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Development and quality evaluation of millet-based beverage using ragi and bajra

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Abstract
Millets have gained increasing attention due to their superior nutritional composition and health-promoting properties. Ragi (*Eleusine coracana*) and Bajra (*Pennisetum glaucum*) are important millet grains rich in dietary fibre, minerals, protein and bioactive compounds. The present study was conducted to develop a millet-based buttermilk using different proportions of ragi and bajra and to evaluate its sensory and nutritional quality. Five formulations (T_0–T_4) were prepared by varying the proportion of ragi and bajra while maintaining other ingredients at constant levels. The developed beverage was evaluated for sensory characteristics using a 9-point Hedonic Scale, and nutritional composition was analysed using standard AOAC methods. Statistical analysis was carried out using Analysis of Variance (ANOVA). The results showed that incorporation of ragi and bajra significantly improved the nutritional quality of buttermilk while maintaining good sensory acceptability. Among all formulations, T_3 exhibited the highest overall acceptability along with desirable nutritional characteristics. The developed Ragi–Bajra Buttermilk may therefore be considered a nutritious functional beverage with potential health benefits and scope for commercial utilization.

Keywords: Ragi, Bajra, Buttermilk, Millet-based Beverage, Functional Food, Nutritional Composition, Sensory Evaluation

1. Introduction

Millets are among the oldest cultivated cereal crops and are recognized worldwide for their exceptional nutritional quality and health-promoting properties. They are rich sources of complex carbohydrates, dietary fibre, proteins, essential minerals and various bioactive compounds that contribute to the prevention of lifestyle-related disorders. Due to their climate resilience, low input requirements and high nutritional value, millets have gained considerable importance in sustainable agriculture and human nutrition.

Among the different millet varieties, ragi (*Eleusine coracana*) is well known for its exceptionally high calcium content, appreciable dietary fibre and quality protein. It also contains essential amino acids and natural antioxidants, making it a valuable ingredient for the development of functional foods. Bajra (*Pennisetum glaucum*) is another nutritionally important millet that provides significant amounts of protein, iron, dietary fibre and energy. Regular consumption of bajra has been associated with improved digestive health, enhanced mineral intake and better nutritional status.

Buttermilk is a traditional fermented dairy beverage widely consumed because of its refreshing taste, easy digestibility and probiotic benefits. However, conventional buttermilk contains relatively low levels of dietary fibre and some essential micronutrients. Incorporating millet flour into buttermilk is an effective approach to enhance its nutritional value while maintaining desirable sensory characteristics. Such millet-based beverages combine the advantages of fermented dairy products with the health benefits of whole grains and can serve as affordable functional beverages for different population groups.

In recent years, consumer preference has shifted towards natural and nutrient-rich foods, increasing the demand for functional beverages prepared from traditional ingredients. Millet-based beverages are gaining popularity because they are rich in nutrients, economical to produce and support the promotion of healthy dietary habits.

Therefore, the present investigation was undertaken to develop Ragi–Bajra Buttermilk using different proportions of ragi and bajra and to evaluate its sensory acceptability and nutritional composition in order to identify the most acceptable formulation with improved nutritional quality.

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2. Materials and Methods

2.1 Procurement of raw materials

The present investigation was carried out in the Department of Food Science and Nutrition, *Chandra* Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. The raw materials required for the preparation of the millet-based beverage, namely ragi (finger millet), bajra (pearl millet), fresh beetroot, curd, ginger, garlic, green chilli, curry leaves, coriander leaves, roasted cumin powder and black salt, were procured from the local market of Kanpur. All ingredients were selected based on their freshness, quality and uniformity. The grains were cleaned manually to remove dust, stones and other foreign materials before processing.

