annual grains. Millets, a historic food, have a brief growth season. Local populations domesticated millets from Asia and Africa. Sorghum, bajra, ragi, kora, tiny, kodo, proso, and barnyard millet are important millet crops in India. These were once called coarse cereals, but the Indian government now calls them “Nutri-cereals” due to their nutrient content. Phenolic acids, glycosylated flavonoids, and vitamins are in millets. Healthy, non-glutinous, non-acid-forming, and easy to digest. Energy, protein, fatty acids, vitamins, minerals, fiber, and polyphenols are provided.

Millets can avoid cancer and cardiovascular disorders, reduce tumour incidence, lower blood pressure, heart disease risk, cholesterol, and fat absorption, delay gastric emptying, and offer gastrointestinal bulk (Sharma and Niranjana, 2018).

Due to the demand for healthier bread products, ingredients have been improved to increase fibre, regulate calories, provide omega and essential fatty acids, and reduce saturated and trans fats. Natural and low-calorie sweeteners are used to make gluten-free baked goods. Paddy rice and foxtail millet are very similar. Foxtail millet is high in crude fiber, improves digestion, and promotes bowel movement, promoting a healthy digestive tract. Health benefits of foxtail millet include cancer prevention and blood sugar and cholesterol decrease.

Table 1: Levels of foxtail and barnyard millet flour for multigrain muffins making.

Treatment	Wheat flour (%)	Foxtail millet flour (%)	Barnyard millet flour (%)
T ₀ : Control (100% wheat flour)	100	0	0
T ₁ : 5% foxtail millet flour, 10% barnyard millet flour, and 85% wheat flour	85	5	10
T ₂ : 5% foxtail millet flour, 20% barnyard millet flour, and 75% wheat flour	75	5	20
T ₃ : 5% foxtail millet flour, 30% barnyard millet flour, and 65% wheat flour	65	5	30
T ₄ : 10% foxtail millet flour, 10% barnyard millet flour, and 80% wheat flour	80	10	10
T ₅ : 10% foxtail millet flour, 20% barnyard millet flour, and 70% wheat flour	70	10	20
T ₆ : 10% foxtail millet flour, 30% barnyard millet flour, and 60% wheat flour	60	10	30
T ₇ : 15% foxtail millet flour, 10% barnyard millet flour, and 75% wheat flour	75	15	10
T ₈ : 15% foxtail millet flour, 20% barnyard millet flour, and 65% wheat flour	65	15	20
T ₉ : 15% foxtail millet flour, 30% barnyard millet flour, and 55% wheat flour	55	15	30

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. Foxtail millet have a significant quantity of antinutritional components such phytates and polyphenols, which prevent the absorption of nutrients (Garwadhiremath, 2011).

Barnyard millet (*Echinochloa* spp.) is becoming a major Asian minor millet crop. The two most popular *Echinochloa* species are *Echinochloa esculenta* (Japanese barnyard millet) and *Echinochloafrumentacea* (Indian barnyard millet). *Echinochloa* has 20-35 annual and perennial species that can grow in every climate or agricultural condition. It is the staple cereal for locations without suitable climates and soils for rice (Sood *et al.*, 2015). Traditional barnyard millet, *Echinochloa species*, grows in India, China, Japan, and Korea. Different genotypes have grain pericarps that range in colour from straw white to light grey and dark grey (Renganathan *et al.*, 2020). The development of millet-based foods suitable for diabetics (Pathak *et al.*, 2000).

Popular bakery muffins are not fast bread and do not contain yeast. Muffins may be glazed, unlike cupcakes. They are usually eaten as breakfast or snacks at one sitting and fit in an adult hand. Wheat flour, sugar, milk, butter, salt, baking soda, and powder are common. Traditional Indian whole grains have variable yields, and new types having medicinal and physiological benefits. Nutraceuticals have increased importance in nutrition. Food that prevents disease is called nutraceutical. Nutritionally valuable millets are underutilized. Due to consumer awareness of nutrition and health, bakery items need to be more nutritious. Healthy bakery options are in demand as consumers become more aware of food-related health issues like obesity, diabetes, and heart disease. The current study focuses on the chemical composition, health benefits, and functional bakery

products developed by incorporating foxtail and barnyard millet flour.

Materials and Methods

Materials

Muffins were made from wheat flour, barnyard millet flour, foxtail millet flour, white butter, oil, sugar, leavening agent, cake gel, WPC, SMP, vanilla powder, vanilla essences, and salt. LDPE (low density polyethylene and PP (polypropylene) were used to pack muffins for storage study.

