ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

NUTRITIONAL ENHANCEMENT AND QUALITY ASSESSMENT OF COFFEE EXTRACT-INCORPORATED COOKIES DEVELOPED USING COMPOSITE FLOUR COMPRISING OF FOXTAIL MILLET AND WHEAT FLOUR

[1]Vyshak M.B., [1]Abhirami K.G., [2]Sanu Jacob, [1]*Maya Raman and [1,3]Bhavya E. P.

[1]Department of Food Science and Technology, Faculty of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, India.

[2]Food Safety and Standards Authority of India, Govt. of India, India.

[3]Department of Food Processing Technology, St. Teresa's College, Ernakulam, India.

*Correspondence: MR, Department of Food Science and Technology, Faculty of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, India.

*Corresponding Author

DOI: https://doi.org/10.51193/IJAER.2025.11512

Received: 18 Sep. 2025 / Accepted: 25 Sep. 2025 / Published: 03 Oct. 2025

ABSTRACT

The study investigates that nutritional quality and shelf-life of coffee extract-enriched cookies produced from wheat-millet composite flour blends. The cookies were packed in polyester-polyethylene coated metalized film and stored at ambient conditions (32±2°C, 80% RH) for 42 d to assess their storage feasibility. The water holding capacity, oil holding capacity, pH, bulk density of the flours was assessed. During the storage, with 14d sampling intervals, parameters such as, colour, water activity, phytic acid, total phenol, flavonoid and sensory parameters were monitored. The foxtail millet-based cookies (C-F) exhibited the highest nutritional and antioxidant properties. C-F had a hardness of 65.2±1.6 N, antioxidant activity of 64.1±0.7%, and total phenol and flavonoid content were 56±0.0 mg/100g gallic acid equivalent and 29.6±0.5 mg/g of quercetin equivalent, respectively. The phytic and tannic acid contents were found to be 7.46±0.48 mg% and 1.13±0.00 mg/g tannic acid equivalent, respectively. Sensory evaluation indicated a slight decline in overall acceptability for C-F, over the 42d storage period. Notably, no significant ($p<0.05$) variations were observed in the total phenol and flavonoid content throughout storage. The study concludes that nutritious cookies with a distinctive coffee aroma, produced from foxtail millet offering a promising functional snack with enhanced nutritional and antioxidant properties.

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

Keywords: Foxtail millet, proximate composition, shelf-life, coffee, phytochemicals

1. INTRODUCTION

Cookies, a classic popular snack, are produced from wheat flour; Olakanmi et al. (2023) reported that heat-treated dough offers a more appealing consumable product. These cookies are cost effective, readily available food source that provide essential nutrients and aid in digestion (Subhasri et al., 2022). The primary ingredients include water, oil, sugar and wheat flour; while milk, salt, food additives, flavourings and aerating agents used to improve the sensory and textural properties (Owheruo et al., 2023). The rising demand for healthier snack options has led to several innovations in the cookie preparation. Studies exploring the alternate flour sources including cassava, potatoes, maize, millet, sorghum and rice were promising and have shown to improve the nutritional and textural properties (Omer et al., 2023).

Millets are small-seeded grains classified as *super-cereals* due to their superior nutritional profile, rapid growth in resource-limited environments and tolerance to extreme climatic conditions (Sharma et al., 2021). The major millets include Pearl (*Pennisetum glaucum*), Finger (*Eleusine coracana*) and Sorghum (*Sorghum bicolor*), while the minor millets encompass Foxtail (*Setaria italica*), Little (*Panicum sumatrense*), Kodo (*Paspalum scrobiculatum*), Barnyard (*Echinochloa frumentacea*), Browntop (*Brachiaria ramosa*) and Proso (*Panicum miliaceum*). Despite their small size, millets outperform major cereals in nutrient density, providing high levels of vitamins, minerals, resistant starch, dietary fibres, antioxidants, phytochemicals and protein content (Sharma and Gujral, 2019). Millets are gluten-free and rich in phenolics and flavonoids, making them an ideal dietary replacement for celiac patients (Kumari et al., 2023). Recognizing these facts, the United Nations declared the year 2023 as *the International Year of Millets*. Millets face limited utilization due to their coarseness, difficulties in processing, aftertaste and short shelf life caused by high unsaturated triglyceride contents. The gluten-free nature of the millet flours results in the lack of visco-elasticity in dough, restricting its utilization in bread and chappati production; nevertheless, giving an apt opportunity for these flour in cookie preparation (Sharma et al., 2017).

Foxtail millet, a pseudo-cereal cultivated in Africa, Europe and South Asia, has garnered increased attention as a significant food grain due to its high nutritional value including proteins, fiber, vitamins, minerals and phytochemicals (Abedin et al., 2022). The nutritional profile of foxtail millet is comparable to that of staple grains such as wheat and rice (Yang et al., 2022). However, the absence of gluten limits its application in baked products, chiefly effecting the structural characteristics (Devisetti et al., 2015). The weak binding and stretching abilities, along with poor color, further limit the application of foxtail millets in baked products (Gallagher et al., 2002). Thus, foxtail millet flour could serve as a sustainable alternative for developing gluten-free products, replacing the conventional composite flours and addressing issues related to structural

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

integrity and sensory properties. Therefore, these could be considered as valuable functional ingredients in gluten-free food formulations, contributing to healthier, convenient food options (Molinari et al., 2018). In view of this, the objective of the study was to develop the formulation for foxtail millet-based cookies and evaluate its physico-chemical, proximate, phytochemical, textural, sensory and functional characteristics. The shelf-life of the cookies packed in polyester-polyethylene coated metalized films were also evaluated.

2. MATERIALS AND METHODS

2.1 Materials

Fresh foxtail millet (*Setaria italica*), wheat flour, sugar and instant coffee was purchased from the local market (Kochi, Kerala, India). Analytical grade chemicals and solvents were purchased from Sigma-Alrich (India) and SRL (India).

The foxtail millet was thoroughly cleaned, dried (60°C, 4 h) using the tray drier,pulverised using household mixer grinder and sieved (50μ). The flour was stored at ambient conditions (32±2°C, 80%RH) in an air tight container until used.

2.2 Physical properties of wheat and foxtail millet flour

2.2.1. pH

The pH of the flour was estimated by using a digital pH meter (ANALAB, India). Briefly, the flour was dispersed in distilled water (1:10), homogenized (2 min) using a vortex mixer (REMI CM-101, India) and pH of the supernatant was measured (Ghribi et al., 2015).

