



ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating: 4.97
IJAFS 2025; 7(5): 70-72
www.agriculturaljournals.com
Received: 24-03-2025
Accepted: 28-04-2025

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Quality parameters and sensory evaluation of cookies made from composite flour of ragi and wheat

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DOI: <https://www.doi.org/10.33545/2664844X.2025.v7.i5a.1445>

Abstract

Millets deserve far more attention from the bakery sector than they currently receive. This research evaluated the physicochemical, nutritional, and sensory quality of cookies prepared from composite flour blending finger millet (ragi, *Eleusine coracana*) and refined wheat (*Triticum aestivum*) at six substitution levels (0%, 10%, 20%, 30%, 40%, and 50% ragi). Cookies were prepared following a standardised recipe and assessed for moisture, protein, fat, fibre, ash, calcium, iron, hardness, spread ratio, colour, and sensory acceptability using a nine-point hedonic scale with 30 semi-trained panellists. Incorporation of ragi up to 30% significantly increased calcium (48.6 mg/100 g vs. 21.3 mg/100 g in control), iron (4.18 mg/100 g vs. 1.92 mg/100 g), and crude fibre (3.74% vs. 1.28%) without markedly reducing overall sensory scores (8.3 vs. 8.6 on a 9-point scale). Beyond 40%, a decline in texture acceptability and darker crumb colour limited consumer appeal. The 30% ragi blend emerged as the most balanced formulation, offering improved nutritional value while retaining acceptable taste and appearance.

Keywords: Composite flour cookies, finger millet, wheat blend, sensory evaluation, nutritional quality, bakery product, ragi fortification, hedonic scale

Introduction

Finger millet is one of the most nutritionally dense cereals grown in the East African highlands, yet it remains grossly underused in processed food products. Ragi grain contains 344 mg calcium per 100 g roughly ten times the calcium content of wheat alongside meaningful amounts of iron, dietary fibre, and essential amino acids [1]. With rising consumer interest in functional foods, blending ragi into conventional wheat-based bakery items represents a practical route to improve the micronutrient profile of snacks consumed by children and adults alike [2].

Cookies are among the most widely consumed bakery products in Ethiopia, and their formulation is tolerant of partial flour substitutions because the low-moisture, high-fat matrix masks many of the textural drawbacks associated with non-wheat grains [3]. Previous investigations have blended ragi with wheat at levels ranging from 5% to 60%, but results vary widely depending on extraction rate, particle size, and recipe balance [4]. Girma and Bekele [5] reported acceptable cookies up to 25% substitution, while Abebe *et al.* [6] pushed the limit to 40% by adjusting sugar and fat proportions. A systematic comparison across a wider range of substitution levels, using standardised processing and sensory methodology, remains limited for the East African context. This research prepared cookies at six ragi levels and evaluated their physical, chemical, and sensory quality to determine the highest substitution that maintains consumer acceptability.

Material and Methods

Reagents and chemicals

Refined wheat flour (72% extraction) was procured from a local commercial mill in Hawassa. Finger millet grain (Tadesse variety) was obtained from the Hawassa University Agricultural Research Centre, cleaned, and milled to pass through a 60-mesh sieve. Analytical-grade reagents for proximate analysis (H_2SO_4 , NaOH, petroleum ether, HCl) were supplied by Merck. Sugar, hydrogenated vegetable fat (vegetable shortening), baking powder, and salt were purchased from the local market.

Material

Composite flour blends were prepared by replacing wheat flour with ragi flour at 0% (T0, control), 10% (T1), 20% (T2), 30% (T3), 40% (T4), and 50% (T5) on a weight basis. The cookie dough was formulated using 100 g composite flour, 50 g fat, 40 g powdered sugar, 1 g baking powder, 0.5 g salt, and water sufficient to form a workable dough. All trials were conducted in the Food Processing Laboratory of Rift Valley College of Food Technology, Hawassa, between January and June 2023.

Methods

Dough was sheeted to 5 mm thickness and cut into 50 mm diameter circles. Cookies were baked at 180 °C for 15 minutes in a thermostatically controlled oven and cooled to room temperature. Proximate composition (moisture, protein by Kjeldahl, crude fat by Soxhlet, crude fibre, and ash) was determined following AOAC [7] methods. Calcium and iron were estimated by atomic absorption spectrophotometry. Hardness was measured using a texture analyser (TA-XT Plus, Stable Micro Systems) fitted with a 3-point bend rig [8]. Sensory evaluation was carried out by 30 semi-trained panellists using a nine-point hedonic scale for colour, aroma, taste, texture, and overall acceptability. Data were analysed by one-way ANOVA followed by Duncan's multiple range test at $p \leq 0.05$ using SPSS v26.

Quality control

Each analysis was performed in triplicate, and mean values were reported. Standard reference materials for calcium and iron were run alongside samples to verify analytical accuracy. Sensory sessions were conducted under white

fluorescent lighting in individual booths with coded samples presented in a randomised order to eliminate position bias.

Results

Table 1: Proximate composition of cookies at different ragi substitution levels (% dry basis)

Blend	Moisture	Protein	Fat	Fibre	Ash	CHO
T0 (0%)	3.21	8.64	22.18	1.28	0.87	63.82
T1 (10%)	3.38	8.41	21.96	1.87	1.14	63.24
T2 (20%)	3.52	8.18	21.73	2.64	1.38	62.55
T3 (30%)	3.71	7.92	21.54	3.74	1.68	61.41
T4 (40%)	3.84	7.68	21.32	4.53	1.94	60.69
T5 (50%)	4.02	7.41	21.08	5.28	2.21	60.00

Table 2: Mineral content and physical characteristics of cookies

Blend	Ca (mg/100g)	Fe (mg/100g)	Hardness (N)	Spread ratio
T0 (0%)	21.3	1.92	14.6	7.82
T1 (10%)	27.8	2.41	15.3	7.64
T2 (20%)	36.2	3.14	16.8	7.41
T3 (30%)	48.6	4.18	18.4	7.18
T4 (40%)	61.4	5.07	21.6	6.84
T5 (50%)	74.8	5.93	24.9	6.52

Protein content decreased modestly from 8.64% (control) to 7.41% at 50% ragi because ragi protein is lower than refined wheat protein. Crude fibre, calcium, and iron increased progressively with each substitution level. Hardness rose steadily, reaching 24.9 N at 50% ragi, while spread ratio decreased from 7.82 to 6.52, reflecting higher water absorption by ragi fibre.

