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Formulation, sensory evaluation, and nutritional characterization of functional bakery products prepared from water chestnut flour and finger millet flour

Sthuthi Anipam, Vinay Swami A V, Darshan R, Prashanth S J, Ajith S*
Department of Food Technology, Kuvempu University, Shankaraghatta, Karnataka, India
Corresponding Authors: Ajith S
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Abstract
The present study aimed to develop and evaluate functional bakery products using water chestnut (*Trapa natans*) flour and finger millet (ragi, *Eleusine coracana*) flour as nutritious alternatives to conventional wheat flour. Water chestnut flour is naturally gluten-free and rich in carbohydrates, dietary fiber, minerals, and antioxidants, whereas finger millet is an excellent source of calcium, iron, dietary fiber, and essential amino acids. Cakes and cookies were prepared using standardized formulations incorporating both flours and evaluated for sensory and nutritional quality. Sensory evaluation was conducted using a 9-point hedonic scale to assess color, appearance, flavor, taste, texture, and overall acceptability. The developed cake achieved high sensory scores for color, appearance, flavor, and taste (8.6), with an overall acceptability score of 8.5, while cookies also received satisfactory sensory ratings. Nutritional analysis of the cake revealed 64.04% carbohydrates, 4.09% protein, 13.34% fat, 12.96% dietary fiber, 1.22% ash, and an energy value of 392.58 kcal/100 g, demonstrating improved nutritional quality compared with conventional bakery products. The findings indicate that water chestnut and finger millet flours can be successfully incorporated into bakery products to enhance nutritional value without compromising sensory acceptability. These products have potential as functional, gluten-free alternatives for health-conscious consumers.

Keywords: Water chestnut flour, finger millet, functional foods, gluten-free bakery products, sensory evaluation, nutritional composition

Introduction

Bakery products such as cakes and cookies are among the most widely consumed convenience foods worldwide because of their palatability, affordability, and ease of preparation. Traditionally, these products are prepared using refined wheat flour, which provides desirable baking properties but is comparatively low in dietary fiber, minerals, and bioactive compounds. Growing consumer awareness of healthy eating, functional foods, and gluten-related disorders has increased the demand for bakery products formulated with nutrient-rich alternative flours that offer enhanced nutritional benefits (Sudha *et al.,* 2007; Saleh *et al.,* 2013) [16, 19].

Water chestnut (*Trapa natans*) is an aquatic crop widely cultivated in Asia, and its flour is naturally gluten-free and rich in carbohydrates, dietary fiber, minerals, and antioxidants. In addition to its nutritional value, water chestnut flour exhibits favorable functional properties, including good water absorption and starch gelatinization, making it suitable for bakery applications. Its gluten-free nature also makes it an attractive ingredient for developing products intended for individuals with gluten intolerance or celiac disease (Singh *et al.,* 2018) [18].

Finger millet (*Eleusine coracana*), commonly known as ragi, is an important cereal crop recognized for its exceptional nutritional composition. It is one of the richest natural sources of calcium among cereals and contains appreciable amounts of iron, dietary fiber, essential amino acids, and polyphenolic compounds (Devi *et al.,* 2014; Saleh *et al.,* 2013) [6, 16]. Regular consumption of finger millet has been associated with improved bone health, better glycemic control, enhanced digestive function, and a reduced risk of lifestyle-related diseases. Consequently, its incorporation into bakery products can significantly improve their nutritional quality while promoting the utilization of traditional and climate-resilient grains.

The combined use of water chestnut flour and finger millet flour offers an opportunity to develop functional bakery products with improved nutritional composition compared with conventional wheat-based products. These flours enhance dietary fiber, mineral content, and antioxidant potential while providing gluten-free alternatives for consumers seeking healthier food choices. However, replacing wheat flour may influence the sensory characteristics of bakery products, including color, texture, flavor, and overall acceptability (Hegde and Chandra, 2015) [8]. Therefore, evaluating consumer acceptance is essential to determine the feasibility of incorporating these alternative flours into bakery formulations.

The present study was undertaken to develop cakes and cookies using water chestnut flour and finger millet flour and to evaluate their sensory and nutritional characteristics. Standardized formulations were prepared, and the developed products were assessed using a 9-point hedonic scale based on color, appearance, flavor, taste, texture, and overall acceptability. Nutritional evaluation was also performed to determine the contribution of the composite flours to the quality of the developed products. The findings of this study are expected to promote the utilization of water chestnut and finger millet in bakery products and support the development of nutritious, functional, and gluten-free alternatives with good consumer acceptability.