2.2.2 Water holding capacity (WHC) and oil holding capacity (OHC)

Briefly, flour (5g) was homogenized with distilled water (1:5) using a vortex mixer (REMI CM-101, India), centrifuged (4000 rpm, 15 min) and the discarded the supernatant after equilibration (30min). The WHC was calculated using the formula:

$$\text{WHC (\%)} = \frac{(\text{ weight of hydrated sample(g)} - \text{weight of dry sample(g)})}{\text{weight of dry sample (g)}} \text{ x } 100$$

The OHC of flour was determined according to Ghribi et al. (2015). Briefly, flour was homogenized with vegetable oil (1:6) using a vortex mixer (REMI CM-101, India). After equilibration (30 min), these were centrifuged (3000 rpm, 25 min) and the excess oil was discarded. The OHC was calculated using the formula:

$$\text{OHC (\%)} = \frac{(\text{weight of hydrated sample (g)} - \text{weight of dry sample (g)})}{\text{weight of dry sample (g)}} \text{ x } 100$$

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

2.2.3 Bulk density, tap density and porosity

Bulk density and tap density of flour was determined by using tap density tester (TDT-101, ANM Industries, India). The flour (30g) was placed in the graduated cylinder (100 ml) and initial volume was noted. The bulk density was obtained from mass and volume (Sharma et al., 2018).

For the tap density determination, the flour (30 g) was placed in the graduated cylinder (100 ml) and tapped (250 tapping/ min for 6 min). The volume was noted and tap density was calculated (Akseli et al., 2019). Hausner's ratio was determined from bulk density and tap density using the equations:

$$\text{Hausner's ratio} = \text{Tapped density}/\text{ bulk density}$$

2.3. Preparation of cookies

The cookies were prepared by incorporating coffee extract to the dough prepared using foxtail millet flour (F) and wheat flour (W). The experimental design is shown in the Table 1. For the combined formulation, the ratio of foxtail millet flour and wheat flour was taken in equal proportion.

Table 1: Experimental composition of different cookies

Composition (%)	Wheat flour-based cookies (W)	Foxtail millet flour-based cookies (F)	Coffee enriched wheat flour-based cookies (C-W)	Coffee enriched Foxtail millet flour-based cookies (C-F)	Coffee enriched wheat-foxtail millet composite flour-based cookies (C-WF)
Wheat flour	87.41	0	85.03	0	42.52
Foxtail millet flour	0	87.41	0	85.03	42.52
Sugar	6.80	6.80	6.80	6.80	6.80
Ghee	5.80	5.80	5.44	5.44	5.44
Coffee extract	0	0	2.72	2.72	2.72

The dry ingredients were added to the cream (beating fat with sugar) and dough was prepared, while in the coffee extract incorporated cookies, the coffee extract was added to the cream, followed by the dry ingredients. The dough as rolled (thickness-13 mm) and cut into round shape using the cookie cutter and placed in a greased pan. The baking was done at 180°C for 20 min in a preheated oven. The cookies were packed in polyester- polyethylene coated metalized films (metalized polyester 50 gauge and polyethylene 220 gauge) and stored at ambient conditions

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

(32±2°C, 80% RH) for 42d. The cookies were evaluated for their physico-chemical characteristics at regular intervals (14d).

2.4. Characteristics of cookies

2.4.1. Water activity, spread ratio and specific volume

The water activity (a_w) was measured using the Novasina AG water activity meter (CH-8853 Lachen, LabSwift-aw, Switzerland). The spread ratio was determined using the standard methodology of Chinma et al. (2022). The thickness and diameter were measured using non-digital vernier caliper (Mitutoyo 500-196-20).

$$\text{Spread ratio} = \frac{\text{Diameter (cm)}}{\text{Thickness (cm)}}$$

The specific volume is the ratio of volume and weight (measured using the electronic weighing balance ATY224, SHIMADZU, Japan) (Reaz et al., 2023).

2.4.2. Colour characteristics of the cookies

Colour properties were determined using the HunterLab colorimeter (4500L, Hunter associates Laboratory Inc., Reston, VA, USA) on the basis of CIE L* (brightness/darkness), a* (redness/greenness), b* (yellowness/blueness) colour system (Owheruo et al. 2023). The total colour difference (ΔE), hueness (h_{ab}*) and chroma (C_{ab}*), browning index were calculated.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$$C_{ab}^* = \sqrt{a^{*2} + b^{*2}}$$

$$h_{ab}^* = \tan^{-1}(b^*/a^*)$$

$$BI = \frac{[100\,(x-0.31)]}{0.17}$$

Where,

$$x = \frac{(a^* + 1.75L^*)}{(5.64L^* + a^* - 3.012b^*)}$$

2.4.3. Textural characteristics of cookies

The texture of the cookies was measured using a texture analyser (EZ-SX, Shimadzu, Universal Testing Machine, Japan) equipped with 3-point bend jig (n=3). The load cell capacity was 200 N capacity, test speed was 1 mm/s and distance was 15mm (Guarch-Perez et al., 2022).

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

2.5. Proximate composition and chemical analysis of cookies

The proximate composition of cookies was determined following AOAC (2000). Moisture content was measured by drying (105°C, 3h) the sample (10g) in a hot air oven (Being Instrument Inc., B0-200NL, China) until constant weight is achieved. Crude protein was quantified by digesting (Kelplus, KES 6L E, Chennai, India) the sample (0.5g) with concentrated H_2SO_4 (10ml) and a catalyst (potassium sulphate and copper sulphate, 0.2g), followed by distillation and titration with HCl (1N); and calculating the protein using the conversion factor of 6.25. Crude lipids were extracted using Soxhlet apparatus (Socplus, SCS 02 E, Pelican equipment, India) using petroleum ether (bp 60-90°C) as solvent. Ash content was determined by ashing a moisture-free sample (1g) in a muffle furnace (Nabertherm GmbH, SN 366762, Bahnhofstr, Germany) at 500°C for 5 h. Total carbohydrates was calculated by difference method and the energy in calories were calculated using the standard formula (FAO 1998). Crude fibre was analysed using the acid-alkali digestion method, as per AOAC (2005). Minerals were determined by Flame photometry (CL 378, Elico Ltd, Hyderabad, India). The reducing sugar was determined by the Lane and Eynon method (AOAC, 2000).

