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Formulation and analysis of micronutrient-dense Ragi Laddu: A potential dietary supplement for iron and calcium deficiency

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Abstract
Ragi (*Eleusine coracana*) is a nutrient-dense millet, rich in protein, calcium, and iron, and is considered beneficial in addressing mineral deficiencies such as calcium and iron deficiency. In this study, the T1 formulation of ragi laddu was evaluated for its sensory and nutritional qualities. Sensory analysis showed high acceptability, with scores of 4.0 for color, 4.1 for texture, aroma, and taste, 4.3 for appearance, and 4.1 for overall acceptability. Nutritional analysis revealed that T1 contained 11.15% moisture, 16.5% fat, 10.73% crude protein, 55.41% carbohydrate, 1.68% ash, and 4.52% crude fiber. The mineral content was also notable, with calcium and iron levels of 199.02 mg/100 g and 4.50 mg/100 g, respectively. These findings suggest that the T1 ragi laddu is a nutrient-rich and organoleptically acceptable product, with potential to improve dietary calcium and iron intake.

Keywords: Ragi, Ragi Laddu, calcium, iron

Introduction
Iron Deficiency Anaemia (IDA) remains an unresolved nutritional issue in India, despite the country being among the first in the world to launch the National Nutritional Anaemia Prophylaxis Program in 1970. Approximately one-third of male peers and one-fifth of girls aged 5-19 are underweight, according to a pooled analysis of 2146 population-based studies involving 128.9 million children, adolescents, and adults worldwide (Lancet, 2017). South Asia has the highest prevalence of moderate to severe underweight.
According to NFHS-5 (2019-21) anemia is still highly widespread (>50%) among Indian women between the ages of 15 and 49. Anemia was observed to affect 67.1% of children between the ages of 6 and 59 months and 52% of pregnant mothers. 24% of teenage girls between the ages of 15 and 19 were underweight (BMI<18.5 kg/m2), with higher rates in rural and tribal groups. Teenage girls require more iron because of the development spurt and menstruation loss. They may be more vulnerable to iron deficiency anemia (IDA), chronic nutritional deficits, and undernutrition if their diet is undiversified and does not contain items high in iron in their daily meals (Bathla and Arora. 2021).
From infants to teenagers, calcium is essential for healthy development. Osteoporosis is a major public health concern for older adults. Its incidence has significantly increased globally in recent years and is expected to continue rising, with the number of individuals with a high fracture risk expected to double by 2040 compared to 2010 [1]. Ca is necessary for many fundamental regulatory processes in the human body, including nerve impulse transmission, muscular contraction and relaxation, blood coagulation cascade, enzyme activation, hormone secretion stimulation, and more (Pravina *et al.*, 2013). Additionally, it aids in preventing malignancies such as breast, prostate, ovarian, and colorectal cancers. Consuming calcium is crucial for the growth of the fetal skeleton, raising birth weight, preventing pre-clamsis in expectant mothers, and preventing prenatal hypertension. Ca deficiency affects 3.5 billion individuals worldwide, with around 90% of those affected in Asia and Africa. (Kumssa *et al*., 2015). Ca insufficiency is a major health issue in emerging Asian and African nations (Sharma *et al*., 2017) [2]. Low calcium diets have been connected to conditions like osteoporosis and, indirectly, to rickets (via vitamin D) (Pettifor, 2008).
The primary cause of osteoporosis is a lack of calcium in the diet and vitamin D, which helps the body absorb calcium.

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In order to prevent calcium and vitamin D deficiencies, a safe and long-lasting diet-based approach should begin in early childhood. This can be accomplished by eating foods that are naturally high in calcium and making sure that the body has enough vitamin D from food, sunlight, and/or supplements. In order to combat anemia, a number of strategies are effective, including making sure the diet is varied, adding iron-rich foods to everyday meals, supplying iron pills, fortifying foods with iron, and educating the public about nutrition (Bathla and Arora. 2021). Finger millet has been shown to be consistently high in calcium (364±58 mg/100 g), regardless of variety, and to be balanced with other minerals like zinc and magnesium. Plant-based calcium, such as that found in traditional staple grains, is important for diets in many countries (Longvah *et al*., 2017). Supplemental calcium tablets or chemically fortified food are frequently used to prevent or treat calcium deficiencies. However, inorganic calcium compounds such calcium carbonate, calcium citrate, and calcium phosphate is commonly found in these tablets and fortifications (Palacios *et al*., 2021). These compounds may have a limited bioavailability and can have unfavorable consequences like kidney stone formation, constipation, bloating, and flatulence. However, calcium from the majority of plant sources is naturally balanced with other minerals, making it a potentially safer choice. Finger millet has a lot of promise for such a role in terms of both calcium content and affordability in the countries where it is farmed, even if milk and milk products are popular dietary options in programs and campaigns to address calcium insufficiency. Millets are acknowledged as smart food because they are "good for you" (nutritious and healthful), "good for the planet" (uses less water and leaves a smaller carbon footprint), and "good for the farmer" (Poole *et al*., 2020). Compared to milled rice and refined wheat, millets have several times more calcium, iron, zinc, selenium, magnesium, fiber, protein, and other minerals (Puranik *et al*., 2017).