Process for standardization of multigrain muffins

Table 1 shows muffin samples with different proportions of foxtail millet flour, barnyard millet flour, and wheat flour. The control sample (T₀) is wheat flour only. The remaining samples (T₁-T₉) replaced wheat flour with 5, 10, 15% foxtail millet flour and 10, 20, 30% barnyard millet flour. The formulations were designed to evaluate the impact of incorporating these millet flours on the nutritional and sensory properties of the muffins shown in Table 1.

The recipes for multigrain muffins

Table 2 lists the recipes for control and multigrain muffin. The control muffin has 125 g of wheat flour, while the multigrain muffins substituted 10%, 20%, 30% barnyard millet flour and 5%, 10%, 15% foxtail millet flour with wheat flour. Muffins require 100 g sugar, 30 ml oil, 30 g white butter, 2.5 g baking powder, 1.25 g baking soda, 5 g whey protein concentrate (WPC), 5 ml vinegar, 25 g skimmed milk powder (SMP), 1 g salt, 2.5 g cake gel, 5 g vanilla powder, 1.25 ml vanilla essence, and 5 ml caramel. The control muffin requires 100 ml water, while the multigrain muffin uses 120.

Preparation of multigrain muffins

Weighing all components starts the muffin preparation. Skimmed milk powder (SMP), water, sugar, cake gel, whey protein concentrate (WPC), and salt were

Table 2: Recipes for preparation of multigrain muffins making.

Sr. No.	Ingredients	Control muffin	T ₁ to T ₉
1	Wheat flour (g)	125	By difference
2	Barnyard millet flour (g)	-	(10, 20, 30 %)
3	Foxtail millet flour (g)	-	(5, 10, 15 %)
4	Sugar (g)	100	100
5	Oil (ml)	30	30
6	White butter (g)	30	30
7	Baking powder (g)	2.5	2.5
8	Baking soda (g)	1.25	1.25
9	WPC (g)	5	5
10	Vinegar (ml)	5	5
11	Water (ml)	100	120
12	Skimmed milk powder (g)	25	25
13	Salt (g)	1	1
14	Cake gel (g)	2.5	2.5
15	Vanilla powder (g)	5	5
16	Vanilla essences (ml)	1.25	1.25

creamed to make a smooth consistency. Adding vanilla essence enhanced the flavor. Then, refined wheat flour, baking powder, and baking soda were added to the creamed mixture. In another phase, oil and white butter were combined and added to the batter. To improve taste and texture, vinegar and caramel were added. After mixing, the mixture was placed into baking cups. For 30-35 minutes, muffins were baked at 170°C. After baking, they cooled for 10-15 minutes before packaging and storing.

Moisture content

Sample moisture was tested using hot air oven (AOAC, 2012). A hot air oven heated the weighed samples at 130°C for 1 h or until constant weight. Equation for moisture content:

$$\text{Moisture content (\%)} = \frac{(W_1 - W_2)}{W} \times 100$$

Here,

W₁: Initial sample weight before drying (g)

W₂: Final sample weight after drying (g)

Fat content

Socsplus used for analysing the crude fat (Ranganna, 2004). Five-gram samples were weighed three times and placed in a guide thimble. At 100°C, extraction took 60 minutes. The fat percentage formula is given below (AOAC, 2012).

$$\text{Fat (\%)} = \frac{(W_1 - W_2)}{W} \times 100$$

Here,

W₁ = Initial sample weight (g)

W₂ = Weight of flask with oil (g)

W = Weight of the empty flask (g)

Crude fibre content

The fibra-plus device (Ranganna, 2004) is used to measure crude fiber. Two grams of triplicate samples were digested in 150 ml of boiling 1.25 % H₂SO₄ for 45 min. After draining the acid through the crucible, the samples were cleaned twice or thrice with distilled water until acid-free. To remove alkali, samples were rinsed with distilled water after 45 min in 150 ml of 1.25 % NaOH. Wastes were burned in a muffle furnace at 550°C for 4 h after drying and weighing (AOAC, 2012). The crude fibre formula is given below.

$$\text{Crude fiber (\%)} = \frac{(W_1 - W_2)}{W} \times 100$$

Here,

W₁ = Weight of sample (g)

W₂ = Weight of crucible + weight after washing and drying (g)

W = Weight of crucible + ash (g)

Protein content

The micro-Kjeldahl (Ranganna, 2004) method was utilized to measure protein content using kel-plus. The following formula assessed sample protein content (AOAC, 2012).

