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Formulation and standardization of cookies with incorporation of finger millet and barnyard millet

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Abstract

Finger millet and barnyard millet are nutrient dense grains, rich in carbohydrates, protein, dietary fibre, iron, zinc, calcium, vitamins and antioxidants. This study aimed to develop eight variations of cookies by incorporating finger millet and barnyard millet flour at 10%, 20%, 30% and 40% composition, respectively, 100% refined wheat flour was utilized to develop the control batch. Refined wheat flour, finger millet flour and barnyard millet flour in 80:10:10, 70:15:15, 60:20:20 and 50:25:25 proportions were used to formulate four different formulations of cookies. All the thirteen formulations of biscuits were evaluated for different organoleptic parameters using 9-point Hedonic rating scale, followed by proximate, mineral and antioxidant profile analysis. The cookies incorporated with 30% and 40% barnyard millet flour (BT_3 and BT_4), 20% and 30% finger millet flour (FT_2 and FT_3) and 15% and 20% mixed millet flour (MT_2 and MT_3) were highly acceptable by panellists. The proximate composition of highly accepted barnyard millet cookies had higher content of fibre (1.76-2.5 vs. 0.36 g), total ash (2.03-2.25 vs. 1.48 g), iron (6.45-7.7 vs. 2.7 mg) along with phosphorous (169-185 vs. 121 mg) in comparison with the control one per 100 g. Finger millet cookies had more amount of total ash (1.52-1.59 g), fibre (0.95-1.28 g), fat (13.69-14.07 g), calcium (87.2-119.3 mg), iron (2.94-3.06 mg) and phosphorous (153.4-169.6 mg) than that of control cookies per 100g. Mixed millet cookies contained significantly higher concentration of fat (13.45-13.85 g), total ash (2.06-2.23 g), fibre (1.87-2.43 g), calcium (69.3-84.8 mg), iron (4.75-5.44 mg) and phosphorous (169.3-185.4 mg) as compared to the control, barnyard millet and finger millet cookies.

1. Introduction

Millets are recognized as smart and superfoods (Rao *et al*., 2021). The major millets include sorghum (jowar), pearl millet (bajra) and finger millet (ragi) while minor millets consist of proso millet, little millet, barnyard millet, kodo millet and foxtail millet. These gluten-free grains (Zeenath *et al.,* 2024) are commonly consumed in India, China, Africa and other regions. Millets are nutritionally rich, providing high-quality protein with a balanced amino acid profile along with fibre, magnesium, niacin, manganese, phosphorus, potassium, iron, thiamine, niacin, riboflavin, pantothenic acid and vitamin A and tocopherol (Shreeja *et al*., 2021). Finger millet (*Eleusine coracana* (L.) Gaertn.), *i.e.*, ragi, rapoko, mandia, nachni and dagusa, is a major small millet widely consumed as a staple food. It contains approximately 81.5% carbohydrates, 18-20% dietary fibre, 65-75% starch, 9.8% protein, 1-1.7% fat, 2.7% minerals and 4.3% crude fibre (Saleh *et al.*, 2013). 100 g of ragi provides 305 kcal of energy, 72 g carbohydrates, 11.5 g dietary fibre, 7.3 g protein, 1.3 g fat, 344 mg of calcium, 3.9 mg of iron, 137 mg magnesium, 283 mg of phosphorous, 408 mg potassium, 14 mg sodium and 2.3 mg zinc and 13.1% moisture (Gopalan *et al.*, 1989). Being the richest source available in cheap price, "Poor man's milk" is another name used for finger millet. It is believed to contain highest amount of iodine among all cereals.

Barnyard millet (*Echinochloa frumantacea*), also known as billion-dollar grass, sawan millet, bhagar, jhangora, oodalu, samo, shyamak is rich in carbohydrate (51.5-62%), protein (11.2-12.7%), dietary fibre (8.1-16.3%), iron (15.6-18.6%), phytate (3.30-3.70%). It contains ample quantity zinc, essential amino acids and vitamins (Singh *et al.*, 2010; Saleh *et al.*, 2013). Barnyard millet contains polyphenols and carotenoids twice that of finger millet (Panwar *et al.*, 2016). Barnyard millet is rich in phytochemicals and dietary fibre, contributing to the management of colon cancer and cardiovascular diseases by exhibiting antioxidant, anti-inflammatory and cholesterol-lowering properties, promoting overall health benefits (Vandana, 2018). Barnyard millet is reported to contain several antioxidants such as phytates, tannins, flavonoids and other

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polyphenols that scavenge oxidative enzymes leading to lipid peroxidation and provide protection against oxidative stress, diabetes mellitus, cardiovascular diseases, obesity and cancer like degenerative disease (Selvan *et al.*, 2023; Sushree and Neena, 2024).

Bakery products are ready-to-eat, convenient snack items enjoyed by people across all age groups. Among these, biscuits and cookies are the most widely consumed, typically made from refined wheat flour. However, refined wheat flour is high in starch and has a high glycaemic index, which increases the risk of lifestyle disorders such as obesity, diabetes mellitus and gluten sensitive enteropathy. Millets, known for their low glycaemic index and gluten free properties, offer a promising alternative to partially or completely replace refined wheat flour in the preparation of cookies and biscuits. Several studies have explored the incorporation of various millets into baked food items including cookies, muffins and biscuits to enhance their nutritional and functional value (Anju and Sarita, 2010; Krishnan *et al*., 2011; Saha *et al*., 2011; Shading and Jaganathan, 2014; Nazni and Karuna, 2016; Shrestha and Srivastava, 2017; Thejasri *et al*., 2017; Kishorgoliya *et al*., 2018; Salunke *et al*., 2019; Kaur *et al*., 2020; Sushree and Gitanjali, 2023). This study aimed to develop value-added cookies by incorporating finger millet and barnyard millet. The specific objectives included standardizing the formulation of millet-based cookies by substituting refined wheat flour and assessing their physiochemical properties.

