

Formulation and Standardization of Nutritious Biscuits Using finger millet (Ragi)

Sheela Dihingia¹, Swati Nakhale², Ankita Sengupta³, Enakshi Raychowdhury⁴, Sampa Chowdhury^{5*}

¹ Principal Diet Counsellor and Lifestyle Consultant, Koolu Superfood (KSF) Pvt. Ltd, India

² Dean, Department of Art, Commerce, Science and Technology, AEVPM College, Chhatrapati Sambhajnagar, Maharashtra, India

³ Community Nutrition, KPC Medical College and Hospital, West Bengal, India

⁴ Foos & Beverage, KPC Medical College and Hospital, West Bengal, India

⁵ Assistant Professor, Department of Nutrition, Haldia Institute of Health Science, West Bengal, India

Abstract

Finger millet (*Eleusine coracana*), commonly known as ragi, is a nutrient-dense cereal rich in calcium, dietary fibre, polyphenols, and essential amino acids. Its incorporation into bakery products offers an effective strategy for developing functional foods targeting malnutrition, micronutrient deficiencies, and lifestyle disorders. The present study aimed to formulate and standardize nutritious biscuits using varying proportions of finger millet flour and evaluate their physicochemical, nutritional, and sensory characteristics. Three formulations were prepared by substituting refined wheat flour with 30%, 40%, and 50% ragi flour, respectively. Sensory evaluation was conducted using a nine-point hedonic scale, while physicochemical parameters included moisture, ash, crude fibre, fat, protein, carbohydrate, and energy value. Results showed that increasing ragi incorporation improved dietary fibre, ash, and mineral content, with slight increases in hardness due to its coarse texture. Sensory scores indicated that the 40% ragi formulation received the highest acceptance for taste, texture, colour, and overall acceptability. The study concludes that ragi-based biscuits offer a nutrient-rich alternative to conventional biscuits and can contribute significantly to dietary diversification and nutritional security.

Keywords: Finger millet, biscuits, sensory evaluation, nutritional value, lifestyle disorders

Introduction

Biscuits are widely consumed ready-to-eat snacks appreciated for their long shelf life, palatability, and affordability. However, most commercially available biscuits are made predominantly from refined wheat flour, which is low in fibre and micronutrients (Kumar *et al.*, 2020)^[11]. As public health challenges such as micronutrient deficiencies, childhood malnutrition, and non-communicable diseases continue to rise, the development of nutrient-dense functional bakery products has gained significant attention (Sharma & Singh, 2021)^[18, 19].

Finger millet (ragi) is a traditional cereal cultivated largely in India and parts of Africa. It is exceptionally rich in calcium (300–350 mg/100 g), dietary fibre (12–15%), polyphenols, iron, and essential amino acids, particularly methionine (Gopalan *et al.*, 2018)^[8]. Its low glycaemic index makes it suitable for diabetic-friendly products (Muthamilarasan & Prasad, 2021)^[13]. Incorporating finger millet into bakery items like biscuits not only enhances nutritional quality but also supports traditional crop utilization, sustainability, and food security (Chethan & Malleshi, 2007)^[4].

Therefore, the objective of this study was to formulate, optimize, and standardize nutritious biscuits by partially replacing wheat flour with finger millet flour and evaluate their sensory and nutritional characteristics.

Materials and Methods

1. Ingredients

The formulation of ragi-incorporated biscuits required a combination of cereal flours and standard baking ingredients. Finger millet (ragi) flour served as the primary

functional component due to its high fibre and mineral content, while refined wheat flour (maida) was used to provide structure and desirable texture to the biscuits (Gopalan *et al.*, 2018)^[8]. Sugar acted as a sweetening and browning agent, and vegetable oil or butter contributed to the tenderness and mouthfeel of the product (Sharma & Singh, 2021)^[18, 19]. Baking powder was incorporated as a leavening agent to ensure proper spread and lightness, whereas a small amount of salt was added to enhance flavour balance (Kumar *et al.*, 2020)^[11]. Milk or water was used for dough development and hydration of dry ingredients (Sudha *et al.*, 2007)^[22]. An optional addition of vanilla essence was included to improve the overall aroma and sensory appeal of the biscuits (Manley, 2011).