Protein Content (%) = % Nitrogen × factor

$$\text{Nitrogen (\%)} = \frac{14 \times (T - N) \times \text{Normality of HCL} \times 100}{W \times 1000}$$

Here,

T = Titre value

N = Titre value of the blank sample

W = Weight of the sample (g)

Ash content

Sample ash content was measured using conventional methods (AACC, 2000). Formula for calculating ash content is as follow:

$$\text{Ash (\%)} = \frac{(W_2 - W_1)}{W} \times 100$$

Here,

W₁ = Empty weight of crucible (g)

W₂ = Weight of crucible + Ash (g)

W = Weight of sample (g)

Carbohydrate content

According to ICMR and NIN (2020) the carbohydrate content was calculated by difference. It was calculated using the formula given below;

$$\text{Carbohydrate (\%)} = 100 - (\% \text{Moisture} + \% \text{Protein} + \% \text{Ash} + \% \text{Fat})$$

Peroxide value

The sample peroxide value was calculated using AOAC (2012). The starch was employed to titrate KI peroxides against thiosulphate. A 250 ml glass stoppered Erlenmeyer flask with 30 ml acetic acid-chloroform solution dissolved 5.0 g of sample. After adding 0.5 ml of saturated KI solution with a Mohr pipette, 30 ml of water was added after a minute of intermittent shaking. Titrating with 0.1 N sodium thiosulphate solution while shaking vigorously until yellow nearly disappears. After adding 0.5 ml of starch solutions, the titration was forcefully shaken to release all I_2 from the chloroform layer until the blue color disappeared. Repeated titrations subtracted a blank (less than 0.5 ml 0.1 N NaS_2O_3).

$$\text{Peroxide value (meq. } O_2/\text{kg oil)} = \frac{S \times M \times 1000}{\text{Weight of sample (G)}} \times 100$$

Here,

S = ml NaS_2O_3 (blank corrected)

M = Normality of NaS_2O_3

Water activity

Water activity meters measured sample water activity. Sample holder with 10-20 g sample was placed in container holder. Triplicate readings were taken.

Colour value

The Lovibond Tintometer (RT850i) is used to evaluate multigrain muffin color in CIE lab color space. Fill the glass cell with muffin samples and place in the tintometer. Colour values were L^* , a^* , and b^* . The measurement of color value uses light reflection. The product L^* , a^* , b^* values were calculated from reflected light. Example lightness is L^* (Zero = black, 100 = white). A^* is the sample's redness or greenness. A^* values between 0 and -60 indicate redness and greenness, respectively. The b^* value is yellow or blue. A b^* value of 0-60 indicates yellowness, while 0-60 indicates blueness.

Texture analysis

TA-HDi and Stable Micro System texture analyzer investigated muffin texture. Testing was done with Exponent connect. On a Heavy-Duty Platform (HDP/90), a stainless-steel probe (75 dia. Compression platen - p/75) examined each muffin's texture. Two compression cycles were recorded during texture analysis. Muffins were arranged horizontally at mould height. A 75 mm diameter twofold compression test with a 5-second delay between cycles was performed at 1.25 cm (50% compression). Hardness, springiness, cohesiveness, gumminess, and chewiness affected curves.

Specific volume

The muffin volume was calculated using rapeseed displacement. Cut the muffin into $25 \times 25 \times 25$ mm cubes. A muffin weight (W_o) was measured and placed in a container, then rapeseed (V_2) was added to the empty space. By adding rapeseed to V_1 , its capacity was determined. The muffin volume (V_o) was calculated by measuring V_1 and V_2 with a graduated cylinder. Specific volume (S_v) was calculated by dividing volume by weight (V_o/W_o) as follow.

$$S_v = V_o/W_o$$

Here,

V_o = Volume of the muffin, calculated as $V_1 - V_2$

W_o = Weight of the muffin

Sensory evaluation of multigrain muffins

Multigrain muffins were examined for color, appearance, taste, flavor, texture and overall acceptability scored on nine-point hedonic scale proforma as listed below.

Nine-point hedonic scale for sensory evaluation multigrain muffins

DATE: _____					TIME: _____	
NAME OF THE PANELIST: _____						
Sample: "Multigrain muffin"						
Instructions: you are requested to judge the sample on the 9 points hedonic scale for the parameters listed below:						
Sample no.	Colour	Appearance	Taste	Flavour	Texture	Overall acceptability
Quality grade distribution			Score	Quality grade distribution		
Like extremely			9	Dislike slightly		
Like very much			8	Dislike moderately		
Like moderately			7	Dislike very much		
Like slightly			6	Dislike extremely		
Neither like nor dislike			5			
Comments if any: _____						
						Signature _____

Microbiological analysis

The developed muffins were microbiologically tested for aerobic plate count, yeast and mould count, and coliform count using Ranganna (2004) method.