2. Materials and Methods

2.1 Acquiring of raw ingredients

The raw ingredients, including refined wheat flour (RWF), barnyard millet (BM), finger millet (FM), sugar and butter, were procured from local market in Bhubaneswar, Odisha, India.

2.2 Preparation of barnyard millet and finger millet flour

The barnyard millet and finger millet grains obtained from the market were thoroughly cleaned and washed with tap water to eliminate dirt, soil and other impurities. Then, the cleaned finger millet and barnyard millet grains were sundried and grounded with the help of a pulveriser and sieved using 60 mesh size sieve to obtain fine flour. The finger millet and barnyard millet flours were stored in air tight glass jars for further research work.

2.3 Formulation of cookies

Various proportions of refined wheat flour (RWF), finger millet flour (FMF) and barnyard millet flour (BMF) were combined with a fixed quantity of 25 g icing sugar and 50 g butter. The cookies were prepared using the creaming method. The butter was creamed till it became smooth and creamy. Sugar was added into the creamy butter and beaten to obtain a light and fluffy mixture with which the flours were mixed uniformly. A control batch was made with 100% refined wheat flour. Eight variations of cookies were developed by incorporating BMF and FMF separately at levels of 10%, 20%, 30% and 40%, labelled as BT_1, BT_2, BT_3, BT_4 (for BMF) and FT_1, FT_2, FT_3, FT_4 (for FMF). Additionally, four variations were prepared using RWF along with a blend of FMF and BMF in ratios of 80:10:10, 70:15:15, 60:20:20 and 50:25:25, designated as MT_1, MT_2, MT_3 and MT_4. To prepare the cookies, 25 g of icing sugar and 50 g of butter were whisked by hand for 2-3 min until a smooth, creamy consistency was achieved. The flours in their respective proportions were then gradually added and mixed thoroughly to prepare the dough which was rolled out evenly, cut into desired shapes and baked at 180°C for 20 min. The oven was pre-heated for 10 min at 180°C prior to baking. Once baked the cookies were cooled and kept in airtight glass containers.

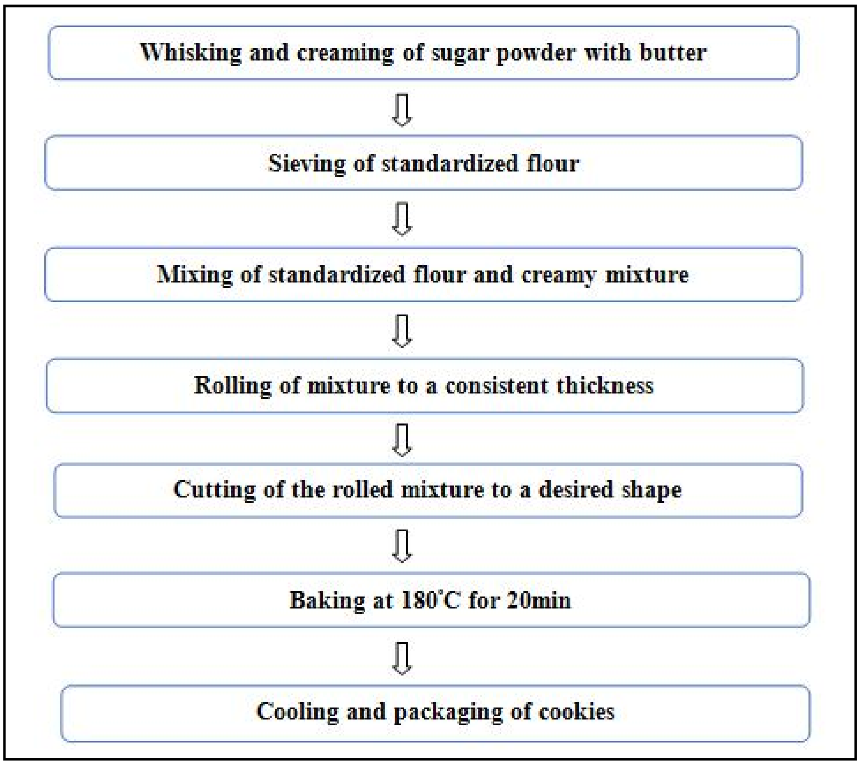

Figure 1: Process flowchart for biscuit preparation.

2.4 Organoleptic evaluation of the developed cookies

Twelve millet incorporated cookie formulations along with control cookies were evaluated by thirty semi-trained panellists for organoleptic attributes including colour, texture, taste, flavour and overall acceptability using a nine-point Hedonic scale (Peryam and Girardot, 1952).

2.5 Physical properties evaluation of the developed cookies

The thickness of the cookies was measured with the help of Vernier calliper, while their diameter was determined using the edge-to-edge method with a scale. The spread ratio was calculated using the formula W/T, where W: diameter and T: thickness of cookies. Baking loss, a physical parameter was assessed by taking weight of five cookies both in pre and post baking phases. It was expressed as the difference in weight between the pre and post baking measurements.

2.6 Nutrient analysis of the developed cookies

The proximate analysis of moisture, fat, protein, mineral and crude fibre was estimated by AOAC method (2007). Moisture content of the developed products was determined by using hot air oven drying methods of (AOAC, 2007). The carbohydrate content was calculated by difference method by subtracting the total amount of moisture, fat, protein, ash and fibre content from 100. Kjeldahl method was used to determine the crude protein content of the developed cookies in KELPLUS Automatic Nitrogen estimator system by following the digestion, distillation and titration processes (AOAC, 2007). Amount of fat of the food sample was determined by the Soxhlet method (AOAC, 2007). The concentration of minerals, *i.e.,* iron, calcium and phosphorous was determined by using inductively coupled plasma optical emission spectrometry (ICP-OES) method.