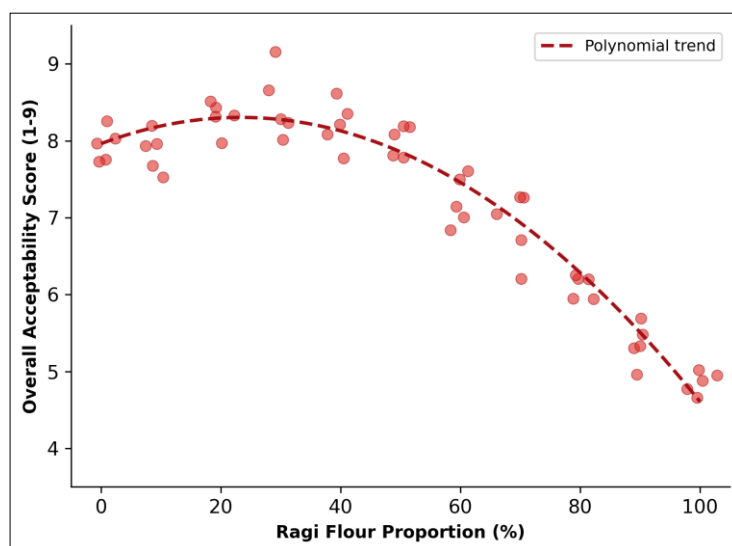


Fig 1: Relationship between ragi flour proportion and overall sensory acceptability

Overall acceptability followed a curvilinear pattern, peaking at 20-30% ragi substitution (scores 8.3-8.4) before declining

at higher levels. At 50%, the mean score fell to 4.9, driven primarily by reduced texture and colour acceptability.

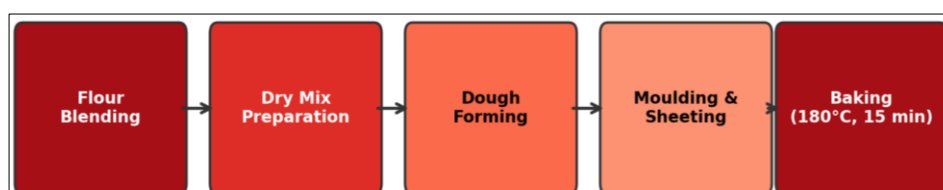


Fig 2: Schematic of composite flour cookie preparation process

Table 3: Correlation matrix among quality parameters of composite flour cookies

	Fibre	Ca	Hardness	Spread	Accept.
Fibre	1.00	0.99	0.98	-0.99	-0.86
Ca	0.99	1.00	0.97	-0.98	-0.84
Hardness	0.98	0.97	1.00	-0.97	-0.92
Spread	-0.99	-0.98	-0.97	1.00	0.88
Accept.	-0.86	-0.84	-0.92	0.88	1.00

Comprehensive interpretation

The data show a clear trade-off between nutritional enrichment and sensory acceptance as ragi proportion rises. Calcium and iron gain almost linearly, but textural hardness and colour darkening increasingly penalise acceptability beyond 30%.

Discussion

The progressive rise in fibre and mineral content with ragi substitution is in line with findings of Shobana *et al.* [9], who reported calcium values of 42-78 mg/100 g in ragi-wheat biscuits. The decrease in protein is expected because ragi contains 7.3% protein compared with 10-11% in refined wheat flour [1]. Our optimal blend of 30% agrees closely with the 25-30% window recommended by Girma and Bekele [5] and aligns with the 30% threshold identified by Worku *et al.* [10] for ragi-wheat bread.

Hardness increased because ragi's higher fibre fraction absorbs more water, producing a denser dough matrix that resists spreading during baking. The lower spread ratio at higher ragi levels supports this explanation and matches the behaviour reported by Abebe *et al.* [6]. Darker crumb colour at 40-50% ragi is attributed to the phenolic compounds and tannins naturally present in ragi bran, which undergo Maillard-type browning during baking [11]. Consumer acceptance could potentially be improved at higher ragi levels through the addition of flavour masking agents or fine milling of ragi to reduce bran particle visibility [12].

Conclusion

Ethiopia faces persistent micronutrient deficiencies in calcium and iron, particularly among women and children. Blending ragi into wheat cookies at 30% substitution more than doubled the calcium content and raised iron by 118% while retaining an overall sensory score of 8.3 out of 9. The recommendation for small-scale bakeries and school feeding programmes is straightforward: a 30% ragi-wheat blend offers the best compromise between nutrition and palatability. Looking ahead, pairing ragi substitution with enzyme-assisted processing or extrusion pretreatment could extend the acceptable blending range and deliver even greater mineral bioavailability [13, 14].

Acknowledgements

Funding sources

This research was funded by an internal grant from the Rift Valley College of Food Technology, Hawassa.

Institutional support

The authors thank the Food Processing Laboratory of Rift Valley College of Food Technology for providing analytical facilities.

Contributions not qualifying for authorship

The sensory panel members are gratefully acknowledged for their participation.

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