2.5.1. Phytochemical composition of the cookies

The total phenolic content, total flavonoid content and tannin were determined in the methanolic extract (Rakesh et al., 2021). In brief, the cookie samples (0.2 g) were ground and dissolved in methanol (80%, 4 ml), sonicated (Ultrasonic cleaner, USC-200, ANM Industries, India; 20 min, 25°C) and centrifuged (Eltek centrifuge, TC 450 D, LABSPIN, Mumbai, India; 1935 rpm, 10 min). The supernatant was collected for phytochemical analysis (Chinma et al., 2014). An aliquot was diluted with Folin-Ciocalteu reagent (1:10) incubated in dark (32±2°C, 1h) with Na_2CO_3 (20%, 5ml). The absorbance was read at 650 nm spectrophotometrically (Lasany International, Microprocessor single beam UV-VIS spectrophotometer, LI-294, Haryana, India) and the total phenolic content was determined as equivalent to gallic acid (GAE) standard (mg GAE/ g crude extract). Total flavonoids content was determined by the aluminium chloride method. Another aliquot (1ml) was diluted with aluminium chloride (10%; 1:5) and incubated in dark (32±2°C, 45min) with sodium acetate (1M, 1ml). The absorbance was estimated at 415 nm and total flavonoid was expressed as mg equivalent to quercetin (QAE)/ g extract. Another aliquot (500 µL) was treated with 500 µL of Folin-Ciocalteu's reagent (1:1 v/v with distilled water), 1000 µL of Na_2CO_3 (35% w/v) and 8000 µL of distilled water and incubated in dark (32±2°C,30 min). The absorbance was read at 700 nm using a UV-Visible spectrophotometer using tannic acid as standard.

The phytic acid was determined according to Young and Greaves (1940). The sample (4g) was soaked in HCl acid (2%, 100 mL, 3 h) and filtered. An aliquot (25 mL) was mixed with NH_4SCN

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

(0.3%, 5 mL) and distilled water (53 mL) and titrated against $FeCl_3$ (0.01 M). Total phytic acid (mg%) was calculated by multiplying the titre value with phytin phosphorus (1 mL=1.19 mg phytin phosphorous) and factor of 3.55 (Bello et al., 2013).

2.5.2. DPPH Radical scavenging activity

A modified methodology was used to measure the antioxidant activity using DPPH (2,2′-diphenyl-1-picrylhydrazyl) (Rakesh et al. 2021). Briefly, sample (250 µL) of methanol extract was treated with DPPH solution (0.004%, 2mL) and incubated in dark (32±2°C, 30 min). The absorbance was read at 517 nm using UV-Visible spectrophotometer (Gopika et al., 2020), with butylated hydroxytoluene (BHT) as standard.

2.6. Sensory evaluation

Sensory evaluation was done by ten semi-trained panel members using a 9-point hedonic scale method with 9 being like extremely and 1 being dislike extremely (Lim et al, 2011).

2.7. Statistical analysis

The experiments were performed in triplicates and the respective results were represented as mean ±SD. One-way ANOVA with Tukey's multiple comparison test was performed to obtain significant differences (McHugh et al., 2011).

3. RESULTS AND DISCUSSION

The development of gluten-free bakery products is challenging as it interferes most prominently with the dough properties. Several sustainable alternatives to develop gluten-free products replacing traditional composite flour with enhanced health and sensorial properties, has gained increasing attention in recent years. In this context, the current study evaluates the effects of foxtail millet flour in cookie preparation and its nutritional and sensorial quality (Fig. 1). The grains were dried, pulverized and their physical properties such as, pH, water holding capacity, oil holding capacity and density were evaluated (Table 2).

The pH of the foxtail flour was near to the neutral (pH 6.9) and these may have a significant role in dough formation and flavour development The wheat flour showed a slightly higher water holding capacity (0.2ml/g), while the oil holding capacity for both the flours were similar. High WHC might be a determining factor for soft and moist baked products whereas OHC is critical for product texture and mouthfeel. The WHC is also contributed by the presence of the soluble sugars possibly produced during processing and the OHC could be related to the protein nature (Sharma and Sharma, 2022). The bulk density of both the flours were similar possibly indication small and similar particle size; and is an important criterion for packaging of the products (Marak et al., 2019).

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

3.1 Physical properties of cookies

The cookies prepared by incorporating coffee extract to wheat and foxtail flour showed a significant difference ($p<0.05$) in diameter, specific volume and spread ratio (Table 3). All the cookies had similar weight (15.5 to 15.8g) and thickness (1.6 to 17mm). The coffee extract incorporated in cookies having equal proportions of foxtail and wheat showed significantly high ($p<0.05$) diameter (5.6mm). The highest spread ratio (3.2) and specific volume (2.6 cm^3/g) was obtained for the mixed cookie possibly contributed by the high dietary fiber content offered by the foxtail millet flour (Sharma et al., 2016). Similar results were reported in cookies containing papaya flour (up to 50%) and burdock root flour (Moro et al., 2018). However, the addition of pumpkin and carrot bagasse reduced the diameter and spread ratio and increased the height and hardness of the cookies (Turksoy and Ozkaya, 2011). The water activity (a_w) is important for determining the shelf-life of the product. Coffee extract incorporated cookies showed lower water activity (0.4 to 0.5) possibly due to the different chemical constituents in the flour blends (Kaur et al., 2022). The color analysis of coffee extract incorporated cookies prepared using wheat and foxtail millet flour is shown in Table 3. Incorporation of coffee extract significantly ($p<0.05$) lowered the L* value while browning index showed a considerable increase (ranging between 78.9 to 81.4). The significantly ($p<0.05$) increased b* (yellowness) and a* (redness) values in the mixed cookies. The color variations in the cookies could be attributed the melanoidins and other browning agents in the coffee extract (Sharma et al., 2021). Changes in the texture of the cookies incorporated with coffee extract and foxtail millet flour were observed. Hardness was significantly ($p<0.05$) high for mixed cookie. This discrepancy in hardness in possibly induced by the coffee extract and the less porous structure caused by the high fiber content (Belmiro et al., 2022). The main constituents of the cookies are flour, sugar and fat. Although water is present in small quantity, it takes part in the formation of the gluten network (Chevallier et al., 2002). The high fiber content in the foxtail millet flour contributes to the corresponding reduction in the starch and hence, the reduction in the hardness of the millet-based cookie. This leads to the reduction in the gluten formation and increased hygroscopicity of the dietary fibers, leading to the lower hardness (Xiao et al., 2021).