2.7 Determination of phytochemicals of the developed cookies

To prepare the cookie extract, 1g cookie sample was soaked in 25 ml ethanol, then agitated using a shaker for 24 h. The mixture was then centrifuged at 10,000 rpm for 15 min. After centrifugation, the solution was filtered using Whatman No. 41 filter paper and clear supernatant was carefully separated. The final volume of the supernatant was made 25 ml and kept at 4°C for further analysis of phenolic content and radical scavenging activity. The total phenolic content of the cookie extract was estimated following the method outlined by Wu *et al*. (2007), using a gallic acid standard curve for comparison. The results were expressed as gallic acid equivalents (GAE) per gram of cookie sample. To evaluate radical scavenging activity, the DPPH assay was employed, as mentioned by Akillioglu and Karakaya (2010). For the estimation of total flavonoid content, the method by Zhisen *et al*. (1999) was followed. A 0.1 ml aliquot of cookie extract was mixed with 4.9 ml of distilled water and 0.3 ml of $NaNO_2$. After 5 min, 0.3 ml of $AlCl_3$ was added, followed by 2 ml of 1M NaOH at the 6 min mark. The mixture was diluted to a final volume of 10 ml with distilled water, thoroughly mixed and the absorbance was recorded in spectrophotometer at 510 nm. A standard curve using catechin hydrate was prepared and the total flavonoid content was expressed as mg catechin equivalents per 100 g of the cookie sample.

2.8 Statistical analysis of data

The collected data was systematically organized, tabulated and subjected to statistical analysis. Analysis of variance (ANOVA) and paired t-test were employed to interpret the differences among variations for individual sensory attributes and nutrient composition by using Microsoft Excel (version 2019).

3. Results

3.1 Organoleptic evaluation of the developed cookies

The developed cookies T_0, BT_1, BT_2, BT_3 and BT_4 scored 8.0, 7.2, 7.1, 7.3 and 7.4 respectively for colour. Mean scores for texture of T_0, BT_1, BT_2, BT_3 and BT_4 were calculated 7.8, 7.2, 7.1, 7.3 and 7.4, respectively. T_0, BT_1, BT_2, BT_3 and BT_4 showed 8.1, 7.0, 7.2, 7.4 and 7.5, respectively as scores for flavour. Mean scores for taste of T_0, BT_1, BT_2, BT_3 and BT_4 were 8.0, 7.2, 7.3, 7.5 and 7.6, respectively. T_0, BT_1, BT_2, BT_3 and BT_4 showed 8.1, 7.0, 7.1, 7.3 and 7.5, respectively, for overall acceptability. The control and BT_1 cookies had highest and lowest organoleptic scores, respectively. The BT_2 and BT_3 were highly acceptable by panellists (Figure 2).

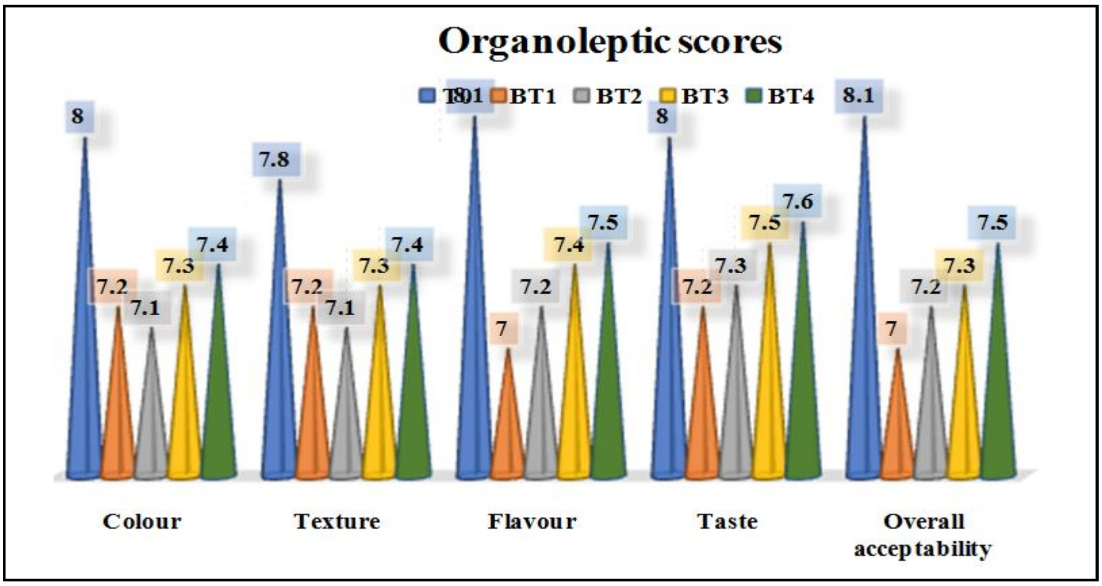

Figure 2: Organoleptic scores for different formulation of barnyard millet cookies.

The cookies T_0, FT_1, FT_2, FT_3 and FT_4 showed scores of 7.9, 7.2, 7.3, 7.4 and 6.9, respectively, for colour. Mean scores for texture of T_0, FT_1, FT_2, FT_3 and FT_4 were observed to be 8.2, 7.3, 7.4, 7.6 and 6, respectively. T_0, FT_1, FT_2, FT_3 and FT_4 obtained 8.1, 6.8, 7.2, 7.5 and 6.1, respectively, for flavour. Mean scores for taste of T_0, FT_1, FT_2, FT_3 and FT_4 were 8.1, 7.0, 7.4, 7.5 and 6.5, respectively. T_0, FT_1, FT_2, FT_3 and FT_4 showed 7.7, 6.9, 7.1, 7.3 and 6.2, respectively, as scores for overall acceptability. The cookies made with RWF (T_0) had highest score and FT_4 had lowest with respect to all organoleptic parameters. FT_2 and FT_3 cookies got highest acceptance by panellists (Figure 3).