Materials and Methods

1. Materials

Water chestnut flour (*Trapa natans*), finger millet (ragi, *Eleusine coracana*) flour, sugar, butter, eggs, refined vegetable oil, baking powder, and dry fruits were procured from the local market. All ingredients used were of food-grade quality.

2. Preparation of Cookies

Cookies were prepared using a composite flour blend containing 60 g water chestnut flour and 40 g finger millet flour, along with sugar (50 g) and butter (75 g). Butter and sugar were creamed until light and fluffy, after which the composite flour blend was incorporated to obtain a uniform dough. The dough was rolled, cut into uniform shapes, and baked at 165°C for 15–20 min. The baked cookies were cooled to room temperature and stored in airtight containers until further analysis (Sudha *et al*., 2007) [19].

3. Preparation of Cake

Cake batter was prepared using 50 g water chestnut flour and 50 g finger millet flour, sugar (100 g), three eggs, vegetable oil (20 g), baking powder, gel, and dry fruits. Eggs and sugar were beaten until light and fluffy, followed by the addition of oil and the dry ingredients to obtain a smooth batter. The batter was poured into greased cake moulds and baked at 165°C for 30 min. The cakes were cooled to room temperature before sensory and nutritional evaluation (AACC International, 2010) [2].

4. Sensory Evaluation

Sensory evaluation was carried out by 20 semi-trained panelists using a 9-point hedonic scale. The developed cakes and cookies were evaluated by a semi-trained sensory panel using a 9-point hedonic scale Peryam and Pilgrim (1957) [15]. The products were assessed for color, appearance, flavor, taste, texture, and overall acceptability, where a score of 9 represented "like extremely" and 1 represented "dislike extremely." Mean sensory scores were calculated to determine consumer acceptability.

5. Nutritional Analysis

The nutritional composition of the developed cake was determined using standard analytical methods. Moisture, ash, protein, fat, carbohydrate, dietary fiber, and energy content were determined according to AOAC (2019) standard methods. The results were expressed on a percentage basis, while energy value was reported as kcal per 100 g.

6. Statistical Analysis

All experiments were conducted in triplicate. Data were expressed as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA, and significant differences among means were determined at $p < 0.05$ (Gomez and Gomez, 1984) [7].

Results and Discussion

The sensory evaluation demonstrated that both the cake and cookies prepared with water chestnut flour and finger millet flour were well accepted by the panelists. The cake achieved higher scores than the cookies for all sensory attributes, with mean scores of 8.6 for color, appearance, and flavor, 8.3 for texture, and 8.5 for overall acceptability, whereas the cookies recorded overall acceptability of 7.1. The darker appearance of the cake may be attributed to the natural pigmentation of finger millet flour and the Maillard browning reaction during baking. Water chestnut flour also contributed to desirable crumb formation and moisture retention, resulting in improved texture and appearance. These findings agree with Hegde and Chandra (2015) [8], who reported that finger millet incorporation enhanced the sensory quality of cakes, and Shobana *et al*. (2013) [17], who observed good consumer acceptance of millet-based cookies. Similar observations were reported by Sudha *et al.* (2007) [19] for composite flour bakery products.

Table 1: Sensory Evaluation of the Developed Cake

Sl. No	Parameter	Description	Hedonic Scale score
1	Color	Visual attractiveness and uniformity of color	8.6
2	Appearance	Overall look and presentation of the product	8.6
3	Flavor and Taste	Pleasant aroma, sweetness, and overall palatability	8.6
4	Texture	Softness, mouthfeel, consistency, and crumb structure	8.3
5	Overall Acceptability	Overall preference and acceptance of the product by panelists	8.5