2.2 Formulation of millet-based beverage

Five formulations were prepared by varying the proportion of ragi and bajra while maintaining the quantity of ingredients constant. The formulations used in the study were as follows:

2.3 Preparation of millet-based beverage

The cleaned ragi and bajra grains were separately milled into fine flour. The required quantities of flour according to each treatment were mixed with water to prepare a smooth slurry. The slurry was heated with continuous stirring until complete gelatinization was achieved. After cooling to room temperature, fresh curd was incorporated to prepare the buttermilk base. Finely chopped ginger, garlic, green chilli, curry leaves, coriander leaves, roasted cumin powder and black salt were added to enhance the flavour and overall acceptability. The beverage was mixed thoroughly in a grinder to obtain a uniform consistency and stored under refrigeration until further analysis.

2.4 Sensory evaluation

The developed beverages were evaluated for sensory quality by a semi-trained panel using the 9-point Hedonic Scale described by Lawless *et al.* (2010) [1]. The sensory attributes evaluated included appearance, colour, flavour, taste, texture and overall acceptability. The samples were coded and presented randomly to minimize bias during evaluation. The mean sensory scores obtained from the panel members were used for statistical analysis.

Treatment	Ragi (%)	Bajra (%)
T_0	0	100
T_1	20	80
T_2	30	70
T_3	40	60
T_4	50	50

2.5 Nutritional analysis

The nutritional composition of the developed beverages was determined by estimating moisture, protein, fat, crude fibre, total ash, carbohydrate, energy, calcium and iron using standard AOAC procedures. Carbohydrate content was calculated by difference, while energy values were estimated using standard conversion factors. The analyses were conducted in triplicate, and the mean values were recorded.

2.6 Statistical analysis

The experimental data obtained from sensory evaluation, physico-chemical analysis and nutritional composition were statistically analysed using Analysis of Variance (ANOVA) under a Completely Randomized Design (CRD). The mean values were compared at the 5% level of significance, and parameters such as Standard Error (SE), Critical Difference (CD) and Coefficient of Variation (CV) were calculated to determine the significance of differences among treatments.

3. Results and Discussion

3.1 Sensory evaluation

The sensory characteristics of the developed millet-based beverages were evaluated using a 9-point Hedonic Scale. The parameters assessed included appearance, colour, flavour, taste, texture and overall acceptability. The results indicated significant differences among the five formulations. while the balanced proportion of ragi and bajra contributed to better flavour and texture.

Among all the formulations, T_3 (40% ragi and 60% bajra) obtained the highest overall acceptability score. The beverage prepared with this formulation exhibited an attractive colour, pleasant flavour, smooth consistency and refreshing taste. Although T_4 contained a higher proportion of ragi, a slight decrease in sensory score was observed, probably because of the characteristic flavour and comparatively thicker consistency of ragi. The control sample (T_0) received comparatively lower scores because of its less intense flavour and lower nutritional appeal.

These findings indicate that an optimum combination of ragi and bajra enhances the sensory quality of millet-based beverages and improves consumer acceptance.

Table 3.1. Sensory Evaluation of Developed Ragi-Bajra Buttermilk

Parameters	Control (Co)	T1	T2	T3	T4	CD (5%)	S.E
Appearance	8.00	7.50	8.20	8.80	8.50	0.742	0.2534
Colour	6.50	7.00	8.30	8.50	7.20	1.164	0.3987
Taste	7.00	7.50	8.50	7.80	8.50	0.895	0.3061
Flavour	8.50	7.50	8.00	8.60	8.20	0.796	0.2714
Texture	6.00	7.00	7.50	8.30	8.00	1.164	0.3987
Overall acceptability	7.90	7.25	8.10	8.54	8.22	0.595	0.2039

3.2 Nutritional composition

The proximate composition of the developed millet-based beverages revealed that the incorporation of ragi and bajra significantly improved their nutritional quality.

The moisture content remained comparatively high in all formulations, which is desirable for fermented beverages and contributes to a refreshing mouthfeel. Slight variations among treatments were observed due to differences in millet proportions.

The protein content varied among the treatments. The optimized formulation (T_3) recorded comparatively higher protein content, indicating that the incorporation of ragi improved the nutritional value of the beverage.