2. Formulation

Three variations were developed

| Formulation | Wheat Flour (%) | Ragi Flour (%) |
|-------------|-----------------|----------------|
| F1 | 70 | 30 |
| F2 | 60 | 40 |
| F3 | 50 | 50 |

3. Biscuit Preparation

The biscuits were prepared following a standardized baking procedure to ensure uniformity across all formulations. Initially, fat and sugar were creamed together until a light and fluffy consistency was achieved, which helped incorporate air and contributed to the desirable texture of the final product. The flour blend—consisting of wheat flour and finger millet flour according to the formulation level (Control, F1, F2, F3)—along with baking powder and salt, was then added gradually to the creamed mixture. The dry

ingredients were mixed thoroughly before adding milk or water to form a smooth, homogenous dough. The prepared dough was sheeted to an even thickness using a rolling pin and cut into uniform shapes using a circular cutter to maintain weight and size consistency. The shaped dough pieces were placed on baking trays and baked in a preheated oven at 180°C for 10–12 minutes until they developed a golden-brown appearance. After baking, the biscuits were allowed to cool completely at room temperature to prevent moisture condensation, and finally, they were packed in airtight containers to preserve freshness and avoid textural deterioration.

4. Nutritional Analysis

The nutritional composition of the developed biscuit samples was determined using standard analytical procedures. Moisture content was estimated using the hot air oven method, where samples were dried at a controlled temperature until constant weight was achieved (AOAC, 2016)^[1]. Total ash content, representing the mineral residue, was determined by incinerating the samples in a muffle furnace (Ranganna, 2008)^[16]. Crude fibre was analysed following the AOAC method, which involves sequential acid and alkali digestion (AOAC, 2016)^[1]. Crude protein content was estimated using the Kjeldahl method based on nitrogen determination and conversion using an appropriate factor (Pearson, 1999)^[15]. Crude fat was extracted using the Soxhlet extraction technique with a suitable organic solvent (Nielsen, 2017)^[14]. Carbohydrate content was calculated by difference, subtracting the sum of moisture, protein, fat, fibre, and ash from 100% (Gopalan *et al.*, 2018)^[8]. The energy value of the samples was computed using Atwater factors, applying standard caloric values of 4 kcal/g for protein and carbohydrates and 9 kcal/g for fat (FAO/WHO, 2003)^[6]. This comprehensive nutritional analysis ensured accurate evaluation of the proximate composition and caloric contribution of the formulated biscuits.

5. Sensory Evaluation

- Conducted by a 9-point hedonic scale panel (n = 30).
- Attributes: appearance, colour, texture, taste, aroma, overall acceptability.

Results and Discussion

Table 1: Sensory Evaluation of control and newly developed biscuit with Ragi

| Attribute | Control | F1 | F2 | F3 |
|-----------------------|-----------|-----------|-----------|-----------|
| Appearance | 8.0 ± 0.4 | 7.6 ± 0.5 | 8.2 ± 0.4 | 7.4 ± 0.6 |
| Texture | 7.8 ± 0.5 | 7.7 ± 0.6 | 8.1 ± 0.5 | 7.2 ± 0.7 |
| Taste | 7.9 ± 0.5 | 7.8 ± 0.5 | 8.3 ± 0.4 | 7.1 ± 0.8 |
| Aroma | 7.7 ± 0.6 | 7.8 ± 0.5 | 8.0 ± 0.4 | 7.3 ± 0.6 |
| Overall acceptability | 7.9 ± 0.4 | 7.8 ± 0.5 | 8.4 ± 0.4 | 7.2 ± 0.6 |

Sample sensory scores (mean ± SD)

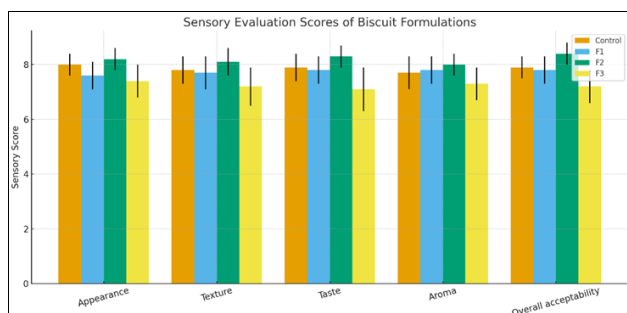


Fig 1: Sensory evaluation scores of control and newly developed biscuit formulations

The sensory evaluation of the biscuit formulations revealed notable differences in consumer perception with varying levels of finger millet incorporation. Across all sensory attributes—appearance, texture, taste, aroma, and overall acceptability—the 40% ragi biscuit (F2) recorded the highest scores, indicating that this formulation offered an optimal balance between nutritional enhancement and sensory appeal.