The cookies T_0, MT_1, MT_2, MT_3 and MT_4 got 7.9, 7.1, 7.2, 7.5 and 6.3 respectively for colour. Mean scores for texture of T_0, MT_1, MT_2, MT_3 and MT_4 were 8.0, 7.2, 7.3, 7.4 and 6.8, respectively. T_0, MT_1, MT_2, MT_3 and MT_4 showed 8, 7.2, 7.3, 7.4 and 6.8, respectively, for flavour. Mean scores for taste of T_0, MT_1, MT_2, MT_3 and MT_4 were 7.9, 7.0, 7.2, 7.4 and 6.9, respectively. T_0, MT_1, MT_2, MT_3 and MT_4 showed overall acceptability scores 8, 6.9, 7.1, 7.4 and 6.6, respectively. The control and MT_4 obtained highest and lowest organoleptic scores. The MT_2 and MT_3 cookies were highly acceptable by panellists (Figure 4).

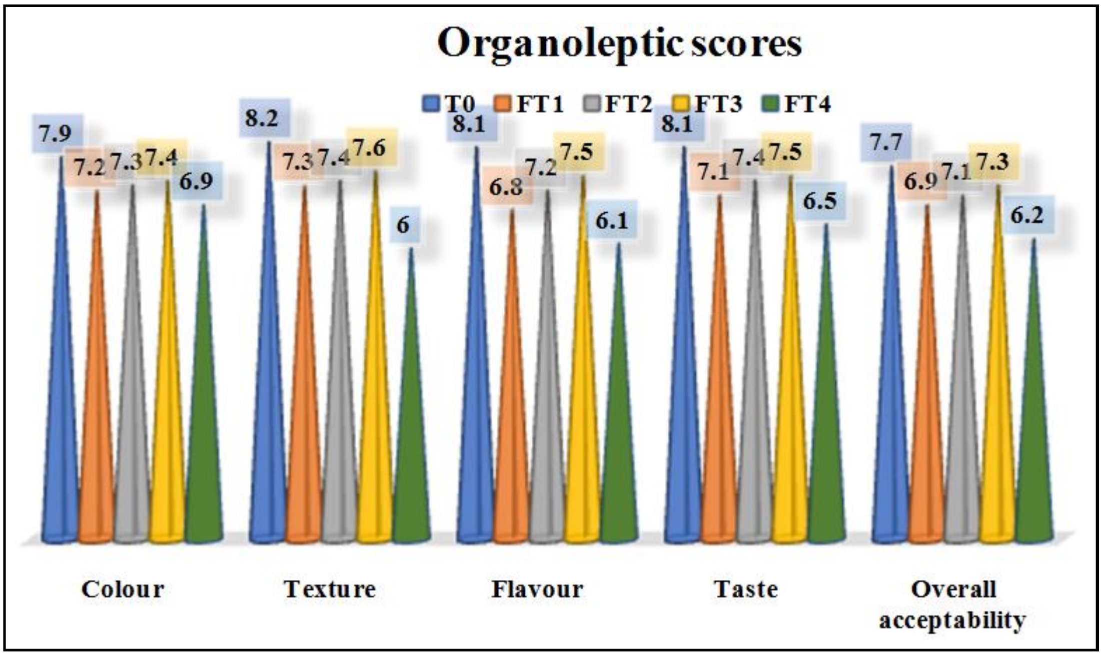

Figure 3: Organoleptic scores for different formulation of finger millet cookies.

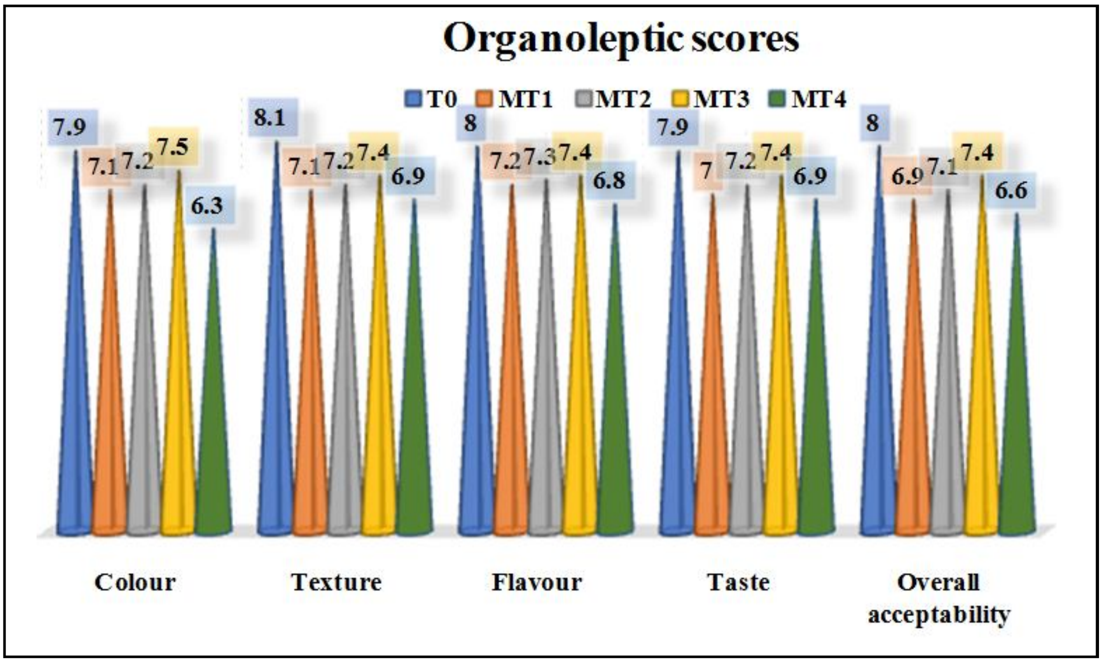

Figure 4: Organoleptic scores for different formulation of mixed millet cookies.