3.2. Proximate composition, mineral, phytochemicals and antioxidant properties

The proximate compositional analysis, mineral content, phytochemicals and antioxidant properties of the different cookies are shown in Table 3. A significant ($p<0.05$) difference in the moisture, protein, fat, ash and total dietary fiber (TDF) content of the coffee extract incorporated cookies were observed. The moisture content of the cookies was lower than the prescribed standards for cookies, to extent the shelf life and prevent spoilage (Manley, 2000). The coffee extract incorporated mixed cookies showed significantly high moisture content ($p<0.05$, 5.6%), while wheat flour and foxtail millet flour alone cookies showed relative low moisture content (4.6 and

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

4.7%, respectively). This could be due to the hygroscopicity of the coffee extract components and fiber content (Sharma et al., 2014). The protein and fat content ranged between 4.2-8.2% and 5.7-8.8%, respectively, with significantly ($p<0.05$) high values in foxtail millet flour-based cookies (8.2 and 8.7-8.8%, respectively). Studies have revealed that foxtail millet flour is nutritionally superior with rich protein content (Verma et al. 2015). The presence of hydrophobic or hydrophilic amino acids and their affinity towards the hydrocarbon side chain of the fat might contribute to the high fat content in based cookies. Increased total fat content contribute to reduced moisture content and enhanced flavour retention capacity (Sreerama et al., 2008). Earlier reports have suggested that foxtail millet fat are rich in polyunsaturated fatty acids that may be utilized to develop functional foods for the obese groups. The total carbohydrate content ranged between 78.3 and 83.9%, with wheat flour based cookies showing highest (83.9%) and foxtail millet flour based cookie showed lowest carbohydrate content (76.4%). These findings were incomparable with the earlier reports (Uthumporn et al., 2015). The total dietary fiber (TDF) was significantly high in foxtail millet flour incorporated cookies (9.0-10.1%). Similar TDF content were reported by Sompong et al. (2011). The mineral content (mg/100g) ranged from 3.3-5.7, 3.0-4.3 and 3.0-4.4 for sodium, potassium and calcium respectively. The foxtail millet flour-based cookies showed significantly ($p<0.05$) mineral contents. The incorporation of the millet enhanced the nutritional content of the cookies.

The phenolic content ranged from 36.0-51.0mg GAE/100g, while flavonoid content ranged from 15.8-29.6mg QE/g. The significantly higher ($p<0.05$) total phenolic content and total flavonoid content was observed in coffee extract incorporated foxtail flour-based cookie, closely followed by the mixed cookie. Normally, it is an established fact that unprocessed ingredients have high phytochemical content than processed products (Sharma and Gujral, 2014). The authors suggested that baking modifies the structure of the phytochemicals by polymerization, and consequently reducing the extractable polyphenols in the baked products. Nevertheless, in this study, the polyphenol content was significantly high possibly from the coffee extract. Tannin content ranged from 0.3-1.1 mgTAE/ g. The phytic acid showed a significant variation with foxtail millet flour incorporated cookies showing high values (7.5mg%). These were in accordance with the earlier reports and the high anti-nutrient content could be attributed to the presence of whole grains with intact seed coat used in the preparation of the composite flour (Itagi and Singh, 2012). The phenolic and flavonoid compounds, natural antioxidants, improve the oxidative stability of the food and have immense health beneficial properties (Devi et al., 2014). The radical scavenging activity (RSA) ranged from 40.6-64.1%, with significantly higher ($p<0.05$) RSA (63%) observed for mixed cookie. These results were in concordance with the total phenolic and flavonoid content, emphasizing the rich phytochemical profile of foxtail millet flour and the baked products.

3.3. Shelf-life study of the cookies

The cookies were packaged in polyester- polyethylene coated metalized films, which provide an effective barrier to moisture and oxygen, ensuring better preservation of the product. These cookies were stored at ambient conditions (32±2°C, 80% RH) for a period of 42d to assess their shelf stability. Water activity, color, phytochemical content and sensory evaluated were conducted for every 14d. The water activity is a crucial factor in determining the shelf life of the baked foods, as it effects the microbial growth and product freshness. The water activity of the cookies remained within the range 0.2-0.6, which is considered low and indicated stable product with minimum risk of spoilage. The cookies retained the quality with negligible nutritional changes, confirming the potential for a longer shelf life of coffee extract incorporated millet cookies. The color parameters (L*, a* and b*) values showed no significant changes over times (Fig. 2). This stability indicates that the cookies maintained the visual appeal that is important for consumer acceptance. The phytochemical profile showed no noticeable variations, suggesting that the storage conditions did not significantly degrade the nutritional quality of the cookies (Fig.3). Sensory analysis measures the consumer acceptance based on attributes such as taste, texture and overall appeal, revealed that cookies made with coffee and foxtail millet flour received better overall acceptance compared to other variations (Fig.4). This suggests that the addition of coffee enhanced the flavour and appeal of the cookies, enhancing its consumer acceptance. The mixed cookies showed lower overall acceptability, which could be attributed to the composite flour combinations.

a) Wheat flour alone (W)

b) Foxtail millet flour alone (F)

c) Coffee extract incorporated wheat flour based cookie (C-W)

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

d) Coffee extract incorporated foxtail millet flour based cookie (C-F)

e) Coffee extract incorporated foxtail millet and wheat flour based cookie (C-FW)

Fig. 1: Wheat flour and foxtail millet cookies incorporated with coffee extract

Table 2: Flour characteristics of wheat and foxtail millet flours

Flours	pH	WHC (ml/g)	OHC (ml/g)	BD (g/ml)	TD (g/ml)	Hausner's ratio
Wheat	5.9±0.1	0.2±0.0	0.1±0.0	0.7±0.0	0.7±0.0	1
Foxtail millet	6.9±0.1	0.1±0.0	0.1±0.0	0.7±0.0	0.7±0.0	1

Values are mean ±SD of three replicates

Table 3: Physico-chemical, color, texture and functional characteristics of cookies.