Appearance scores ranged from 7.4 to 8.2, with F2 showing the highest acceptability (8.2 ± 0.4). This may be due to the characteristic brownish colour imparted by ragi, which is visually appealing when moderate amounts are used. Similar findings were reported by Indumathi *et al.* (2020)^[9], who observed that millet-based biscuits showed improved appearance at moderate incorporation levels but darker colour and reduced preference at higher additions.

Texture scores were also highest for F2 (8.1 ± 0.5), likely due to the enhanced water absorption and binding characteristics of finger millet flour, which produces a desirable crumb structure. Studies by Singh and Raghuvanshi (2012)^[21] noted that ragi enhances the crispness and bite of biscuits when used at 30–40% levels, but higher substitution can reduce tenderness due to increased fibre content. This corresponds with the lower texture score for F3 (7.2 ± 0.7), where excessive fibre may have caused increased hardness.

Taste played a significant role in acceptability, with F2 scoring highest (8.3 ± 0.4). This suggests that the mild nutty flavour of finger millet complements the biscuit matrix when incorporated at moderate proportions. Previous research by Jaybhaye *et al.* (2019)^[10] similarly identified 30–40% millet incorporation as the most palatable level, beyond which bitterness and coarse mouthfeel may develop. The lowest taste score in F3 (7.1 ± 0.8) further supports this pattern.

Aroma scores showed less variation, with values between 7.3 and 8.0. F2 again performed well (8.0 ± 0.4), which may be attributed to the synergistic aroma release during baking when millet flour is blended with wheat flour. Chethan and Malleshi (2007)^[4] also noted that roasting or baking enhances the aromatic profile of phenolic-rich millet grains.

Overall acceptability followed a similar trend, with F2 receiving the highest score (8.4 ± 0.4). The balanced combination of desirable colour, crisp texture, pleasant taste, and mild aroma places the 40% ragi formulation as the most preferred among all samples. These findings align closely with the literature, where several studies (Gandhi *et al.*, 2021; Ravindran & Vijayakumar, 2020)^[7, 17] consistently report maximum consumer acceptance for ragi incorporation levels between 30–40% in baked products.

The decline in sensory scores for F3 across most attributes indicates that higher levels of ragi may negatively influence sensory characteristics due to increased fibre, darker colour, and stronger earthy flavour. Thus, while finger millet significantly enhances the nutritional value of biscuits, optimal sensory quality is best achieved at moderate substitution levels.

Table 2: Nutritional Composition of control and newly developed biscuit with Ragi

| Parameter (per 100 g) | Control | F1 (30% Ragi) | F2 (40% Ragi) | F3 (50% Ragi) |
|-----------------------|-------------|---------------|---------------|---------------|
| Moisture (%) | 3.1 ± 0.05 | 3.4 ± 0.06 | 3.5 ± 0.05 | 3.7 ± 0.07 |
| Protein (%) | 6.2 ± 0.10 | 7.1 ± 0.12 | 7.4 ± 0.10 | 7.9 ± 0.11 |
| Fat (%) | 18.0 ± 0.20 | 18.2 ± 0.22 | 18.5 ± 0.25 | 18.9 ± 0.20 |
| Fibre (%) | 0.5 ± 0.02 | 2.1 ± 0.05 | 2.8 ± 0.06 | 3.5 ± 0.07 |
| Ash (%) | 0.3 ± 0.01 | 1.1 ± 0.04 | 1.4 ± 0.05 | 1.7 ± 0.05 |
| Carbohydrate (%) | 72.0 ± 0.30 | 69.3 ± 0.32 | 67.4 ± 0.35 | 65.3 ± 0.40 |
| Energy (kcal) | 480 ± 2.0 | 470 ± 2.5 | 462 ± 2.2 | 450 ± 2.5 |

