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Development of eggless protein-enriched millet brownie using ragi, quinoa and jaggery

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Abstract
The present investigation focused on the development of a nutritionally enhanced eggless brownie by incorporating ragi (*Eleusine coracana*) and quinoa (*Chenopodium quinoa*) flours and replacing refined sugar with jaggery. Conventional bakery products are often deficient in essential nutrients due to the use of refined ingredients. In this study, two formulations were prepared: a control (sugar-based) and an experimental (jaggery-based) brownie containing 10% ragi and 15% quinoa flour. Sensory evaluation using a 9-point hedonic scale indicated significantly higher acceptability of the jaggery-based brownie in terms of taste (8.0) and overall acceptability (7.5). Proximate analysis revealed improved mineral content, protein levels (6.52 g/100 g), and enhanced antioxidant activity (145 mg/100 g) in the jaggery formulation. The study demonstrates that millet and pseudocereal incorporation, along with natural sweeteners, can significantly improve the nutritional and functional quality of bakery products while maintaining desirable sensory attributes.

Keywords: Ragi, quinoa, jaggery, functional foods, millet brownie, eggless bakery

Introduction

In recent years, there has been a growing consumer demand for healthier and functional foods due to the increasing incidence of lifestyle-related disorders such as obesity, diabetes, and cardiovascular diseases. Diets high in refined carbohydrates and sugars, particularly from bakery products made with refined wheat flour and sugar, contribute significantly to these health concerns [18]. Conventional bakery products are typically energy-dense but lack essential nutrients such as dietary fiber, minerals, and bioactive compounds, necessitating the development of nutritionally improved alternatives [5].

Millets have gained considerable attention as sustainable and nutrient-rich grains capable of enhancing the nutritional quality of food products. Ragi (*Eleusine coracana*), in particular, is recognized for its high calcium content, dietary fiber, and polyphenolic compounds, which contribute to its antioxidant activity and potential role in managing metabolic disorders [13] [14]. The inclusion of ragi in food formulations has been reported to improve mineral content and functional properties, making it a suitable ingredient for value-added products.

Quinoa (*Chenopodium quinoa*), a pseudocereal, is widely acknowledged for its superior nutritional profile, especially its high-quality protein containing all essential amino acids. In addition to its protein content, quinoa is rich in vitamins, minerals, and bioactive compounds that exhibit antioxidant and health-promoting properties [17]. The incorporation of quinoa into bakery products has been shown to enhance protein quality and overall nutritional value.

The use of alternative sweeteners is another important strategy in the development of functional foods. Jaggery, an unrefined form of sugar, retains significant amounts of minerals such as iron, calcium, and magnesium, along with phenolic compounds that contribute to its antioxidant activity. Compared to refined sugar, jaggery has been reported to improve the nutritional and functional characteristics of food products [10].

The incorporation of such functional ingredients into widely consumed bakery products offers an effective approach to improving dietary intake without compromising sensory attributes. Among bakery products, brownies are highly popular due to their appealing taste and texture; however, they are typically high in sugar and low in nutritional value. Previous studies have demonstrated that the incorporation of millet and pseudocereal flours into baked products can enhance their nutritional composition while maintaining acceptable sensory qualities [7].

Therefore, the present study was undertaken to develop an eggless, protein-enriched brownie by incorporating ragi and quinoa flour and replacing refined sugar with jaggery, and to evaluate its sensory, nutritional, and functional properties.

Methods and Materials

1. Raw Materials

Ragi (*Eleusine coracana*) flour, quinoa (*Chenopodium quinoa*) flour, jaggery, refined sugar, cocoa powder, dark chocolate compound, milk, refined oil, ghee, baking powder, and flavouring agents (vanilla and chocolate essence) were procured from the local market of Pune, Maharashtra, India. All chemicals and reagents used for analytical purposes were of analytical grade.