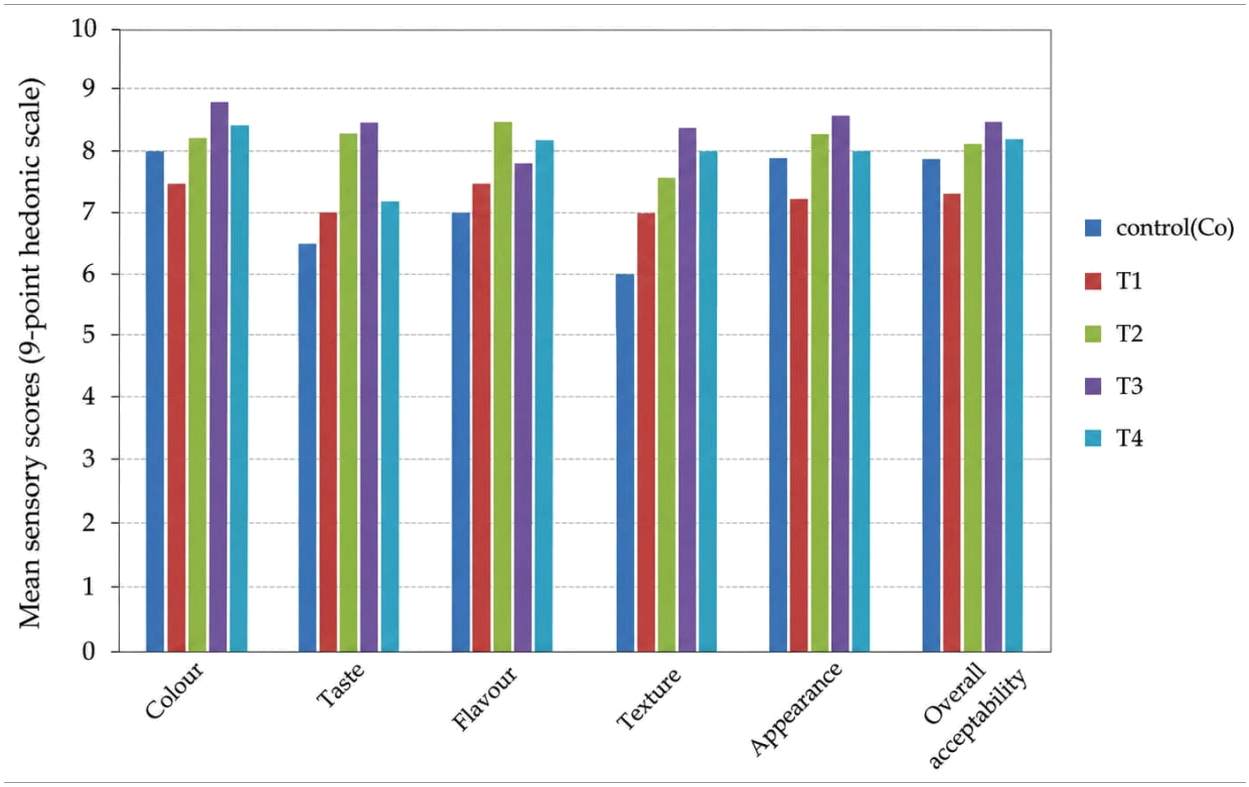
The fat content remained low in all treatments, making the beverage suitable for health-conscious consumers. Since both ragi and bajra naturally contain moderate amounts of fat, only minor differences were observed among the formulations.

The crude fibre content increased with the incorporation of ragi. Dietary fibre plays an important role in improving digestive health, reducing the glycaemic response and enhancing satiety. Therefore, the developed beverage can be considered a fibre-rich functional drink.

Similarly, ash content reflected the presence of essential minerals contributed by the millet grains. The carbohydrate and energy values

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showed slight variation among treatments but remained within the desirable range for nutritious beverages.



Overall, the proximate composition confirmed that the developed millet-based beverage possessed superior nutritional quality compared with conventional buttermilk.

Mineral composition

Calcium and iron are two important nutritional attributes of millet-based beverages. The results indicated that the developed formulations contained appreciable amounts of both minerals.