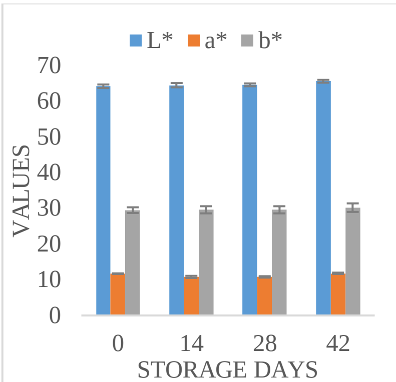
Properties	W	F	C-W	C-F	C-FM
Physical characteristics					
Weight (g)	15.5±1.0	15.6±0.1	15.5±0.2	15.5±0.1	15.8±0.1
Thickness (mm)	1.6±0.1	1.7±0.0	1.6±0.1	1.6±0.0	1.7±0.0
Diameter (mm)	4.41±0.1	4.5±0.1	5.2±0.1	4.6±0.0	5.6±0.0
Specific volume (cm^3/g)	1.55±0.1	1.7±0.1	2.2±0.1	1.7±0.1	2.6±0.1
Spread ratio	2.8±0.1	2.7±0.1	3.2±0.0	2.8±0.0	3.2±0.1
Water activity	0.2±0.0	0.2±0.0	0.4±0.0	0.5±0.1	0.5±0.0
Color characteristics					
L*	64.2±0.5	64.9±0.9	58.9±0.8	58.7±1.0	61.8±1.7
a*	11.7±0.1	9.9±0.5	11.9±0.4	9.5±0.5	10.6±0.1
b*	29.5±0.8	26.4±1.8	29.1±1.2	30.1±2.8	30.5±2.9
ΔE			5.3±0.6	7.2±0.7	7.5±0.7
C_{ab}^*	31.7±0.5	28.2±0.6	31.4±0.6	31.6±0.5	32.3±0.6
h*	-1.4±0.5	-1.9±0.5	-1.2±0.6	37.3±0.6	-3.7±0.5
BI	73.7±0.5	62.7±0.6	81.4±0.6	81.8±0.6	78.9±0.6

Textural characteristics					
Hardness (N)	52.5±0.8	50.3±1.3	67.8±2.1	65.2±1.6	73.1±1.6
Proximate composition					
Moisture (%)	4.6±0.3	4.7±0.5	5.7±0.5	4.9±0.3	5.6±0.8
Protein (%)	4.9±0.2	8.2±0.2	4.7±0.3	8.2±0.1	8.2±0.3
Fat (%)	5.9±0.2	8.7±0.2	5.8±0.1	8.8±0.2	8.8±0.2
Ash (%)	0.9±0.1	2.8±0.2	0.9±0.7	2.9±0.2	2.2±0.2
Carbohydrates (%)	83.9±0.2	76.4±0.2	83.9±0.2	78.3±0.1	79.8±0.2
Fiber (%)	2.9±0.1	10.0±0.1	2.9±0.1	10.1±0.1	9.0±0.0
Total sugar (%)	1.7±0.1	1.6±0.1	1.7±0.1	1.6±0.1	1.6±0.1
Energy (Kcal)	409.2±0.6	417.9±0.7	407±0.5	421.3±0.5	410±4.8
Minerals					
Sodium (mg/100g)	3.3±0.2	5.6±0.2	3.6±0.1	5.7±0.2	5.4±0.7
Potassium (mg/100g)	3.0±0.3	4.3±0.3	3.4±0.5	4.5±0.4	4.3±0.4
Calcium (mg/100g)	3.0±0.3	4.2±0.3	3.4±0.2	4.4±0.3	4.3±0.2
Phytochemicals					
Total phenolic content (mg GAE/ 100g)	36.0±0.0	51.0±0.0	42.0±0.0	56.0±0.0	52.0±0.0
Total flavonoid content (mg QE/g)	15.8±1.2	28.2±0.5	16.2±0.5	29.6±0.5	29.2±0.4
Tannin (mg TAE/g)	0.3±0.0	0.5±0.0	0.8±0.0	1.1±0.0	0.9±0.0
Phytic acid (mg%)	3.5±0.2	7.5±0.5	3.5±0.2	7.5±0.5	7.5±0.5
Functional property					
Radical scavenging activity (%)	40.6±0.6	57.0±0.6	44.1±0.4	64.1±0.7	63.0±0.3

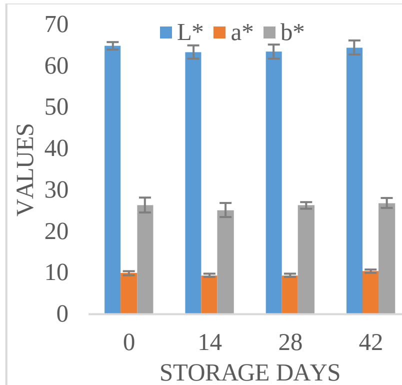
Values are mean±SD. Cookies:-W:Wheat flour alone, F:Foxtail flour alone, C-W:Coffee extract+Wheat flour, C-F:Coffee extract+Foxtail flour, CFW:Coffee extract+Foxtail flour and Wheat flour

ISSN: 2455-6939

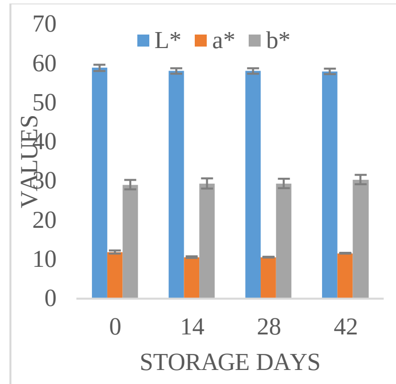
Volume: 11, Issue: 05 "September-October 2025"



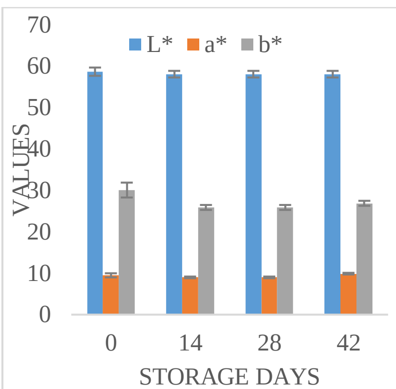
a) Wheat flour alone



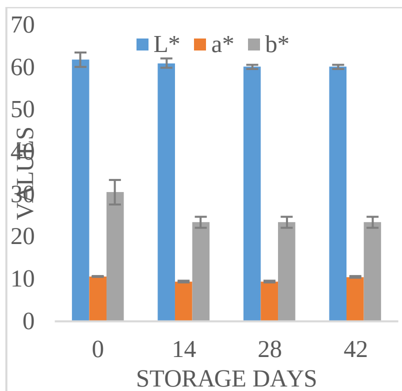
b) Foxtail flour alone



c) Coffee extract +Wheat flour



d) Coffee extract+Foxtail flour



e) Coffee extract+Foxtail and Wheat flour

Fig. 2: Colour variations in the cookies upon storage for 42 days. Values are mean±SD. Cookies:- W: Wheat flour alone, F: Foxtail flour alone, C-W:Coffee extract+Wheat flour, C-F:Coffee extract+Foxtail flour, CFW:Coffee extract+Foxtail flour and Wheat flour