2. Formulation and Preparation of Brownie

Two formulations were developed:
S1 (Control): Sugar-based brownie
S2 (Experimental): Jaggery-based brownie

Both formulations incorporated 10% ragi flour and 15% quinoa flour as partial substitutes.

Preparation Procedure

The brownies were prepared following a standardized baking procedure with slight modifications for millet incorporation. Dry ingredients (ragi flour, quinoa flour, cocoa powder, and baking powder) were sieved to ensure uniform mixing. Sugar (S1) or jaggery (S2) was dissolved in

warm milk to prepare the liquid phase. Oil and ghee were added to the liquid mixture and homogenized. The dry ingredients were gradually incorporated into the liquid mixture to form a uniform batter. Flavouring agents were added, and the batter was poured into greased baking trays. Baking was carried out in a preheated oven at 180°C for 30 minutes. The baked brownies were cooled at ambient temperature and cut into uniform pieces. The preparation method was adapted from standard bakery processing techniques reported for functional baked products [1].

Table 1: Formulation Table

Ingredient	Sugar Brownie (%)	Jaggery Brownie (%)
Ragi flour	10	10
Quinoa flour	15	15
Sugar/Jaggery	22 (Sugar)	22 (Jaggery)
Cocoa powder	4.16	4.16
Dark compound	8.33	8.33
Baking powder	0.83	0.83
Oil	6.66	6.66
Ghee	3.88	3.88
Milk	28.88	28.88
Vanilla essence	0.13	0.13
Chocolate essence	0.13	0.13

3. Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale, where 9 indicates "like extremely" and 1 indicates "dislike extremely". The attributes evaluated included colour, taste, texture, flavour, and overall acceptability. A semi-trained panel consisting of students and faculty members evaluated the samples. The samples were coded and presented randomly to minimize bias.

Proximate Analysis

The proximate composition of brownie samples was determined using standard methods:

- Moisture content: Determined by hot air oven method at 105°C until constant weight [2].
- Ash content: Determined by incineration in a muffle furnace at 550°C [2].
- Crude protein: Determined by Kjeldahl method using nitrogen conversion factor (6.25) [2].
- Crude fat: Determined by Soxhlet extraction method [2].
- Carbohydrates: Calculated by difference method.
- Energy value: Calculated using Atwater factors (4 kcal/g for protein and carbohydrates, 9 kcal/g for fat).

These methods are widely accepted for food composition analysis [2].

Determination of Sugar Profile

- Reducing sugars: Determined using the dinitrosalicylic acid (DNS) method [9]
- Total sugars: Determined using standard titrimetric method (Lane and Eynon method) as described by [11].
- Non-reducing sugars: Calculated as the difference between total sugar and reducing sugar.

Determination of Antioxidant Activity

Total antioxidant activity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, which measures the ability of antioxidants to neutralize free radicals [4]. The absorbance was measured spectrophotometrically, and results were expressed as mg/100 g.

Determination of Tannin Content

Tannin content was estimated using the Folin–Denis method, which involves reaction of tannins with phosphotungstomolybdic acid reagent to produce a blue color measured spectrophotometrically [12].

Microbial Analysis

Microbial quality of brownie samples was evaluated using:

- Total Plate Count (TPC): Determined using pour plate method on nutrient agar
- Yeast and Mold Count (YMC): Determined using potato dextrose agar

The plates were incubated at appropriate temperatures, and results were expressed as colony forming units per gram (CFU/g). Standard microbiological procedures were followed [3].

Results

Sensory Evaluation

Table 2: Sensory Scores of Developed Brownies

Parameter	S1 (Sugar)	S2 (Jaggery)
Colour	7.0	7.5
Taste	6.5	8.0
Texture	6.5	7.0
Flavour	6.0	7.0
Overall Acceptability	6.0	7.5