Aerobic plate count

In a test tube, mix 1 ml muffin sample with 9 ml sterile distilled water. Wait 10 minutes. Plate replicates with 1 ml diluted sample (Ranganna, 2004). Transfer 15 ml of molten nutritional agar to sterile petri plates in laminar airflow. Mix and chill. Incubate petri plates inverted at $37 \pm 0.5^\circ\text{C}$ for 24 hours in an incubator (Khera Instruments Pvt. Ltd., New Delhi). Digital colony counter (Labtronics, Ahmedabad) counted cfu/ml colonies.

Yeast and mold count

In a test tube, add 1 ml of muffin sample to 9 ml of

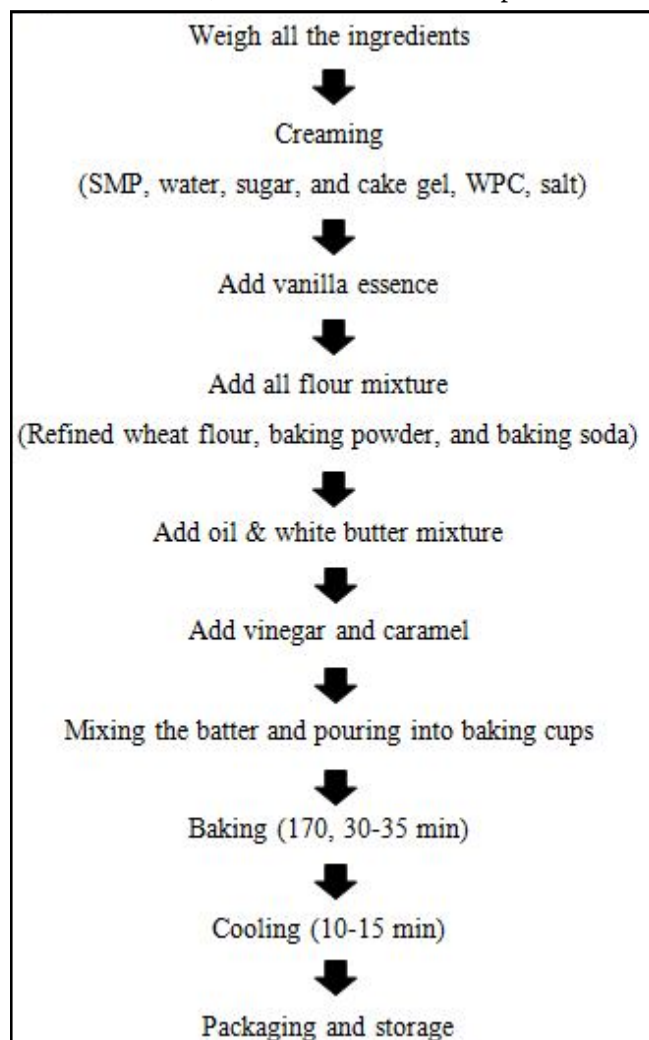
Table 3: Proximate composition of foxtail, barnyard millet flour and muffins.

Parameter	Foxtail millet flour		Barnyard millet flour		Control muffins		Developed muffins	
	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis	Wet basis	Dry basis
Moisture (%)	7.58±0.12	-	8.05 ± 0.11	-	20.61±0.16	-	20.49±0.19	-
Protein (%)	12.30± 0.11	13.31±0.13	9.40± 0.12	10.22 ± 0.13	4.25 ± 0.05	5.35±0.04	7.36±0.08	9.26 ± 0.05
Fat (%)	4.69±0.09	5.07±0.09	3.99± 0.07	4.34 ± 0.03	12.69±0.21	15.98±0.19	13.84±0.14	17.41 ± 0.17
Crude fiber (%)	7.40± 0.09	8.00± 0.08	10.50±0.15	11.42±0.11	0.54±0.01	0.68±0.02	1.98±0.01	2.49±0.01
Ash (%)	1.37±0.01	1.48±0.01	0.45±0.03	0.49±0.01	0.89±0.002	1.12±0.001	0.48±0.001	0.60±0.001
Carbohydrate (%) (by difference)	74.06±0.36	80.13±0.44	78.11±0.56	84.95±0.34	61.56±0.38	77.54±0.29	57.83±0.33	72.73±0.32

sterile distilled water. Keep it for 10 minutes. Then use 1 ml of diluted sample for plating in duplicates (Ranganna, 2004). Aseptically pour 15 ml of molten potato dextrose agar (PDA) into sterile petri plates. Mix the contents, and allow it to cool. Put the petri plates in inverted position, and incubate at 25±0.5°C for 48-72 h inside incubator. Colony was counted using digital colony counter, and was reported as number of cfu/ml.