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

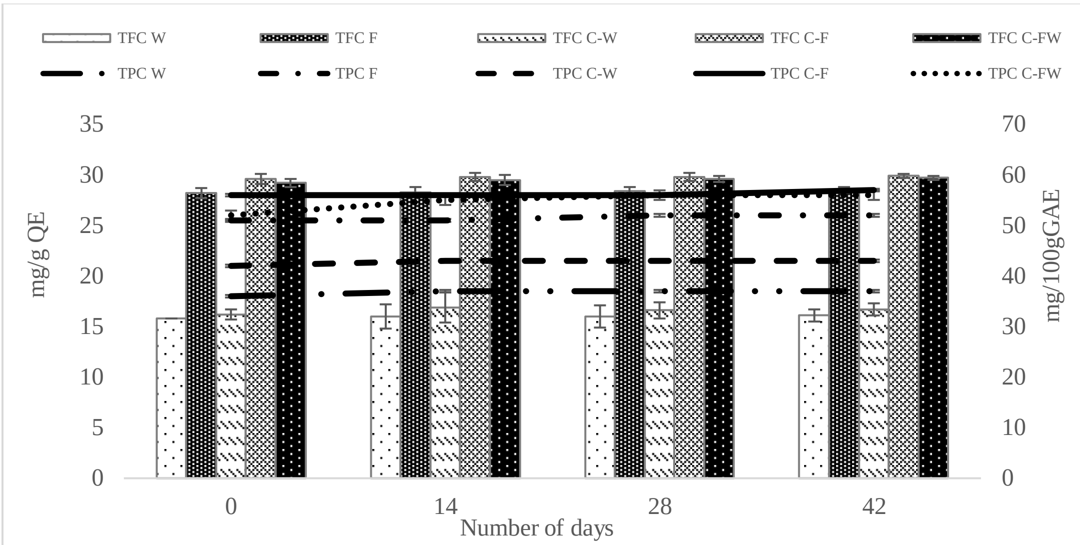
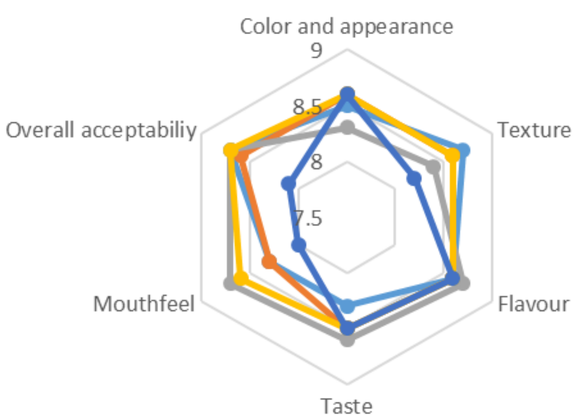


Fig. 3: Phytochemical composition in the cookies upon storage for 42 days. Values are mean±SD. Cookies:-W:Wheat flour alone, F: Foxtail flour alone, C-W:Coffee extract+Wheat flour, C-F:Coffee extract+Foxtail flour, CFW:Coffee extract+Foxtail flour and Wheat flour



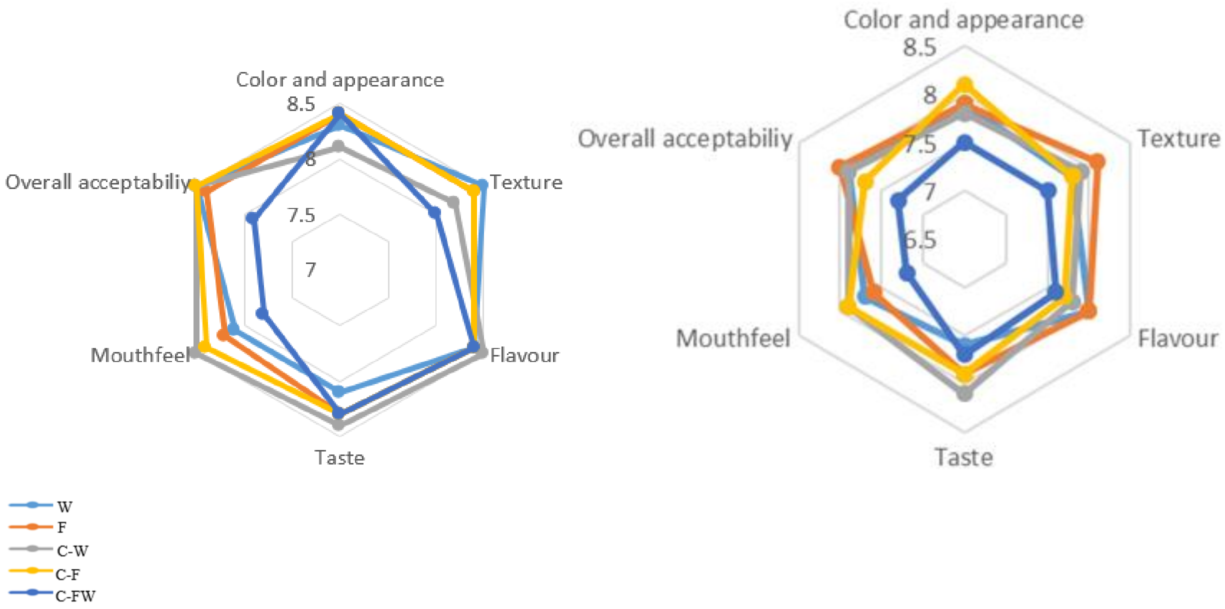
a) 0 days

b) 14 days

International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"



c) 28 days

d) 42 days

Fig. 4: Sensory evaluation of the cookies upon storage for 42 days. Values are mean±SD. Cookies:-W:Wheat flour alone, F: Foxtail flour alone, C-W:Coffee extract+Wheat flour, C-F:Coffee extract+Foxtail flour, CFW:Coffee extract+Foxtail flour and Wheat flour