Table 1: Physical properties of control and most preferred cookies

Treatments	Weight (g)	Thickness (mm)	Diameter (mm)	Spread ratio	Bake loss (g/100 g)
T_0	12.15 ± 0.11	7.67 ± 0.40	51.12 ± 0.02	5.64 ± 0.04	16.67 ± 0.25
BT_3	13.21 ± 0.16	8.36 ± 0.13	51.56 ± 0.15	6.08 ± 0.05	15.72 ± 0.17
BT_4	13.48 ± 0.14	8.42 ± 0.11	51.43 ± 0.12	6.17 ± 0.03	15.36 ± 0.11
FT_2	13.46 ± 0.10	8.38 ± 0.12	50.87 ± 0.10	6.25 ± 0.02	15.85 ± 0.13
FT_3	13.39 ± 0.13	8.45 ± 0.10	50.73 ± 0.16	6.31 ± 0.04	15.68 ± 0.10
MT_2	14.02 ± 0.11	8.47 ± 0.09	50.77 ± 0.11	6.52 ± 0.03	15.82 ± 0.14
MT_3	14.16 ± 0.12	8.50 ± 0.10	50.82 ± 0.15	6.57 ± 0.06	15.91 ± 0.10

Note: Values are mean ± SE of three replications.

3.2 Physical and nutritional characteristics of the developed cookies

The weight of the cookies ranged between 12.15-14.16 g which increased with percentage of millet flours. Thickness of cookies also ranged from 7.67 mm to 8.5 mm. Diameter of cookies decreased from 51.12 mm to 50.82 mm with increasing concentration of millet flours. The spread ratio of control and MT_3 cookies was observed to be lowest and highest respectively. Addition of millet flours enhanced the spread ratio of cookies. Baking loss was highest in control cookies (T_0), *i.e.*, 16.67 and lowest in barnyard millet cookies, *i.e.,* BT_3 (Table 1).

Table 2: Proximate composition of barnyard millet cookies (per 100 g on dry matter basis)

Nutrients (per 100 g)	T_0	BT_1	BT_2	BT_3	BT_4	CD @ 5%
Moisture (%)	5.23 ± 0.02^a	1.04 ± 0.008^d	4.56 ±0.01^d	3.88 ± 0.01^e	4.71 ± 0.01^c	0.06
Crude protein (g)	11.3 ± 0.11^a	11.14 ± 0.008^b	11.03 ± 0.01^b	10.98 ± 0.01^{bc}	10.93 ± 0.005^c	0.06
Crude fat (g)	13.36 ± 0.14^{bc}	13.25 ± 0.008^c	13.42 ± 0.005^b	13.5 ± 0.01^b	14.00 ± 0.04^a	0.21
Crude fibre (g)	0.36 ± 0.01^e	1.04 ± 0.008^d	1.76 ± 0.008^c	2.57 ± 0.01^b	3.22 ± 0.01^a	0.03
Carbohydrate (g)	68.25 ± 0.23^a	67.77 ± 0.01^b	67.18 ± 0.02^c	66.87 ± 0.04^{cd}	64.57 ± 0.07^d	0.34
Total ash (g)	1.48 ± 0.01^e	1.75 ± 0.01^d	2.03 ± 0.005^c	2.25 ± 0.02^b	2.56 ± 0.01^a	0.05
Energy (Kcal)	438.44 ± 0.26^a	434.89 ± 0.07^c	433.62 ± 0.16^d	436.9 ± 0.24^b	428.00 ± 0.21^e	0.42

Note: Values are mean ± SE of three replications. Mean with same superscript (a, b, c, d, e) in the same row differ significantly ($p \leq 0.05$).

The moisture contents of barnyard millet cookies were ranged from 5.03-4.71% which gradually decreased from BT_1 to BT_4. The ash and fat contents ranged from 1.75-2.56% and 13.25-14% respectively. The protein contents ranged from 11.14-10.93% which gradually decreased from BT_1 to BT_4. The crude fibre contents of barnyard millet cookies ranged from 1.04-3.22% which gradually increased from BT_1 to BT_4. The carbohydrate contents of cookies ranged from 67.77-64.57%. The proximate composition of highly accepted cookies (BT_3 and BT_4) had moisture-3.88% and 4.71%, ash-2.25% and 2.56%, protein-10.98% and 10.93%, fat-13.5% and 14%, fibre-2.5% and 3.22%, carbohydrate-66.87% and 64.57%. Control and all four formulations of barnyard millet cookies differ significantly ($p \leq 0.05$) on their proximate value (Table 2).