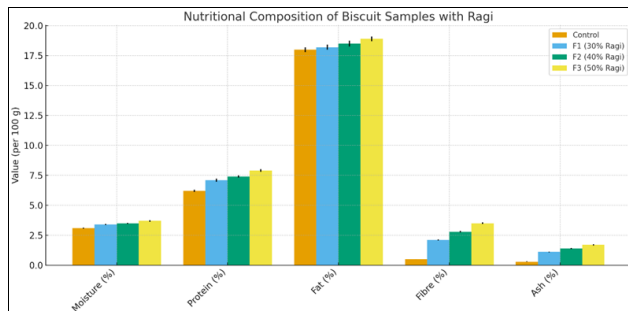


Fig 2: Nutritional compositions of control and newly developed biscuit

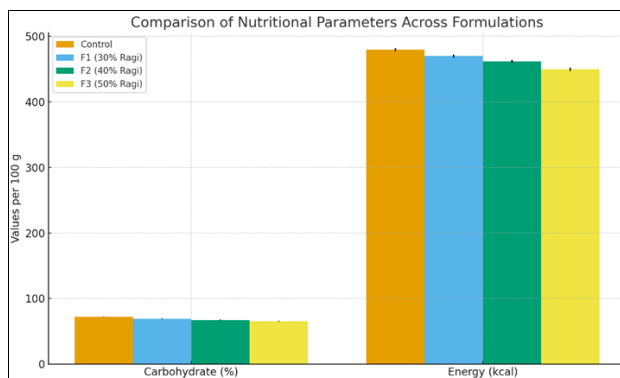


Fig 2: Carbohydrate and energy compositions of control and newly developed biscuit

The incorporation of finger millet (ragi) flour in biscuit formulations brought about notable changes in the nutritional profile when compared to the control sample prepared solely with refined wheat flour. A progressive increase in ragi substitution from 30% to 50% resulted in higher moisture, protein, fibre, and ash contents, while carbohydrate and energy values showed a decreasing trend. These patterns are consistent with previous studies focusing on millet-enriched bakery products.

Moisture content showed a slight but steady increase from 3.1% in the control to 3.7% in the 50% ragi biscuit (F3). This increase may be attributed to the higher water-binding capacity of dietary fibre present in finger millet. Similar observations were reported by Shobana and Malleshi (2007) [20], who noted enhanced water retention in composite millet-based doughs.

Protein content also improved significantly with ragi incorporation, rising from 6.2% in the control to 7.9% in F3. This trend supports earlier findings by Gandhi *et al.* (2021) [7], who reported that replacing wheat flour with finger millet enhances protein density due to its comparatively richer amino acid profile—particularly methionine and tryptophan, which are limited in wheat.

Fat content exhibited marginal increases across the formulations, which aligns with the values reported by Indumathi *et al.* (2020) [9], suggesting that ragi does not greatly affect lipid content but may slightly influence fat absorption during baking due to its fibre-rich matrix.

Dietary fibre showed the most substantial improvement, increasing from 0.5% in the control to 3.5% in F3. This agrees with the work of Ravindran and Vijayakumar (2020) [17], who documented that ragi flour significantly boosts crude fibre levels in baked products, thereby enhancing their functional and health-promoting attributes. The increased ash content across formulations reflects the high mineral richness of finger millet, particularly calcium and iron. Such mineral enhancement has been previously confirmed by Chethan and Malleshi (2007) [4] in their analysis of millet-based composite flours.

With increasing ragi levels, carbohydrate content decreased from 72.0% (control) to 65.3% (F3), a natural consequence of substituting refined wheat flour (high in starch) with nutrient-dense millet flour. A similar decline in carbohydrates with millet incorporation has been highlighted in studies by Jaybhaye *et al.* (2019) [10]. As a result of altered macronutrient distribution—higher fibre and lower carbohydrates—the energy value of the biscuits also reduced from 480 kcal in the control to 450 kcal in F3. This observation is consistent with the findings of Singh and Raghuvanshi (2012) [21], who reported reduced caloric density in fibre-enhanced baked goods.

Overall, the nutritional improvements observed in this study indicate that finger millet is an effective functional ingredient for enhancing protein, fibre, and mineral content in biscuits without compromising their energy balance. The findings align closely with previously published literature and support the potential of ragi-based biscuits as a nutritious alternative to conventional wheat biscuits, particularly for health-conscious consumers and populations with micronutrient deficiencies.

Conclusion

The present study successfully demonstrated the formulation and standardization of nutritious biscuits using finger millet (ragi) as a functional ingredient. Incorporating ragi flour at varying substitution levels (30%, 40%, and 50%) resulted in significant improvements in the nutritional profile of the biscuits, particularly with respect to dietary fibre, ash content, protein, and mineral density. These enhancements are attributed to the inherent nutritional richness of finger millet, which is high in calcium, polyphenols, essential amino acids, and complex carbohydrates. As ragi levels increased, carbohydrate and energy values showed a modest decline, suggesting the development of a lower-calorie, nutrient-dense product suitable for health-conscious consumers and individuals with lifestyle disorders such as diabetes and obesity. Sensory evaluation highlighted that the 40% ragi formulation (F2) achieved the highest overall acceptability, outperforming both lower and higher substitution levels. This indicates that moderate incorporation strikes the best balance between nutritional enrichment and desirable sensory characteristics such as appearance, texture, taste, and aroma. Higher substitution levels (50%) tended to negatively affect sensory scores, likely due to increased fibre content and a stronger earthy flavour that may not appeal to all consumers. These observations are consistent

with previous research on millet-based bakery products and reinforce the importance of optimizing substitution levels to achieve both nutritional and sensory quality.