Ragi contributed significantly to the calcium content because it is naturally rich in calcium, while bajra improved the iron content of the beverage. The optimized formulation (T_3) exhibited a desirable balance of calcium and iron, making it suitable for improving the nutritional status of children, adolescents and women who require increased mineral intake.

The presence of these essential minerals enhances the functional value of the beverage and supports bone health, haemoglobin formation and normal physiological functions.

Moisture :-

The moisture content of the developed ragi–bajra buttermilk beverages ranged from 85.90 to 87.00 per cent. The moisture content recorded in T_0, T_1, T_2, T_3 and T_4 was 85.90, 86.20, 86.50, 86.70 and 87.00 per cent, respectively. The highest moisture content was observed in T_4 (87.00%), while the lowest was recorded in T_0 (85.90%). The increase in moisture content may be attributed to the water-holding capacity of ragi and bajra flour during beverage preparation. Statistical analysis revealed that the S.Em value was 0.441 and the CV was 0.712 per cent, indicating very low variation among the treatments. The results suggest that all formulations maintained a desirable moisture level, contributing to beverage acceptability.

Protein :-

The protein content of the developed ragi–bajra buttermilk beverages ranged from 3.50 to 4.10 per cent. The protein content recorded in T_0, T_1, T_2, T_3 and T_4 was 4.10, 3.90, 3.80, 3.70 and 3.50 per cent, respectively. The highest protein content was observed in T_0 (4.10%), whereas the lowest was found in T_4 (3.50%). The differences in protein content may be due to variation in the composition of the formulations. Statistical analysis showed an S.Em value of 0.257 and a CV of 7.984 per cent, indicating low variation among the treatments. The results suggest that all treatments provided appreciable protein content.

Fat :-

The fat content of the developed ragi–bajra buttermilk beverages ranged from 1.50 to 1.80 per cent. The fat content recorded in T_0, T_1, T_2, T_3 and T_4 was 1.80, 1.70, 1.70, 1.60 and 1.50 per cent, respectively. The highest fat content was observed in T_0 (1.80%), while the lowest was recorded in T_4 (1.50%). The S.Em value was 0.139 and the CV was 9.865 per cent. The results indicated relatively low variation among treatments and showed that fat content remained fairly stable across formulations.

Table 3.2. Nutritional and mineral composition of Ragi Bajra Buttermilk (in 100 ml)

Nutrient	Control (Co)	T1	T2	T3	T4	SE	CV
Moisture	85.90	86.20	86.50	86.70	87.00	0.441	0.712
Protein	4.1	3.9	3.8	3.7	3.5	0.257	7.984
Fat	1.8	1.7	1.7	1.6	1.5	0.139	9.865
Fiber	1.700	1.600	1.500	1.400	1.300	0.171	13.774
Ash	1.2	1.10	1.10	1.00	0.90	0.144	15.421

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Nutrient	Control (Co)	T1	T2	T3	T4	SE	CV
Carbohydrate	8.50	8.20	8.80	7.80	7.50	0.498	7.741
Energy	64.000	62.000	60.000	58.000	56.000	3.691	7.923
Calcium	160.00	152.00	145.00	138.00	130.00	11.118	8.947
Iron	3.20	2.90	2.70	2.40	2.10	0.492	21.884

Crude fiber :-

The crude fiber content of the developed ragi–bajra buttermilk beverages ranged from 1.30 to 1.70 per cent. The fiber content recorded in T_0, T_1, T_2, T_3 and T_4 was 1.70, 1.60, 1.50, 1.40 and 1.30 per cent, respectively. The highest fiber content was observed in T_0 (1.70%), whereas the lowest was recorded in T_4 (1.30%). Statistical analysis revealed an S.Em value of 0.171 and a CV of 13.74 per cent. The results indicated moderate variation among treatments while maintaining acceptable fiber levels.

Ash :-

The ash content of the developed ragi–bajra buttermilk beverages varied from 0.90 to 1.20 per cent. The ash content recorded in T_0, T_1, T_2, T_3 and T_4 was 1.20, 1.10, 1.10, 1.00 and 0.90 per cent, respectively. The highest ash content was observed in T_0 (1.20%), while the lowest was recorded in T_4 (0.90%). The S.Em value was 0.144 and the CV was 15.421 per cent. The results indicated moderate variability among the treatments with respect to mineral content.