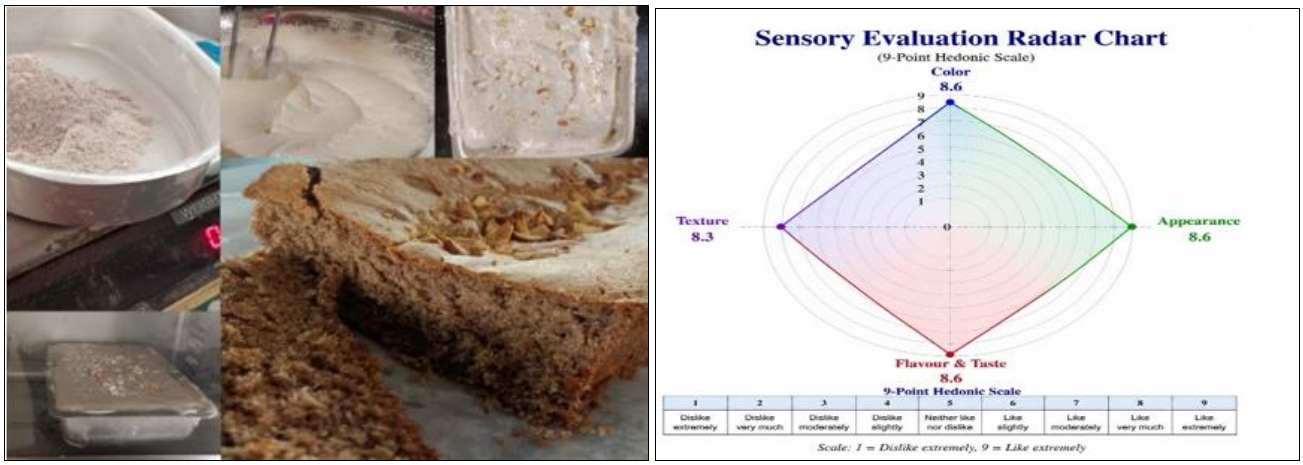

Fig 1: Developed cake prepared using water chestnut flour and finger millet flour.

Nutritional analysis indicated that the developed cake possessed an improved nutritional profile compared with conventional wheat-based cakes. The product contained 64.04% carbohydrates, 4.09% protein, 13.34% fat, 12.96% dietary fiber, 1.22% ash, and an energy value of 392.58 kcal/100 g. The high carbohydrate content mainly originated from water chestnut, flour and finger millet, providing a sustained source of energy. Finger millet contributed significant dietary fiber and minerals, while water chestnut flour enhanced starch quality and antioxidant potential. The relatively high dietary fiber content (12.96%) is particularly advantageous because it may improve digestive health, increase satiety, and support glycemic regulation.

Table 2: Sensory Evaluation of the Developed Cookies

Sl. No	Parameter	Description	Point Hedonic Scale score
1	Color	Visual attractiveness and uniformity of color	7.7
2	Appearance	Overall look and presentation of the product	7.9
3	Flavor and Taste	Pleasant aroma, sweetness, and overall palatability	8.0
4	Texture	Softness, mouthfeel, consistency, and crumb structure	7.9
5	Overall Acceptability	Overall preference and acceptance of the product by panelists	7.1

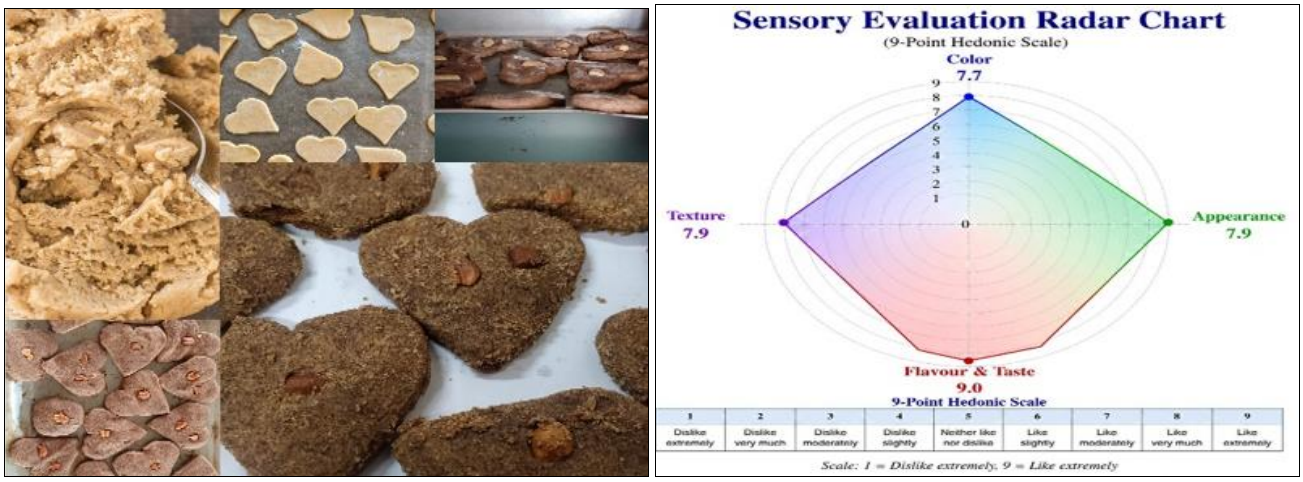

Fig 2: Developed Cookies prepared using water chestnut flour and finger millet flour