Table 3: Proximate composition of finger millet cookies (per 100 g on dry matter basis)

Nutrients (per 100 g)	T_0	FT_1	FT_2	FT_3	FT_4	CD@5%
Moisture (%)	5.23 ± 0.02^a	4.33 ± 0.02^e	4.52 ± 0.02^d	4.72 ± 0.02^c	5.06 ± 0.02^b	0.08
Crude protein (g)	11.3 ± 0.11^a	10.82 ± 0.02^b	10.42 ± 0.02^c	10.08 ± 0.02^d	9.69 ± 0.06^e	0.19
Crude fat (g)	13.36 ± 0.14^c	13.46 ± 0.08^{bc}	13.69 ± 0.01^b	14.07 ± 0.02^{ab}	14.14 ± 0.05^a	0.25
Crude fibre (g)	0.36 ± 0.01^e	0.63 ±0.01^d	0.95 ± 0.02^c	1.28 ± 0.008^b	1.62 ± 0.02^a	0.05
Carbohydrate (g)	68.25 ± 0.23^b	69.22 ± 0.08^a	68.8 ± 0.05^{ab}	68.43 ± 0.22^b	67.71 ± 0.04^c	0.48
Total ash (g)	1.48 ± 0.01^d	1.52 ± 0.02^d	1.59 ± 0.01^c	1.66 ± 0.01^b	1.75 ± 0.01^a	0.06
Energy (Kcal)	438.44 ± 0.25^c	441.3 ± 0.11^a	440.09 ± 0.8^b	440.67 ± 0.3 ^{b}	336.86 ± 0.7^d	0.39

Note: Values are mean ± SE of three replications. Mean with same superscript (a, b, c, d, e) in the same row differ significantly ($p \leq 0.05$).

The moisture contents of finger millet cookies were ranged from 4.33-5.06% which gradually increased from FT_1 to FT_4. The ash and fat contents of finger millet cookies ranged from 1.52-1.75% and 13.46-14.14% respectively. The protein contents ranged from 10.82-9.69% which gradually decreased from FT_1 to FT_4. The crude fibre contents ranged from 0.63-1.62% which gradually increased from FT_1 to FT_4. The carbohydrate contents of finger millet cookies ranged from 69.22-67.71% which is gradually increases from FT_1 to FT_4. The proximate composition of FT_2 and FT_3 had moisture-4.52% and 4.72%, ash-1.59% and 1.66%, protein-10.42% and 10.08%, fat-13.69% and 14.07%, fibre-0.95% and 1.28%, carbohydrate-68.8% and 68.43%. Control and all four formulations of finger millet cookies differ significantly ($p \leq 0.05$) on their proximate value (Table 3).

Table 4: Proximate composition of mixed millet cookies (per 100 g on dry matter basis)

Nutrients(per 100 g)	T_0	MT_1	MT_2	MT_3	MT_4	CD @ 5%
Moisture (%)	5.23 ± 0.02[a]	4.97 ± 0.008[b]	4.84 ± 0.01[c]	4.25 ± 0.008[e]	4.5 ±0.01[d]	0.05
Crude protein (g)	11.3 ± 0.11[a]	10.53 ± 0.01[b]	10.35 ± 0.01[c]	10.18 ± 0.01[d]	9.98 ± 0.01[e]	0.16
Crude fat (g)	13.36 ± 0.14[bc]	13.33 ± 0.08[b]	13.45 ± 0.01[b]	13.85 ± 0.01[a]	13.95 ± 0.01[a]	0.2
Crude fibre (g)	0.36 ± 0.01[e]	1.35 ± 0.01[d]	1.87 ± 0.01[c]	2.43 ± 0.01[c]	2.96 ± 0.01[a]	0.04
Carbohydrate (g)	68.25 ± 0.23[a]	67.92 ± 0.02[a]	67.41 ± 0.03[b]	67.04 ± 0.01[c]	66.16 ± 0.04[d]	0.33
Total ash (g)	1.48 ± 0.01[e]	1.87 ± 0.008[d]	2.06 ± 0.01[c]	2.23 ± 0.01[b]	2.43 ±0.01[a]	0.04
Energy (Kcal)	438.44 ± 0.26[a]	433.77 ± 0.06[b]	432.09 ± 0.09[c]	433.53 ± 0.05[b]	430.11 ± 0.12[d]	0.38

Note: Values are mean ± SE of three replications. Mean with same superscript (a, b, c, d and e) in the same row differ significantly ($p \leq 0.05$).

The moisture contents of mixed millet cookies were ranged from 4.97-4.5% which gradually decreased from MT_1 to MT_4. The ash and fat contents of mixed millet cookies ranged from 1.87-2.43% and 13.33-13.95%, respectively. The protein contents of mixed millet cookies ranged from 10.53-9.98% which gradually decreased from MT_1 to MT_4. The crude fibre contents ranged from 1.35-2.96% which gradually increased from MT_1 to MT_4. The carbohydrate contents of mixed millet cookies ranged from 67.92-66.16%. The proximate composition of MT_2 and MT_3 had moisture-4.84% and 4.25%, ash-2.06% and 2.23%, protein-10.35% and 10.18%, fat-13.45% and 13.85%, fibre-1.87%and 2.43%, carbohydrate-67.41% and 67.04%. Control and all four formulations of mixed millet cookies differ significantly ($p \leq 0.05$) on their proximate value (Table 4).

Table 5: Mineral composition of control and most highly accepted cookies

Treatments	Calcium (mg/100 g)	Iron (mg/100 g)	Phosphorus (mg/100 g)
T_0	23 ± 0.43	2.7 ± 0.11	121 ± 1.76
BT_3	19.4 ± 0.29	6.45 ± 0.13	169 ± 1.45
BT_4	18.2 ± 0.26	7.7 ± 0.17	185 ± 1.2
FT_2	87.2 ± 0.26	2.94 ± 0.18	153.4 ± 0.37
FT_3	119.3 ± 0.23	3.06 ± 0.06	169.6 ± 0.47
MT_2	69.3 ± 0.23	4.75 ± 0.08	169.3 ± 0.34
MT_3	84.8 ± 0.17	5.44 ± 0.12	185.4 ± 0.44
CD @ 5%	0.88	0.42	3.22

Note: Values are mean ± SE of three replications. Mean in the same column differ significantly ($p \leq 0.05$).