Carbohydrate :-

The carbohydrate content of the developed ragi–bajra buttermilk beverages ranged from 7.50 to 8.50 per cent. The carbohydrate content recorded in T_0, T_1, T_2, T_3 and T_4 was 8.50, 8.20, 8.00, 7.80 and 7.50 per cent, respectively. The highest carbohydrate content was observed in T_0 (8.50%), whereas the lowest was recorded in T_4 (7.50%). Statistical analysis showed an S.Em value of 0.498 and a CV of 7.741 per cent, indicating low variation among the treatments. The carbohydrate content contributed significantly to the overall energy value of the beverage.

Energy :-

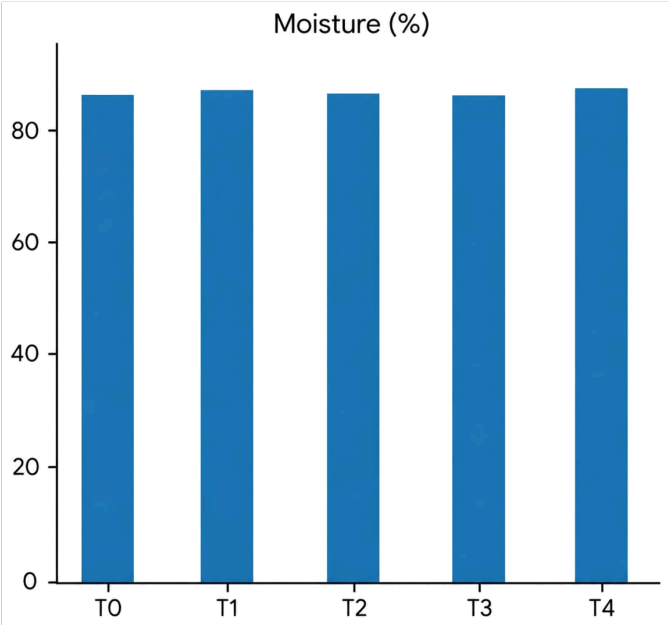
The energy value of the developed ragi–bajra buttermilk beverages ranged from 56.00 to 64.00 kcal per 100 g. The energy values recorded in T_0, T_1, T_2, T_3 and T_4 were 64.00, 62.00, 60.00, 58.00 and 56.00 kcal per 100 g, respectively. The highest energy value was observed in T_0, while the lowest was recorded in T_4. Statistical analysis revealed an S.Em value of 3.691 and a CV of 7.923 per cent. The results indicated low variation among treatments and consistency in the caloric value of the beverages.