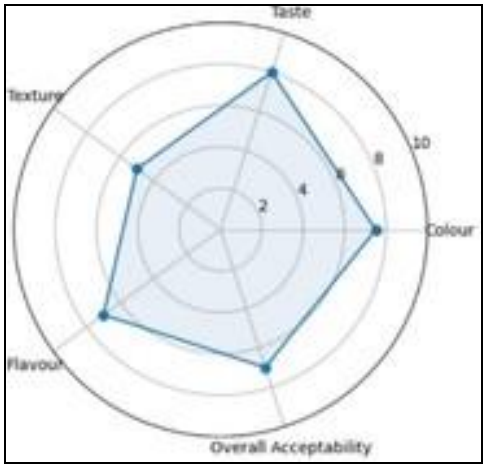

Fig 1: Sample 1

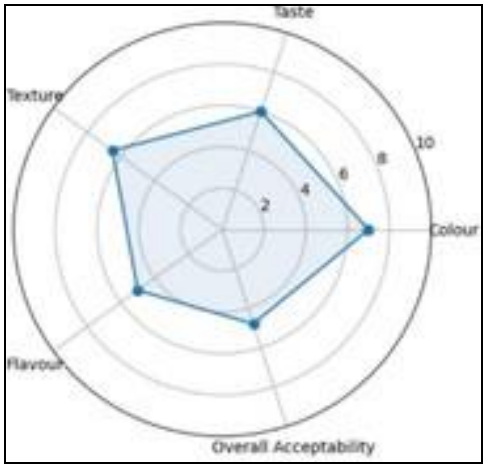

Fig 2: Sample 2

Sensory evaluation revealed that the jaggery-based brownie (S2) scored higher in all sensory attributes compared to the control (S1). The improvement in taste and overall acceptability can be attributed to the presence of natural sugars and flavour compounds in jaggery, which undergo caramelization and Maillard reactions during baking, leading to enhanced flavour development and desirable colour formation.

The higher colour score of S2 is likely due to the presence of reducing sugars in jaggery, which promote non-enzymatic browning reactions. Similar findings have been reported where incorporation of unrefined sweeteners improved sensory characteristics of bakery products [10].

Texture improvement in S2 may be associated with higher moisture retention due to hygroscopic nature of jaggery, which helps in maintaining softness and chewiness. Studies on functional bakery products also report that incorporation of alternative sweeteners and millet flours can enhance sensory acceptability when optimized properly [7].

Proximate Composition

Table 3: Proximate Composition of Brownies (g/100 g)

Parameter	S1	S2
Moisture	20.50	22.08
Ash	1.10	2.13
Protein	6.40	6.52
Fat	16.00	16.08
Carbohydrates	56.00	53.19
Energy (kcal)	398	383.56

The proximate composition analysis indicates that incorporation of ragi, quinoa, and jaggery significantly improved the nutritional profile of the brownie.

The higher moisture content in S2 may be attributed to the hygroscopic nature of jaggery, which enhances water retention in baked products. Increased moisture contributes positively to texture and shelf stability. Similar observations have been reported in jaggery-based bakery formulations [10].

The ash content, an indicator of total mineral content, was significantly higher in S2. This is due to the presence of mineral-rich ingredients such as ragi and jaggery. Ragi is known for its exceptionally high calcium content, while jaggery contributes iron and trace minerals [13] [14].

The protein content was marginally higher in S2 due to the inclusion of quinoa flour, which contains high-quality protein with a balanced amino acid profile [17]. The fat content remained relatively constant across samples, indicating that formulation changes did not significantly affect lipid content.

A slight reduction in carbohydrate content and overall energy value was observed in S2, suggesting a comparatively healthier nutritional profile. Similar findings have been reported in millet-based bakery products, where substitution of refined ingredients leads to improved nutritional quality [7].

Sugar Profile

Table 4: Sugar Composition (g/100 g)

Parameter	S1	S2
Total Sugar	26.00	21.04
Reducing Sugar	10.50	8.60
Non-reducing Sugar	13.00	6.20

The sugar profile analysis shows a significant reduction in total sugar content in the jaggery-based brownie (S2). This indicates that jaggery can be effectively used as a natural alternative to refined sugar to reduce overall sugar content while maintaining sweetness.