The control cookies contained lowest amount of calcium, iron and phosphorous, *i.e.*, 23, 2.7 and 121 mg per 100 g. The finger millet cookies contained highest amount of calcium as compared to barnyard millet and mixed millet incorporated cookies. Barnyard millet cookies were inferior to control one in terms of calcium and superior to all other treatments in terms of iron content. Finger millet cookies contained lower quantity of iron as compared to mixed and barnyard millet cookies though higher than the control one. Phosphorous contents of BT_4 and MT_3 were higher than that of all other treatments (Table 5).

Table 6: Phytochemical composition of control and most highly accepted cookies

Treatments	Total phenol content (mg GAE/100 g)	DPPH (%)	Total flavonoid content (mg QE/100 g)
T_0	0.06 ± 0.014[a]	5.53 ± 0.012[a]	0.003 ± 0.001[a]
BT_3	0.21 ± 0.010[b]	5.58 ± 0.014[a]	0.004 ± 0.001[a]
BT_4	0.24 ± 0.011[b]	5.62 ± 0.011[a]	0.006 ± 0.000[b]
FT_2	0.43 ± 0.025[c]	6.02 ± 0.010[b]	0.005 ± 0.000[a]
FT_3	0.47 ± 0.021[c]	6.06 ± 0.011[b]	0.006 ± 0.001[b]
MT_2	0.51± 0.013[d]	6.11 ± 0.012[c]	0.006 ± 0.000[b]
MT_3	0.54 ± 0.010[d]	6.14 ± 0.010[c]	0.007 ± 0.001[c]
CD @ 5%	0.48	0.61	0.004

Note: Values are mean ± SE of three replications. Mean in the same column differ significantly ($p \leq 0.05$).

The DPPH and total flavonoid contents of control cookies were lowest in control cookies. The total phenol content (TPC) was 0.06-0.54 mg GAE per 100 g of cookies. The total phenol content was observed to be increased with gradual rise in millet flour content. The DPPH content was found to be 6.02-6.14% in finger millet and mixed millet cookies which increased with increased addition of millet flours. The total flavonoid content (TFC) was found to be 0.003-0.007 mg QE/100 g cookies sample. The total flavonoid contents increased with increasing concentration of millet flours (Table 6).

4. Discussion

4.1 Organoleptic evaluation of developed biscuits

4.1.1 Organoleptic evaluation of barnyard millet cookies

Figure 2 represents the organoleptic evaluation of barnyard millet cookies by the panellists. The results showed that cookies prepared with refined wheat flour (T_0) received the highest scores across all sensory attributes, while the BT_1 formulation had the lowest scores. Among the barnyard millet variations, the cookies with 30% (BT_3) and 40% (BT_4) barnyard millet flour were the most preferred by the panellists.

4.1.2 Organoleptic evaluation of finger millet cookies

Figure 3 indicates the organoleptic assessment of finger millet cookies. The control cookies achieved the highest sensory scores, while the FT_4 formulation scored the lowest for all attributes. The FT_2 and FT_3 cookies were well accepted by the panellists. The sensory qualities including colour, texture, flavour, taste and overall acceptability remained relatively stable after incorporating finger millet flour, except for FT_4 variation. All the organoleptic attributes for FT_4 showed a declined value due to presence of relatively higher amounts of phenolic compounds as compared to other formulations.

4.1.3 Organoleptic evaluation of mixed millet cookies

Figure 4 shows the organoleptic evaluation of cookies prepared using a blend of barnyard millet and finger millet flours. Similar to the previous findings, the control cookies (T_0) had the highest scores, while MT_4 received the lowest ratings. The 20% (MT_2) and 30% (MT_3) mixed millet formulations were highly appreciated by the panellists. Overall, the cookies made with mixed barnyard and finger millet flours displayed organoleptic scores for colour, texture, flavour, taste and overall acceptability slightly lower to control cookies.

4.2 Physical and nutritional properties of the developed cookies

Table 1 reveals that the weight, thickness, diameter and spread ratio of millet-based cookies exhibited a gradual increment by incorporation of millet flours. The increased spread ratio made the millet incorporated cookies more brittle as compared to control one. This could be because of lower viscosity of millet flours compared to wheat flour, allowing cookies made with millet to spread more easily than those prepared from high-viscosity dough (Sudha *et al*., 2007). Additionally, the baking loss of millet cookies decreased with addition of barnyard millet and finger millet flours when compared to the control cookies, aligning with the findings of Sudha *et al*. (2007).

Table 2 represents the proximate composition of the control (T_0) cookies, which contained 5.23% moisture, 1.48% ash, 11.3% crude protein, 13.36% crude fat, 0.36% crude fibre and 68.25% carbohydrates. The moisture content of barnyard millet cookies ranged from 5.03% to 4.71%, with a gradual decrease observed as the proportion of barnyard millet flour increased. This reduction in moisture may be linked to the higher fibre content in BT_1 to BT_4 formulations, a finding consistent with the studies of Salunke *et al*. (2019) and Anju and Sarita (2020). The ash content showed an increasing trend, ranging from 1.75% to 2.56%, likely due to the higher mineral composition of barnyard millet flour, as also mentioned by Salunke *et al*. (2019) and Anju and Sarita (2020). The protein, fat, fibre and carbohydrate content of barnyard millet cookies varied between 11.14%-10.93%, 13.25%-14%, 1.04%-3.22% and 67.77%-64.57% respectively. A gradual decline in protein content was observed with increasing barnyard millet flour incorporation, whereas fat content showed an increasing trend. Crude fibre content also progressively increased from BT_1 to BT_4. Among all variations, the control cookies (T_0) had the lowest fat, fibre and carbohydrate content but the highest moisture and protein levels. On the other hand, BT_4 exhibited the highest fibre, ash and fat content, along with the lowest protein levels. The most organoleptically preferred formulations, BT_3 and BT_4, contained higher total ash, fat and fibre than control. A significant difference ($p \leq 0.05$) was observed in the proximate composition between the control and all four barnyard millet cookie formulations. These findings are in agreement with previous studies by Salunke *et al*. (2019) and Anju and Sarita (2020), which reported similar results while formulating biscuits with barnyard millet flour.