Coliform count

In a test tube, add 1 ml of muffin sample to 9 ml of

**Fig. 1:** Flow chart of Preparation of multigrain muffins.

sterile distilled water. Keep it for 10 minutes. Then use 1 ml of diluted sample for plating in duplicates (Ranganna, 2004). Aseptically pour 15 ml of molten MacConkey agar into sterile petri plates. Mix the contents, and allow it to cool. Put the petri plates in inverted position, and incubate at 37±0.5°C for 48 h inside incubator. Colony was counted using digital colony counter, and was reported as number of cfu/ml.

Shelf-life study

LDPE and PP were used to pack muffins. Muffins were stored at room temperature until organoleptically satisfactory. To estimate the shelf life of muffins, they were stored at 30±2°C and tested for moisture content, textural qualities, peroxide value, microbiological (APC, yeast & mold, coliform), and sensory evaluation. Standard protocols were used to assess muffin moisture, textural, and sensory qualities every three days during storage.

Statistical analysis

Completely randomized design (CRD) was used for the data analysis and standardization of the muffins.

Results and Discussion

The proximate composition of barnyard millet and foxtail millet, characterization of their flour, optimization of their levels in multigrain muffins, and physicochemical properties of optimized multigrain muffins are the objectives of this study.

Proximate composition of foxtail and barnyard millet flour

The proximate composition of foxtail millet flour on wet and dry basis is given in Table 3. On a wet basis, foxtail millet flour had 7.58 % moisture, 4.69 % fat, 12.30 % protein, 1.37 % ash, 7.40 % crude fiber and 74.06 % carbohydrate. The 5.07 % fat, 13.31 % protein, 1.48 % ash, 8.00 % crude fiber, and 80.13 %, carbohydrate make up the dry weight of foxtail millet flour. Similar results were observed by Hasan *et al.*, (2019).

Proximate composition of barnyard millet flour is given in Table 3. On a wet basis, barnyard millet flour had 8.05 % moisture, 3.99 % fat, 9.40 % protein, 0.45 % ash,

Table 4: Effect of incorporation of foxtail and barnyard millet flour on baking, textural and sensory quality of multigrain muffins.

Treatment	Levels of flour (%)			Specific volume (cm ³ /g)	Hardness (N)	Gumminess	Sensory score					
	WF	FM	BM				C	Ap	T	F	Tex	OA
Control	100	-	-	2.59	1682.33	1759.73	7.83	7.66	8.16	8.00	8.33	7.98
T ₁	85	5	10	2.52	2417.03	2536.32	7.67	7.66	7.66	7.66	7.50	7.67
T ₂	75	5	20	2.57	3335.78	2866.52	8.33	8.33	8.16	8.33	8.16	8.20
T ₃	65	5	30	2.55	3109.51	2611.17	7.66	7.83	7.67	7.66	7.66	7.66
T ₄	80	10	10	2.49	3292.56	3124.27	7.67	7.67	7.16	7.00	7.33	7.67
T ₅	70	10	20	2.47	3863.36	3701.86	7.67	7.67	6.50	6.83	7.33	7.67
T ₆	60	10	30	2.44	3260.99	3023.62	7.50	7.50	6.33	6.33	7.33	7.50
T ₇	75	15	10	2.48	2767.37	2547.19	7.33	7.33	5.66	6.00	7.16	7.33
T ₈	65	15	20	2.47	3980.84	3405.88	7.16	7.33	5.50	5.66	7.00	7.16
T ₉	55	15	30	2.50	3361.81	3381.48	7.16	7.33	5.16	5.33	6.68	7.16
Treatment				*	*	*	*	*	*	*	*	*
S.E.m. ±				0.01	216.81	202.70	0.183	0.183	0.217	0.23	0.149	0.122
C.D. (%)				0.03	639.59	597.97	0.424	0.542	0.646	0.682	0.343	0.341
C.V. (%)				0.60	12.12	12.17	4.161	4.14	5.53	5.78	3.47	2.90
C: Color; Ap: Appearance; T: Taste; F: Flavor; Tex: Texture; OA: Overall acceptability (FM: Foxtail millet flour, BM: Barnyard millet flour, WF: Wheat flour, ‘*’ = 5 % level of significant, NS: Non-significant)												

10.50 % crude fiber and 78.11 % carbohydrate (by difference). The 4.34 % fat, 10.22 % protein, 0.49 % ash, 11.42% crude fiber, and 84.95 % carbohydrate (by difference) make up the dry weight of barnyard millet flour. The results were matching with findings given by Singh *et al.*, (2022).