The lower non-reducing sugar content in S2 suggests a shift in carbohydrate composition, which may contribute to a lower glycaemic response. Jaggery contains a complex mixture of sucrose, glucose, and fructose along with minerals, which results in a slower release of sugars compared to refined sugar [10].

The presence of reducing sugars plays a critical role in flavour and colour development through Maillard reactions, which explains the improved sensory characteristics observed in S2.

Bioactive Properties

Table 5: Bioactive Compounds

Parameter	S1	S2
Antioxidant Activity (mg/100 g)	50	145
Tannin Content (mg/100 g)	10	52

A substantial increase in antioxidant activity was observed in the jaggery-based brownie (S2), which can be attributed to the presence of phenolic compounds in ragi, cocoa, and jaggery.

Ragi is known to contain significant amounts of polyphenols and flavonoids, which exhibit strong antioxidant properties [13] [14]. Similarly, jaggery contains phenolic compounds that contribute to its antioxidant potential [10].

The increased tannin content in S2 further supports the functional nature of the product. Tannins are known to possess antioxidant and antimicrobial properties, contributing to improved shelf stability and health benefits.

The enhancement in antioxidant activity aligns with findings from functional food studies, where incorporation of whole grains and natural sweeteners significantly improves bioactive properties [7].

Microbial Analysis

Table 6: Microbial Quality

Parameter	S1	S2
TPC (CFU/g)	2.5×10^2	1.8×10^2
YMC (CFU/g)	<10	<10

The microbial analysis indicated that both brownie samples were microbiologically safe, with counts well within acceptable limits for bakery products.

The low microbial load can be attributed to the baking process, which involves high temperatures that effectively reduce microbial contamination. Additionally, the low moisture content and presence of sugar contribute to reduced water activity, inhibiting microbial growth.

The slightly lower microbial count in S2 may be due to the presence of phenolic compounds in jaggery, which possess antimicrobial properties [10].

Similar observations have been reported in baked products, where proper processing and ingredient selection ensure microbial safety [8].

Food Labelling and Packaging Packaging Material

Fig 3: Single Piece Brownie Container

Fig 4: Label

Discussion

The results of the present study clearly indicate that the incorporation of ragi and quinoa flour along with the replacement of refined sugar by jaggery had a positive effect on the quality of the developed brownie. The jaggery-based sample (S2) showed higher sensory scores compared to the control (S1), particularly in taste (8.0) and overall acceptability (7.5). This improvement can be attributed to the presence of natural sugars in jaggery, which enhance flavor through caramelization and Maillard reactions during baking. In addition, the slightly higher moisture content observed in S2 (22.08%) may have contributed to improved texture and softness of the product due to the hygroscopic nature of jaggery [10].

The nutritional analysis further supports the effectiveness of the formulation. The protein content of S2 (6.52 g/100 g) was slightly higher than S1, which can be linked to the inclusion of quinoa flour, known for its high-quality protein [17]. The higher ash content (2.13%) indicates an overall increase in mineral composition due to the incorporation of ragi and jaggery [13, 14]. Moreover, the antioxidant activity of S2 (145 mg/100 g) was considerably higher than S1, suggesting enhanced functional properties due to bioactive compounds present in ragi, cocoa, and jaggery. The microbial analysis also confirmed that both samples were within safe limits, indicating good product stability [8]. These findings demonstrate that the developed brownie offers improved nutritional and functional benefits compared to conventional formulations.

Conclusion

The present study successfully developed an eggless, nutritionally enriched brownie using ragi and quinoa flour with jaggery as a natural sweetener. The experimental formulation (S2) showed better sensory acceptability along with improved nutritional properties such as higher protein content and enhanced antioxidant activity compared to the control sample.

Overall, the results confirm that the incorporation of millets and natural sweeteners can enhance the nutritional and functional quality of bakery products without compromising their acceptability. The developed brownie has good potential as a health-oriented functional product, with scope for further studies on shelf life and commercialization.

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