4. CONCLUSION

The study investigates the nutritional quality and shelf-life of coffee extract-enriched cookies made from wheat-foxtail millet composite flour blends. The cookies were stored at ambient conditions for 42 d, with key parameters such as water activity, pH, antioxidant capacity and sensory qualities evaluated every 14 d. Among the formulations, foxtail millet-based cookies (C-F) exhibited the highest nutritional and antioxidant properties, including 64.1% antioxidant activity, 56 mg/100g total phenol, and 29.6 mg/g flavonoid content. Sensory evaluation showed a trivial decline in acceptability over storage, but no significant changes in phenol or flavonoid content. The study concludes that foxtail millet flour-enriched cookies offer a nutritious, functional snack with stable antioxidant properties during storage. The cookies maintain good sensory quality and nutritional stability during storage, making them a viable choice for consumers seeking a nutritious and flavorful alternative to traditional cookies.

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

Author contributions: Vyshak M.B, Abhirami K.G: Planning and Writing–original draft, Investigation, Formal analysis, Data curation. Sanu Jacob: Editing, Maya Raman: Writing – review & editing, Supervision & Bhavya E P: Editing.

Funding: No funding was obtained for this study

Conflict of Interest: The authors declare that they have no known competing financial interests or personal ties that could appear to have influenced the work revealed in this paper.

REFERENCES

[1]. Abedin MJ, Abdullah ATM, Satter MA, Farzana T. 2022. Physical, functional, nutritional and antioxidant properties of foxtail millet in Bangladesh. Heliyon 8: e11186. DOI: 10.1016/j.heliyon.2022.e11186.

[2]. Akseli I, Hilden J, Katz JM, Kelly RC. 2019. Reproducibility of the measurement of bulk/tapped density of pharmaceutical powders between pharmaceutical laboratories. J Pharm Sci 108: 1081–1084. DOI: 10.1016/j.xphs.2018.10.009.

[3]. AOAC International. 2005. Official Methods of Analysis (18th ed.). AOAC International.

[4]. Bello OM, Ogbesejana AB, Balkisu A, Osibemhe M, Musa B. 2022. Polyphenolic fractions from three millet types (Fonio, Finger millet, and Pearl millet): Their characterization and biological importance. Clin Complement Med Pharmacol 2: 100020. DOI: 10.1016/j.ccmp.2022.100020.

[5]. Belmiro RH, de Carvalho Oliveira L, Tribst AAL. 2022. Techno-functional properties of coffee by-products are modified by dynamic high pressure: A case study of clean label ingredient in cookies. LWT - Food Sci Technol 154: 112601. DOI: 10.1016/j.lwt.2021.112601.

[6]. Chevallier S, Della Valle G, Colonna P, Broyart B, Trystram G. 2002. Structural and chemical modifications of short dough during baking. J Cereal Sci 35: 1–10. DOI: 10.1006/jcrs.2001.0388.

[7]. Chinma CE, Abu JO, Adedeji OE, Aburime LC, Joseph DG. 2022. Nutritional composition, bioactivity, starch characteristics, thermal and microstructural properties of germinated pigeon pea flour. Food Biosci 49: 101900. DOI: 10.1016/j.fbio.2022.101900.

[8]. Chinma CE, Gbadamosi KB, Ogunsina BS, Oloyede OO, Salami SO. 2014. Effect of addition of germinated moringa seed flour on the quality attributes of wheat-based cake. J Food Process Preserv 38: 1737–1742. DOI: 10.1111/jfpp.12136.

[9]. Devi A, Khatkar BS. 2016. Physicochemical, rheological and functional properties of fats and oils in relation to cookie quality: A review. J Food Sci Technol 53: 3633–3641.

[10]. Devisetti R, Ravi R, Bhattacharya S. 2015. Effect of hydrocolloids on quality of proso millet cookie. Food Bioprocess Technol 8: 2298–2308. DOI: 10.1007/s11947-015-1573-

0.

[11]. Food and Agriculture Organization of the United Nations. 1998. FAO website. Available at: https://www.fao.org/

[12]. Gallagher E, Gormley TR, Arendt EK. 2004. Recent advances in the formulation of gluten-free cereal-based products. Trends Food Sci Technol 15: 143–152. DOI: 10.1016/j.tifs.2003.09.012.

[13]. Ghribi AM, Gafsi IM, Sila A, Blecker C, Danthine S. 2015. Effects of enzymatic hydrolysis on conformational and functional properties of chickpea protein isolate. Food Chem 187: 322–330. DOI: 10.1016/j.foodchem.2015.04.109.

[14]. Gopika M, Joshi S. 2024. Elucidating the effect of nixtamalization on the functional, nutritional, and microstructure properties of pearl millet flour. J Cereal Sci 117: 103891. DOI: 10.1016/j.jcs.2024.103891.

[15]. Guarch-Pérez C, Shaqour B, Riool M, Verleije B, Beyers K, Vervaet C. 2022. 3D-printed gentamicin-releasing poly-ε-caprolactone composite prevents fracture-related Staphylococcus aureus infection in mice. Pharmaceutics 14: 1363. DOI: 10.3390/pharmaceutics14071363.

[16]. Itagi HBN, Singh V. 2012. Preparation, nutritional composition, functional properties and antioxidant activities of multigrain composite mixes. J Food Sci Technol 49: 74–81. DOI: 10.1007/s13197-011-0267-6.

[17]. Kaur A, Singh G, Kukreja V, Sharma S, Singh S. 2022. Adaptation of IoT with blockchain in food supply chain management: An analysis-based review in development, benefits and potential applications. Sensors 22: 8174. DOI: 10.3390/s22218174.

[18]. Kumari S, Singh B, Kaur A. 2023. Influence of malted buckwheat, foxtail and proso millet flour incorporation on the physicochemical, protein digestibility and antioxidant properties of gluten-free rice cookies. Food Chem Adv 3: 100557. DOI: 10.1016/j.focha.2023.100557.

[19]. Lim J. 2011. Hedonic scaling: A review of methods and theory. Food Qual Prefer 22: 733–747. DOI: 10.1016/j.foodqual.2011.05.008.