Table 3 represents the proximate composition of control (T_0) and finger millet cookies. The control cookies (T_0) contained 5.23% moisture, 1.48% ash, 11.3% crude protein, 13.36% crude fat, 0.36% crude fibre and 68.25% carbohydrates. The moisture content of finger millet cookies ranged from 4.33% to 5.06%, showing a decreasing trend as the proportion of finger millet flour increased from FT_1 to FT_4. This reduction in moisture might be linked to the higher fibre content in finger millet flour, a finding supported by Saha *et al*. (2011), Kishorgoliya *et al*. (2018) and Kaur *et al*. (2020). The ash content of finger millet cookies varied between 1.52% and 1.75%, rising with the increasing addition of finger millet flour due to its higher mineral content than control. These results align with those of Kishorgoliya *et al*. (2018) and Kaur *et al*. (2020). The protein content ranged from 10.82% to 9.69%, with a gradual decline observed from FT_1 to FT_4. Fat, crude fibre and carbohydrate levels were found to be between 13.46%-14.14%, 0.63%-1.62% and 69.22%-67.71%, respectively. The control cookies (T_0) had the highest moisture, protein and carbohydrate levels but the lowest fibre, fat and ash content. FT_4 contained the maximum fibre, ash and fat, while having the lowest protein and carbohydrate content. A significant difference ($p \leq 0.05$) was noted in the proximate values between the control and all four finger millet cookie formulations, consistent with the findings of Krishnan *et al*. (2011), Saha *et al*. (2011), Kishorgoliya *et al*. (2018) and Kaur *et al*. (2020).

Table 4 highlights the proximate composition of control (T_0) and mixed millet cookies. The control cookies had 5.23% moisture, 1.48% ash, 11.3% crude protein, 13.36% crude fat, 0.36% crude fibre and 68.25% carbohydrates. The moisture content of mixed millet cookies was 4.97%-4.5%, which decreased with increasing millet flour levels, likely due to the higher fibre content. Ash content rose from 1.87% to 2.43% as more mixed millet flour was incorporated, attributed to the combined mineral richness of barnyard and finger millet flours. The protein, fat, crude fibre and carbohydrate content ranged from 10.53%-9.98%, 13.33%-13.95%, 1.35%-2.96% and 67.92%-66.16%

respectively. T_0 had the highest protein, carbohydrate and moisture content, while MT_4 exhibited the highest fibre and ash content, with the lowest protein levels. A significant difference ($p \leq 0.05$) was found between the control and all mixed millet formulations. The most organoleptically preferred variations, MT_2 and MT_3 contained higher amounts of fat, fibre and ash but lower protein, carbohydrate and energy values compared to the control. These observations are in line with studies by Krishnan *et al*. (2011), Saha *et al*. (2011), Kishorgoliya *et al*. (2018) and Kaur *et al*. (2020).

Table 5 compares the mineral content of control and millet cookies. The incorporation of barnyard millet, finger millet and their combination led to a noticeable increase in calcium, iron and phosphorus levels. Among the most accepted variations, finger millet cookies had the highest calcium content, followed by mixed millet cookies, while barnyard millet cookies contained the least. Regarding iron content, barnyard millet cookies ranked highest, followed by mixed millet cookies. Both barnyard millet and mixed millet cookies contained similar phosphorus levels, whereas finger millet cookies had slightly lower amounts. Control cookies showed the lowest levels of all three minerals. These results are at par with the studies by Desai *et al*. (2010), Kulkarni *et al*. (2012), Lande *et al*. (2017) and Dangal *et al*. (2021).

Table 6 outlines the phytochemical composition of control and millet cookies. Finger millet and mixed millet cookies exhibited higher total phenolic content (TPC) compared to the control and barnyard millet cookies. Similar results were reported by Bello *et al*. (2022). The DPPH antioxidant activity showed no significant difference between control and barnyard millet cookies, but finger millet and mixed millet cookies demonstrated significantly higher DPPH values. All millet cookies displayed strong antioxidant activity, with values exceeding 50%, consistent with the findings of Gull *et al*. (2016). Although there were no significant differences in flavonoid content across the millet cookies, their levels were notably higher than those of the control. Similar trends were noted by Bello *et al*. (2016). The relatively lower TPC and TFC values observed may be attributed to heat-induced losses during the baking process, a phenomenon also highlighted by Venkatachalam and Nagarjana (2017).

Thus, the barnyard millet, finger millet and mixed millet cookies were observed to contain higher amount of fibre, total ash, iron and phosphorous as compared to the control cookies. The finger millet incorporated and barnyard millet incorporated cookies contained highest calcium and iron contents than all other formulations. Mixed millet cookies were the most superior one in terms of their nutritional composition. The largest difference was observed in fibre, total ash and calcium contents of control and millet incorporated cookies.

5. Conclusion

The study concluded that incorporating finger millet and barnyard millet flour enhanced the concentrations of micronutrients such as dietary fibre, total ash, calcium, iron and phosphorus, along with bioactive compounds like DPPH antioxidant value, total phenolic and flavonoid content in cookies. The addition of millet flour also improved the spread ratio of the cookies which may increase the consumer acceptability among the children and elderly group due to its relatively lower hardness as compared to refined wheat flour cookies. This fortification of various millets in baked products, such as cookies, presents a promising strategy to elevate nutritional as well as functional property of snack items. Incorporating millet flour into daily diets can contribute to better health and nutrition for all age groups, potentially reducing the risk of diabetes mellitus, cardiovascular diseases, obesity, gluten intolerance and other metabolic disorders.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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