Standardization of foxtail and barnyard millet flour in multigrain muffins

Wheat flour replaced with foxtail (5, 10, and 15%)

Table 5: Baking and sensory properties of muffins.

Parameter	Control muffins	Developed muffins
Weight (g)	37.43 ± 1.73	38.43 ± 1.13
Volume (cm ³)	52.35 ± 2.11	53.65 ± 2.31
Specific volume (cm ³ /g)	2.58 ± 0.017	2.57 ± 0.013
Sensory Evaluations		
Colour	7.45 ± 0.11	7.95 ± 0.16
Appearance	7.89 ± 0.15	8.11 ± 0.11
Flavour	8.05 ± 0.14	8.56 ± 0.13
Texture	7.69 ± 0.15	8.31 ± 0.13
Taste	8.03 ± 0.10	8.39 ± 0.12
Overall acceptability	7.82 ± 0.10	8.27 ± 0.15
Peroxide value (meq O ₂ /kg)	3.26 ± 0.21	3.43 ± 0.17
Water activity	0.647 ± 0.19	0.673 ± 0.11
Colour value		
L*	71.46 ± 0.71	73.78 ± 0.89
a*	2.71 ± 0.19	2.37 ± 0.13
b*	30.86 ± 0.21	28.47 ± 0.19
n: Mean of three repetitions (Baking properties); n: Mean of nine repetitions (Sensory Evaluation)		

and barnyard (10, 20, and 30%) millet flour. The produced multigrain muffins were tested for sensory evaluation, textural qualities (hardness, gumminess, resilience, springiness), and overall acceptance.

Multigrain muffins made with 5% foxtail millet flour, 20% barnyard millet flour, and 75% wheat flour obtained the highest volume, textural property, and acceptance score. In comparison to other muffins, the developed ones have 2.58 cm³/g specific volume, 3335.784 N hardness, 2866.525 gumminess, 0.111 resilience, 1.00 springiness, and 8.27 overall acceptability based on baking quality, textural quality, and overall acceptability, for additional storage testing, 5% foxtail millet flour, 20% barnyard millet flour, and 75% wheat flour muffins were best (Table 4). Physicochemical, baking, and organoleptic tests were performed on multigrain muffins. Optimized multigrain muffins made with 5% foxtail millet flour, 20% barnyard millet flour, and 75% wheat flour using normal method.

Baking quality of muffins

Optimized multigrain muffin had 38.43 g weight, 53.65 cm³ volume, and 2.58 cm³/g specific volume, while control muffin was 37.43 g, 52.35 cm³, and 2.58 cm³/g specific volume (Table 5). The specific volume of muffins affected with increased level of foxtail and barnyard millets. The data revealed from studies of Donelson *et al.*, (1988) showed that loss of volume of cake was observed with incorporation of starch tailing of water solution fraction for cake making.

Sensory quality of muffins

Table 6. Effect of packaging material on moisture content (%) of multigrain muffins at ambient storage condition.

Days	Moisture content (%)			Peroxide value (meq O ₂ /kg)			Hardness (N)			Overall acceptability		
	LDPE	PP	Mean	LDPE	PP	Mean	LDPE	PP	Mean	LDPE	PP	Mean
0	22.76	22.76	22.76	3.42	3.26	3.34	3459.56	2998.98	3229.27	8.02	8.22	8.12
2	21.62	21.86	21.74	3.56	3.34	3.45	3598.11	3239.78	3418.94	7.92	8.10	8.01
4	20.66	21.42	21.04	3.63	3.51	3.57	4207.75	4656.50	4432.13	7.44	7.50	7.47
6	18.45	20.58	19.52	4.02	3.52	3.77	4771.35	5158.97	4965.16	7.04	7.25	7.15
8	17.15	20.10	18.62	4.51	4.11	4.31	5035.52	5577.16	5306.34	6.78	6.83	6.80
Mean	20.13	21.35		3.83	3.55		4214.46	4326.28		7.44	7.58	
Variable	S.E.m. ±	C.D. (5%)	C.V. %	S.E.m. ±	C.D. (5%)	C.V. %	S.E.m. ±	C.D. (5%)	C.V. %	S.E.m. ±	C.D. (5%)	C.V. %
P	0.088	0.258	1.64	0.029	0.086	1.26	98.128	NS	8.90	0.024	0.072	1.26
S	0.138	0.409		0.046	0.136		155.154	457.705		0.039	0.114	
P×S	0.196	0.578		0.065	0.192		219.422	NS		0.055	NS	