[20]. Manley M, Van Zyl L, Osborne BG. 2002. Using Fourier transform near infrared spectroscopy in determining kernel hardness, protein and moisture content of whole wheat flour. J Near Infrared Spectrosc 10: 71–76.

[21]. Marak NR, Malemnganbi CC, Marak CR, Mishra LK. 2019. Functional and antioxidant properties of cookies incorporated with foxtail millet and ginger powder. J Food Sci Technol 56: 5087–5096. DOI: 10.1007/s13197-019-03981-6.

[22]. McHugh ML. 2011. Multiple comparison analysis testing in ANOVA. Biochem Med 21: 203–209. DOI: 10.11613/BM.2011.029.

[23]. Molinari R, Costantini L, Timperio AM, Lelli V, Bonafaccia F. 2018. Tartary buckwheat

ISSN: 2455-6939

Volume: 11, Issue: 05 "September-October 2025"

malt as ingredient of gluten-free cookies. J Cereal Sci 80: 37–43. DOI: 10.1016/j.jcs.2017.11.011.

[24]. Moro LB, Polanczyk RA, de Carvalho JR, Pratissoli D, Franco CR. 2012. Biological parameters and life table of Tetranychus urticae (Acari: Tetranychidae) at papaya cultivars. Cienc Rural 42: 487–494.

[25]. Olakanmi SJ, Jayas DS, Paliwal J. 2023. Applications of imaging systems for the assessment of quality characteristics of bread and other baked goods: A review. Compr Rev Food Sci Food Saf 22: 1817–1838. DOI: 10.1111/1541-4337.13131.

[26]. Omer SHS, Hong J, Zheng X, Khashaba R. 2023. Sorghum flour and sorghum flour enriched bread: Characterizations, challenges, and potential improvements. Foods 12: 4221. DOI: 10.3390/foods12234221.

[27]. Owheruo JO, Edo GI, Makia RS, Gaaz TS, Okolie MC. 2024. Nutritional qualities of cookies made from wheat/cashew nut composite flour. Food Humans 3: 100452. DOI: 10.1016/j.foohum.2024.100452.

[28]. Rakesh K, Umesha C, Balachandra Y. 2021. Influence of nitrogen and zinc levels on pearl millet (Pennisetum glaucum L.). Biol Forum Int J 13: 128–132. DOI: 10.33545/2618060X.2024.v7.i7Sh.1140.

[29]. Reaz AH, Abedin MJ, Abdullah ATM, Satter MA, Farzana T. 2023. Physicochemical and structural impact of CMC-hydrocolloids on the development of gluten-free foxtail millet biscuits. Heliyon 9: e17176. DOI: 10.1016/j.heliyon.2023.e17176.

[30]. Sharma B, Gujral HS, Solah V. 2017. Effect of incorporating finger millet in wheat flour on Mixolab behavior, chapatti quality and starch digestibility. Food Chem 231: 156–164. DOI: 10.1016/j.foodchem.2017.03.118.

[31]. Sharma IK, Di Prima S, Essink D, Broerse JE. 2021. Nutrition-sensitive agriculture: A systematic review of impact pathways to nutrition outcomes. Adv Nutr 12: 251–275.

[32]. Sharma N, Niranjan K. 2018. Foxtail millet: Properties, processing, health benefits, and uses. Food Rev Int 34: 329–363.

[33]. Sharma P, Gujral HS. 2014. Cookie making behavior of wheat–barley flour blends and effects on antioxidant properties. LWT Food Sci Technol 55: 301–307. DOI: 10.1016/j.lwt.2013.08.019.

[34]. Sharma R, Sharma S. 2022. Anti-nutrient & bioactive profile, in vitro nutrient digestibility, techno-functionality, molecular and structural interactions of foxtail millet (Setaria italica L.) as influenced by biological processing techniques. Food Chem 368: 130815. DOI: 10.1016/j.foodchem.2021.130815.

[35]. Sharma SK, Al-Badi AH, Govindaluri SM, Al-Kharusi MH. 2016. Predicting motivators of cloud computing adoption: A developing country perspective. Comput Human Behav 62: 61–69. DOI: 10.1016/j.chb.2016.03.073.[36] Sompong R, Siebenhandl-Ehn S,

Linsberger-Martin G, Berghofer E. 2011. Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. Food Chem 124: 132–140. DOI: 10.1016/j.foodchem.2010.05.115.

[36]. Sreerama YN, Sashikala VB, Pratape VM, Singh V. 2012. Nutrients and antinutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. Food Chem 131: 462–468. DOI: 10.1016/j.foodchem.2011.09.008.

[37]. Subhasri D, Dutta S, Leena MM, Moses JA, Anandharamakrishnan C. 2022. Gastronomy: An extended platform for customized nutrition. Future Foods 5: 100147. DOI: 10.1016/j.fufo.2022.100147.

[38]. Turksoy S, Özkaya B. 2011. Pumpkin and carrot pomace powders as a source of dietary fiber and their effects on the mixing properties of wheat flour dough and cookie quality. Food Sci Technol Res 17: 545–553. DOI: 10.3136/fstr.17.545.

[39]. Uthumporn U, Nadiah NI, Koh WY, Zaibunnisa AH, Azwan L. 2016. Effect of microwave heating on corn flour and rice flour in water suspension. Int Food Res J 23: 2493.

[40]. Verma V, Wang Y, El-Afifi R, Fang T, Rowland J. 2015. Fractionating ambient humic-like substances (HULIS) for their reactive oxygen species activity–assessing the importance of quinones and atmospheric aging. Atmos Environ 120: 351–359. DOI: 10.1016/j.atmosenv.2015.09.010.

[41]. Xiao X, Hu S, Lai X, Peng J, Lai W. 2021. Developmental trend of immunoassays for monitoring hazards in food samples: A review. Trends Food Sci Technol 111: 68–88. DOI: 10.1016/j.tifs.2021.02.045.

[42]. Yang T, Ma S, Liu J, Sun B, Wang X. 2022. Influences of four processing methods on main nutritional components of foxtail millet: A review. Grain Oil Sci Technol 5: 156–165. DOI: 10.1016/j.gaost.2022.06.005.

[43]. Young SM, Greaves JE. 1940. Influence of variety and treatment on phytin content of wheat. J Sci Food Agric 10: 1701–1705. DOI: 10.1111/j.1365-2621.1940.tb17171.x.