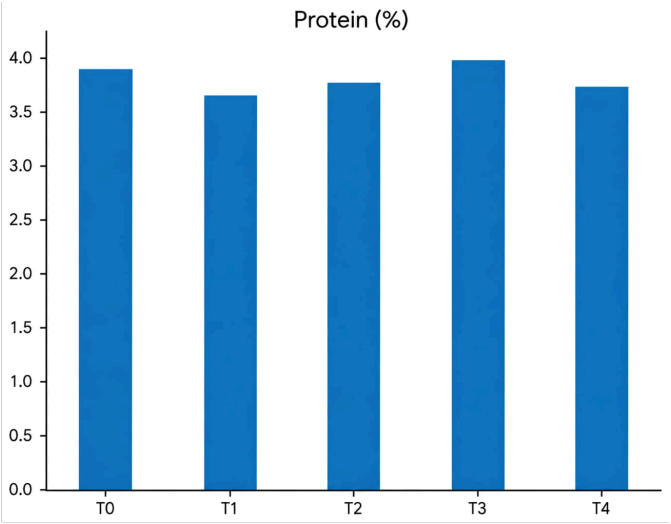
Calcium :-

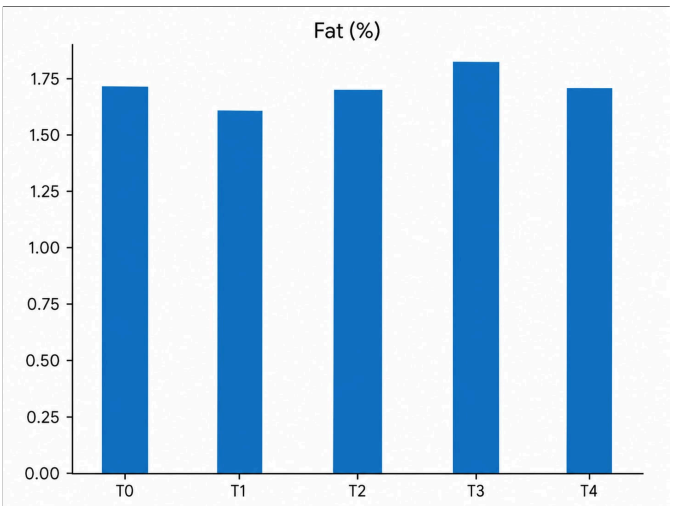
The calcium content of the developed ragi–bajra buttermilk beverages ranged from 130.00 to 160.00 mg per 100 g. The calcium content recorded in T_0, T_1, T_2, T_3 and T_4 was 160.00, 152.00, 145.00, 138.00 and 130.00 mg per 100 g, respectively. The highest calcium content was observed in T_0 (160.00 mg/100 g), whereas the lowest was recorded in T_4 (130.00 mg/100 g). The S.Em value was 11.118 and the CV was 8.947 per cent. The results indicated comparatively low variation among treatments and confirmed the beverage as a good source of calcium.

Iron :-

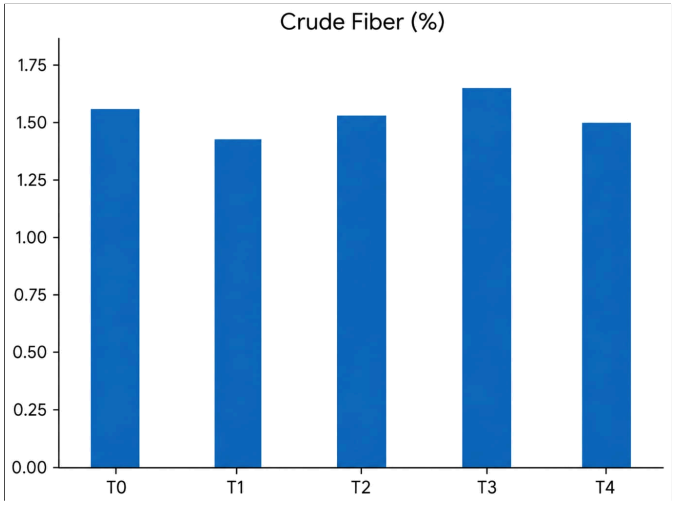
The iron content of the developed ragi–bajra buttermilk beverages ranged from 2.10 to 3.20 mg per 100 g. The iron content recorded in T_0, T_1, T_2, T_3 and T_4 was 3.20, 2.90, 2.70, 2.40 and 2.1 mg per 100 g, respectively. The highest iron content was observed in T_0 (3.20 mg/100 g), while the lowest was recorded in T_4 (2.10 mg/100 g). Statistical analysis showed an S.Em value of 0.492 and a CV of 21.84 per cent. The results indicated comparatively higher variation among treatments with respect to iron content, although all formulations contained appreciable amounts of iron.