(n: Mean of three replications, LDPE: Low density polyethylene, PP: Polypropylene, P: Packaging material, S: Storage period, P×S: Interaction)

On a 9-point hedonic scale, judges assessed muffins' organoleptic quality based on color, appearance, taste, flavor, texture, and overall acceptability. Table 4 shows control and optimized multigrain muffin sensory scores. An optimized muffin outperformed the control muffin in all parameters, showing considerable sensory quality improvements. The optimized muffin got 7.95 for color, 8.11 for appearance, 8.56 for flavor, 8.31 for texture, 8.39 for taste, and 8.27 for overall acceptability. Increased sensory scores indicate that the optimization method produced a more appealing muffin. On the 9-point hedonic scale, Goswami *et al.*, (2015) made gluten-free muffins with 100% barnyard millet flour scored 6.98, 6.85, and 7.09 for taste, texture, and overall acceptability. Increased replacement of millets at slightly higher levels caused increase in hardness of muffins. Similar findings were observed by Nazni and Karuna (2016).

Chemical composition of muffins

The proximate composition of control and developed muffins on wet and dry basis is given in Table 5. On dry basis, control muffins had 5.35 % protein, 15.98 % fat, 0.68 % fibre, 1.12 % ash and 77.54 % carbohydrates (calculation by difference). The control muffins had 3.26 meq O₂/kg of peroxide value, 0.65 water activity, 72.46 L*-value, 2.71 a*-value and 30.86 b*-value. On dry basis, developed muffins had 9.26 % protein, 17.41 % fat, 2.49 % fibre, 0.60 % ash and 72.73 % carbohydrates (calculation by difference). The developed muffins had 3.43 meq O₂/kg of peroxide value, 0.67 water activity, 73.78 L*-value, 2.37 a*-value and 28.47 b*-value (Table 3 and Table 5).

Shelf-life study of developed multigrain muffins

Based on baking and sensory quality, multigrain muffins made with 5% foxtail millet flour, 20% barnyard millet flour, and 75% wheat flour were optimized. To

assess shelf life, optimized muffins were packaged in LDPE and PP and stored at 30 ± 2°C until acceptable on textural, sensory, and microbiological quality. Standard approach was used to assess muffins for moisture, textural qualities, peroxide value, sensory quality, and microbiological content (aerobic plate count, yeast and mold count, and coliform count) every two days during storage.

Effect of packaging material on moisture content (%) of multigrain muffins at ambient storage condition

Table 6 illustrates the variations in moisture content of multigrain muffins packaged in LDPE and PP materials maintained under ambient conditions. The moisture content of multigrain muffins enclosed in LDPE packaging diminished dramatically from 22.76% on day 0 to 17.15% by day 8 under ambient storage. The moisture content of multigrain muffins encased in PP packaging material dramatically diminished from 22.76% on day 0 to 20.10% by day 8 during ambient storage. Data indicates that PP material is superior to LDPE material in preserving the moisture content of multigrain muffins during ambient storage. The individual effects of packing material, storage duration, and their combination on the moisture content of multigrain muffins packaged in LDPE and PP were shown to be significant during the ambient storage period (30 ± 2°C). Jadhav *et al.*, (2021) showed that Jaggery muffins had higher water activity (aw) and lower pH and sensory score than sugar muffins.

Effect of packaging material on peroxide value of multigrain muffins at ambient storage condition

Table 6 displays the alterations in peroxide value of multigrain muffins packaged in LDPE and PP materials, held under ambient settings (30 ± 2°C). The peroxide value of multigrain muffins enclosed in LDPE packaging

escalated from 3.42 meq O₂/kg on day 0 to 4.51 meq O₂/kg on days 8 during ambient storage. The peroxide value of multigrain muffins packaged in PP material considerably rose from 3.26 meq O₂/kg on day 0 to 4.11 meq O₂/kg by days 8 during ambient storage. The peroxide value, measured in milliequivalents of oxygen per kilogram (meq O₂/kg), reveals the oxidation of lipids and reflects the freshness and stability of the muffins.

Effect of packaging material on hardness (N) of multigrain muffins at ambient storage condition

Table 6 displays the variations in hardness (N) of multigrain muffins packaged in LDPE and PP packing materials and kept at room temperature. Over the course of the ambient storage period, the multigrain muffins' hardness (N), which was 3459.56 N on day 0 and 5035.52 N on day 8 when packaged in LDPE, increased significantly. The hardness (N) of multigrain muffins packaged in PP packaging material increased significantly from 2998.98 N on day 0 to 5577.16 N by days 8. During the storage period, multigrain muffins packed in PP packaging material experienced a greater increase in hardness than those placed in LDPE packaging. According to data, LDPE material outperforms over the PP material in maintaining the hardness (N) of multigrain muffins during ambient storage. For multigrain muffins packed in LDPE and PP, the individual effects of packaging material and interaction on hardness (N) were found to be non-significant, whereas the individual effects of storage time were significant during the ambient storage period (30±2°C). Hardness is a peak force required to compress of multigrain muffins to maximum extent. Goswami *et al.*, (2015) reported the hardness of barnyard millet muffins at 3459.54 (N), while Bhaduri *et al.*, (2015) reported a comparatively higher value for hardness for gluten free rice muffins.