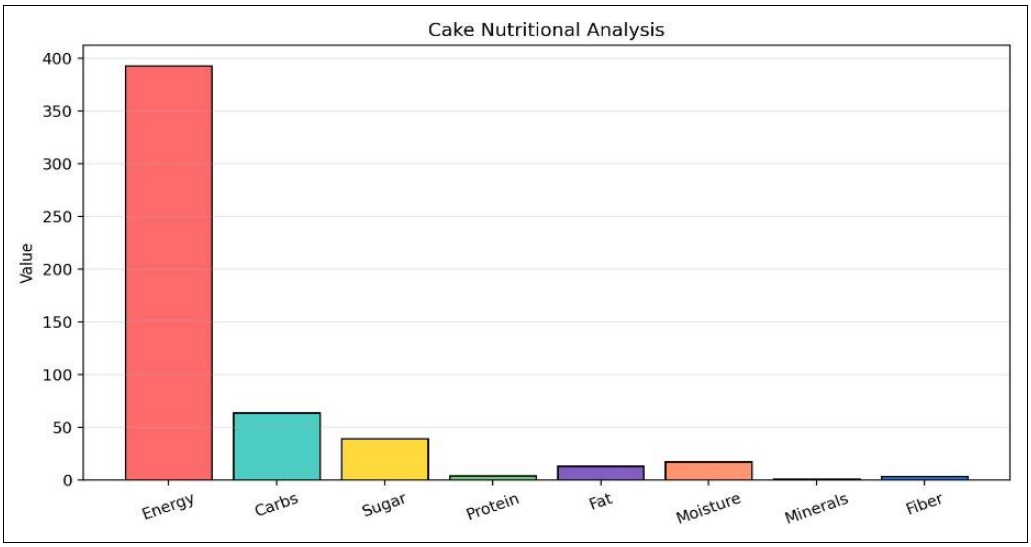

Figure 3: Graphical representation of cake nutritional analysis

Table 3: Nutritional Composition of the Developed Cake

Sl. No.	Parameter	Result (%)
1	Energy (kcal/100 g)	392.58
2	Total Carbohydrates (%)	64.04
3	Total Sugar (%)	39.69
4	Total Protein (%)	4.09
5	Total Fat (%)	13.34
6	Moisture (%)	10.31
7	Total Mineral Content (%)	1.22
8	Dietary Fiber (%)	12.96

The ash content (1.22%) reflects the contribution of essential minerals, particularly calcium, iron, potassium, and magnesium, derived mainly from finger millet and water chestnut flour. Although the protein content was moderate (4.09%), it was higher than that of many conventional bakery products due to the inclusion of finger millet and eggs. The fat content (13.34%) contributed to desirable mouthfeel, tenderness, and flavor, which was reflected in the high sensory scores.

The findings are consistent with previous studies demonstrating that the incorporation of finger millet and

water chestnut flour improves the nutritional quality of bakery products without compromising sensory acceptability. Devi *et al.* (2014) [6] reported that finger millet is an excellent source of dietary fiber, calcium, and polyphenols, while Hussain *et al.* (2020) [10] highlighted the functional properties and nutritional benefits of water chestnut flour in bakery applications. Similarly, Saleh *et al.* (2013) [16] reported that millet-based foods provide slowly digestible carbohydrates and enhanced nutritional quality, making them suitable for the development of functional foods.

Overall, the results indicate that the combined use of water chestnut flour and finger millet flour successfully produced nutritionally enriched cakes and cookies with high consumer acceptability. The developed products represent promising functional bakery alternatives with potential applications in gluten-free and health-oriented food markets.

Conclusion

The present study demonstrated the successful development of functional bakery products using water chestnut (*Trapa natans*) flour and finger millet (*Eleusine coracana*) flour as nutritious alternatives to conventional wheat flour. The incorporation of these flours significantly enhanced the nutritional quality of the developed cake by increasing dietary fiber, mineral content, and other health-promoting components while maintaining desirable sensory characteristics. Sensory evaluation indicated high consumer acceptability, with the cake receiving excellent scores for color, appearance, flavor, texture, and overall acceptability, confirming that the use of composite flours did not adversely affect product quality. Nutritional analysis revealed appreciable levels of carbohydrates, dietary fiber, protein, minerals, and energy, highlighting the potential of water chestnut and finger millet flours to produce nutrient-enriched bakery products. The developed product offers a promising functional and gluten-free alternative for health-conscious consumers and supports the utilization of underutilized crops in value-added food products. The findings suggest good commercial potential for incorporating these flours into bakery formulations. Future research should focus on optimizing flour proportions, evaluating shelf life, determining antioxidant activity and glycemic index, and conducting large-scale consumer studies to further improve product quality and expand its commercial applications.

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