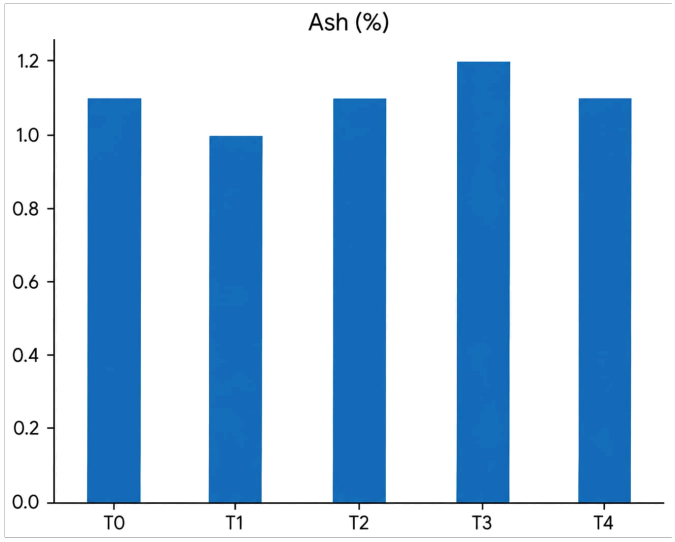


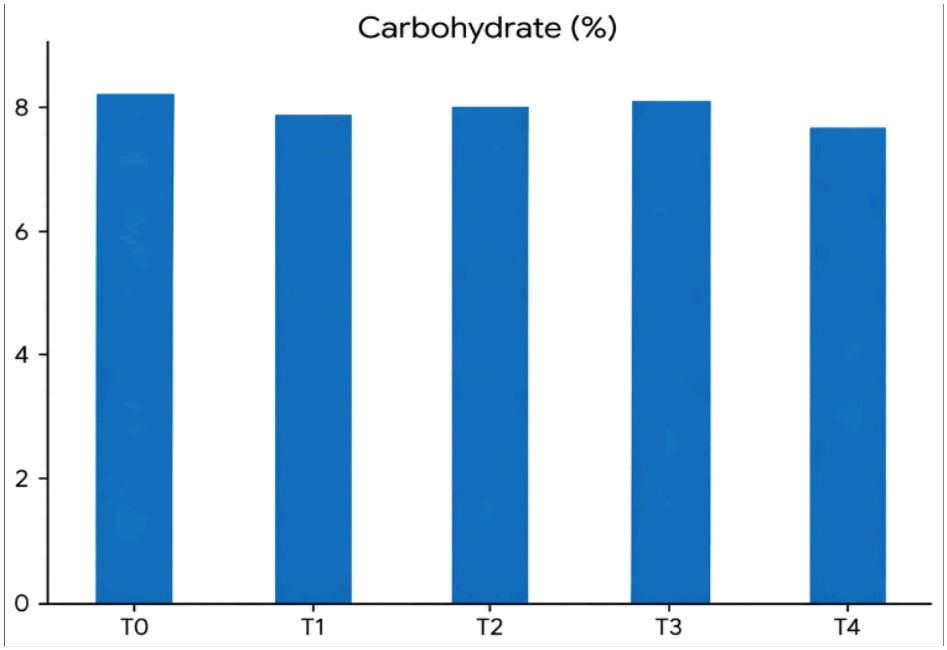


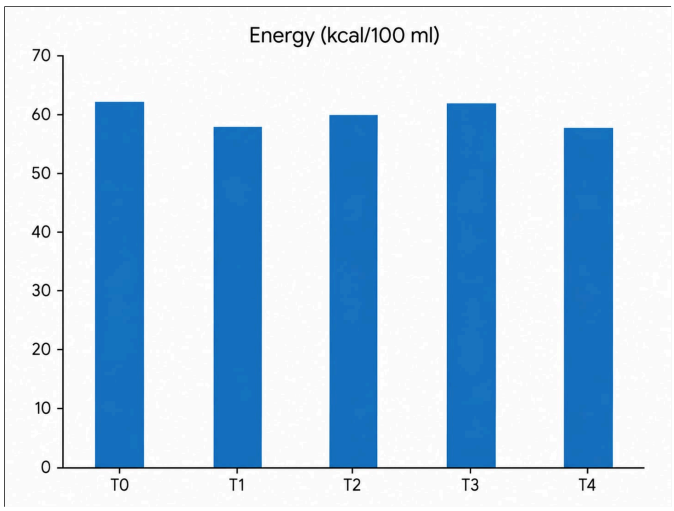


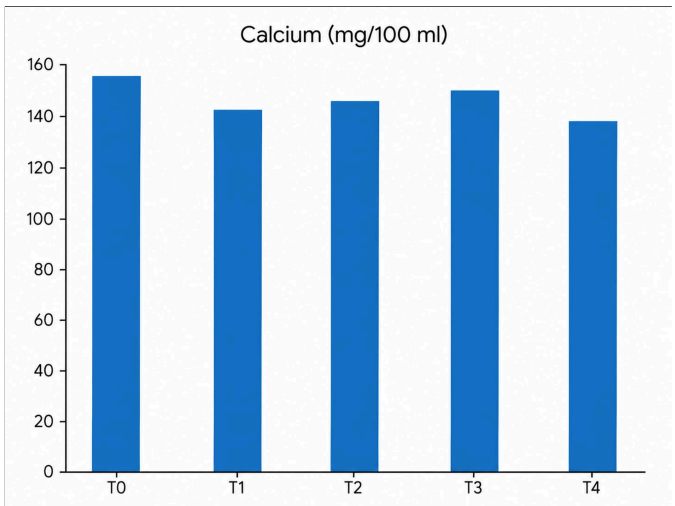
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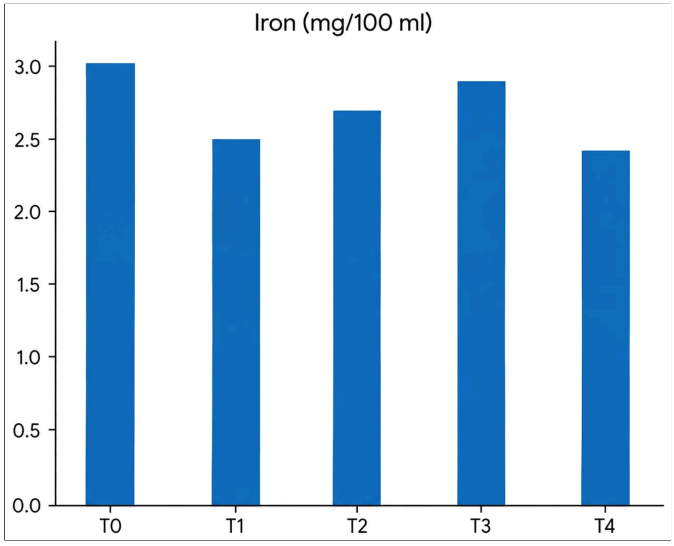


3.4 Overall discussion

The present investigation demonstrated that the incorporation of ragi and bajra successfully enhanced the nutritional quality as well as the sensory acceptability of the developed beverage. Millets contributed protein, dietary fibre and essential minerals.

Among the different formulations, T_3 (40% ragi and 60% bajra) was found to be the most acceptable formulation because it provided the best balance between nutritional quality and sensory characteristics. The findings of the present study are in agreement with previous reports, which have shown that millet-based functional beverages possess improved nutritional quality, better sensory acceptability and significant health-promoting potential.

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The developed beverage may therefore be considered a nutritious functional drink with promising applications in promoting millet utilization, improving dietary diversity and supporting nutritional security.

4. Conclusion

The present study was undertaken to develop and evaluate a millet-based beverage using ragi and bajra with the objective of improving its nutritional quality and consumer acceptability. The incorporation of these ingredients significantly enhanced the nutritional composition of the beverage by increasing dietary fibre, protein, calcium and iron while maintaining desirable sensory characteristics. The physicochemical properties of all formulations remained within the acceptable range, indicating the suitability of the developed beverage for regular consumption.

Among the different formulations, T_3 (40% ragi and 60% bajra) was found to be the most acceptable based on sensory evaluation and nutritional quality. The developed beverage can therefore be considered a nutritious, affordable and functional health drink suitable for consumers of different age groups.

The findings of the present investigation suggest that millet-based beverages prepared from ragi, bajra have considerable potential for commercial production and can contribute to increasing millet utilization, improving nutritional security and promoting healthier dietary practices. Further studies on storage stability, microbial quality and large-scale consumer acceptance may facilitate commercialization of the developed product.

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