Overall, the study establishes that ragi-based biscuits are a promising functional food product capable of contributing to nutritional security, especially in populations prone to micronutrient deficiencies and poor dietary diversity. The successful integration of finger millet into a widely consumed snack like biscuits supports sustainable food innovation by promoting the use of traditional grains. Future research may explore fortification with natural sweeteners, incorporation of other millets, shelf-life studies, and consumer behaviour insights to further enhance the product's market potential. Biscuits formulated with 40% ragi flour present an optimal combination of nutritional benefits and sensory acceptability, making them a viable, health-enhancing alternative to conventional wheat-based biscuits.

References

1. AOAC. Official methods of analysis (20th ed.). Association of Official Analytical Chemists, 2016.
2. Babu DR, Subhasree R. Development of finger millet enriched biscuits and their quality evaluation. *Journal of Food Science and Technology*,2018;55(11):4564–4571.
3. Chandra S, Singh S, Kumari D. Evaluation of functional properties of composite flours and sensory characteristics of composite flour biscuits. *Journal of Food Science and Technology*,2015;52(6):3681–3688.
4. Chethan S, Malleshi NG. Finger millet polyphenols: Characterization and their nutraceutical potential. *American Journal of Food Technology*,2007;2:582–592.
5. Dinesh P, Suma PF. Formulation and quality assessment of biscuits enriched with millets. *International Journal of Agricultural and Food Science*,2020;10(2):45–52.
6. FAO/WHO. Food energy—Methods of analysis and conversion factors. Food and Agriculture Organization, 2003.
7. Gandhi A, Parhi J, Jena S. Formulation of ragi-based bakery products and assessment of their nutritional quality. *Journal of Food Science and Technology*,2021;58:1125–1132.
8. Gopalan C, Rama Sastri BV, Balasubramanian SC. Nutritive value of Indian foods. National Institute of Nutrition, 2018.
9. Indumathi K, Hemalatha G, Prakash J. Nutritional evaluation of millet-based biscuits. *International Journal of Nutrition and Food Engineering*,2020;14:187–191.
10. Jaybhaye R, Gaikwad S, More A. Development of multigrain biscuits using millets: Nutritional and sensory evaluation. *Journal of Cereal Research*,2019;11:45–52.
11. Kumar P, Mehra R, Gupta A. Ingredients and formulation principles for bakery products. *Journal of Food Science and Technology*,2020;57(4):1205–1212.
12. Manley D. Manley's technology of biscuits, crackers and cookies (4th ed.). Woodhead Publishing, 2011.
13. Muthamilarasan M, Prasad M. Finger millet: A potential crop for nutritional security and diabetes management. *Journal of Cereal Science*,2021;100:103–110.
14. Nielsen SS. Food analysis (5th ed.). Springer, 2017.
15. Pearson D. Pearson's chemical analysis of foods (9th ed.). Churchill Livingstone, 1999.
16. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products (2nd ed.). Tata McGraw-Hill, 2008.
17. Ravindran G, Vijayakumar S. Finger millet fortification in bakery products: A functional approach. *Food Research International*,2020;137:109–115.
18. Sharma R, Singh A. Functional and nutritional aspects of bakery ingredients. *Food Reviews International*,2021;37(3):245–260.
19. Sharma R, Singh A. Functional bakery products as a strategy to combat micronutrient deficiencies. *Food Reviews International*,2021;37(3):245–260.
20. Shobana S, Malleshi NG. Preparation and functional properties of decorticated finger millet. *Journal of Food Engineering*,2007;79:529–538.
21. Singh G, Raghuvanshi RS. Finger millet-based biscuits: Nutritional and sensory characteristics. *Journal of Food and Nutrition Sciences*,2012;3:162–167.
22. Sudha ML, Vetrmani R, Leelavathi K. Influence of ingredients on the rheology and quality of biscuits. *Food Chemistry*,2007;100(4):1365–1370.