Effect of packaging material on overall acceptability score of multigrain muffins at ambient storage condition

Table 6 illustrates the variations in the overall acceptability of multigrain muffins packaged in LDPE and PP materials under ambient storage conditions. The overall acceptability score of multigrain muffins packaged in LDPE material dramatically declined from 8.02 on day 0 to 6.78 on days 8 at ambient storage. The overall acceptability score of multigrain muffins packaged in PP material dramatically declined from 8.22 (day 0) to 6.83 (day 8) during the ambient storage. The overall acceptance score indicates the general customer preference for food products. Data indicates that PP material is superior than LDPE material in maintaining the overall acceptability of multigrain muffins during

ambient storage. The individual impact of packaging material and storage duration on the overall acceptability score of multigrain muffins made from foxtail and barnyard millet flour was significant over the storage period, whereas the interaction between packaging material and storage duration on the overall acceptability score was non-significant. Multigrain muffins packaged in LDPE and PP materials remain suitable for consumption until the eighth day under ambient storage conditions. The panel of judges expressed moderate approval on the eighth day of the storage period.

Effect of packaging material on microbial load of multigrain muffins at ambient storage condition

The microbiological load (plate count, yeast and mold count, and coliform count) of the multigrain muffin including foxtail and barnyard millet flour was assessed according to conventional procedures. The microbial examination of multigrain muffins packaged in LDPE and PP materials was conducted at two-day intervals. No visible increase in microbial load was seen until the eighth day of storage for both packing materials, LDPE and PP. Microbial growth was evident on the ninth day of the storage period; therefore, the shelf-life study for multigrain muffins was terminated. Multigrain muffins containing foxtail and barnyard millet flour exhibited acceptable baking quality, peroxide value, textural properties, organoleptic quality, and microbial content for up to 8th days packed in LDPE and PP packaging material stored at ambient conditions (30±2°C) without any chemical preservatives. The multigrain muffins possess a shelf life of 8 days under ambient storage conditions (30±2°C) for both types of packing materials.

Conclusions

Muffins composed of 5% foxtail millet flour, 20% barnyard millet flour, and 75% wheat flour exhibited optimal baking and sensory characteristics for subsequent shelf-life analysis. The optimal multigrain muffins include 20.49% moisture, 7.36% protein, 13.84% fat, 1.98% fiber, 0.48% ash, and 57.83% carbohydrates. The peroxide value of the optimized multigrain muffin was 3.43 meq O₂/kg of oil. The water activity of the optimized muffin was marginally elevated (0.67) in comparison to the control muffin (0.65). The L*, a*, and b* values of the optimized multigrain muffins were 73.78, 2.73, and 28.47, respectively. The weight, volume, and specific volume of multigrain muffins were 38.43 g, 53.65 cm³, and 2.57 cm³/g, respectively. The optimized multigrain muffins received scores of 7.95, 8.11, 8.56, 8.31, 8.39, and 8.27 for color, appearance, flavor, texture, taste, and overall acceptability, respectively. The moisture level of LDPE and PP packed multigrain muffins was 17.15% and

20.10%, respectively, on the eighth day of the storage period. The peroxide value of multigrain muffins enclosed in LDPE packaging rose dramatically from 3.42 meq O₂/kg on day 0 to 4.51 meq O₂/kg by day 8 during ambient storage. The peroxide value of multigrain muffins packaged in PP material rose significantly from 3.26 meq O₂/kg on day 0 to 4.11 meq O₂/kg by day 8 under ambient storage. The total acceptance score of multigrain muffins packaged in LDPE material was 6.78 on the eighth day of the storage period. The total acceptance score of multigrain muffins packaged in polypropylene material was 6.83 on the eighth day of the storage period. No visible microbiological development was seen in multigrain muffins packaged in LDPE and PP materials until the eighth day of the storage period. Multigrain muffins remained satisfactory until the eighth day of the storage period. Following eight days of ambient storage, the muffins harden significantly, which was unfavourable to the sensory panellists. Consequently, the shelf-life investigation was terminated on the ninth day.

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