Finger millet is regarded as a poor man's food since it is utilized as animal feed (straw) in rich countries and as food (grains) in poorer countries. (Ceasar *et al*., 2018; Wambi *et al*., 2020). In the dry and semiarid regions of developing Asian and African nations, it is a significant crop. (Ceasar *et al*., 2018; Krishna *et al*., 2020). Finger millet is the fourth most produced millet worldwide, behind sorghum (Sorghum bicolor) and pearl millet [Cenchrus americanus (new name), Pennisetum glaucum (old name)]. and Setaria italica, or foxtail millet (Maharajan *et al*., 2019).

Snacking has increased and eating habits have shifted. Snacking in between meals helps satisfy dietary guidelines and contributes to nutrient intake; however, the nutritional quality of the snack must be prioritized. A classic Indian sweet snack called laddu is usually created with several ingredients. It is widely consumed by people from a variety of socioeconomic backgrounds and is thought to be a promising tool for nutritional interventions, especially those that target iron deficiency anemia. A major dietary need for the prevention of anemia is addressed by the creation of nutrient-dense, iron-rich laddu from several ingredients.

Materials and method

Material Procurement

Ragi flour, almonds, fox nuts, jaggery, split black gram flour, white and black sesame seeds, dates and ghee were procured from the local market in Amethi, India. The present study was performed in the Department of Food and Nutrition, School of Home Science, Babasaheb Bhimrao Ambedkar University (BBAU), Satellite Campus Amethi, Uttar Pradesh, India.

Preparation of Finger millet flour

Finger millet grains were first cleaned to remove dust, stones, and other impurities. The cleaned grains were then washed thoroughly and dried until all surface moisture had evaporated. Once fully dried, the grains were ground using a grinder to obtain a fine powder. The flour was then sieved (60 mesh) to ensure uniform particle size, yielding clean and refined finger millet flour ready for use.

Preparation of split black gram flour

Split black gram was first cleaned and dried, then roasted over moderate heat with constant stirring until aromatic and lightly golden. After cooling, it was ground into a fine powder and sieved using a 60-mesh sieve for uniformity before storage or use.

Preparation of black and white sesame seeds

Formulation of Ragi Laddu

Finger millet flour, almonds, fox nuts, ghee, jaggery, split black gram and water were utilized in this preparation. All ingredients were measured and kept aside prior to processing. Ghee was heated, and finger millet flour was roasted with continuous stirring until aromatic. After roasting, split black gram flour was added and mixed thoroughly. In a separate pan, water and jaggery were heated to form a homogeneous syrup. Almonds and fox nuts were ground into a fine powder and combined with the roasted flours. The jaggery syrup was added, and the mixture was stirred into a thick mixture. After cooling slightly, the mixture was shaped into small laddus using ghee-greased palms.

Table 1: Combination of ingredients used in the formulation of Ragi Laddus

Treatments	Ingredients (g)							
	Ragi Flour	Black gram flour	Jaggery	Ghee	Almonds	Fox nuts	Black sesame seeds	White sesame seeds
T1	50	50	50	20	15	25	5	5
T2	40	60	50	20	15	25	5	5
T3	30	70	50	20	15	25	5	5

Sensory evaluation

The sensory evaluation of the prepared ragi laddus was conducted using a 5-point hedonic scale with a panel of 30 judges, assessing six parameters: color, texture, aroma, taste, appearance, and overall acceptability.

Nutritional quality of Ragi Laddu

Proximate composition

All estimations were performed in triplicate. Moisture, crude protein, total ash, crude fat, and crude fibre were estimated in triplicate using the methods described by AOAC (1995). Carbohydrate content (%) was calculated by subtracting the sum of protein (%), crude fat (%), moisture (%), ash (%), and crude fibre (%) from 100.

Minerals: Minerals viz calcium and iron in the muffins sample were estimated in triplicate. Calcium content of muffin sample was estimated by titrametric method of AOAC (1995). Iron was estimated using atomic absorption spectrophotometer samples. Representative samples in liquid form were sprayed into the flame of an atomic absorption spectrophotometer and the absorption or emission of the mineral to be analyzed was measured at a specific wavelength.

Statistical analysis

The data obtained from the sensory analysis were analyzed to calculate the mean and standard deviation.

Result and discussion

Sensory evaluation

The findings of sensory evaluation are given in Table 2. For all sensory qualities, T1 obtained the highest score, while the treatment T3 had the lowest score followed by treatment T2 and. The score of T1 for color, texture, aroma, taste, appearance, and over all acceptability were 4.0, 4.1, 4.1, 4.1, 4.3 and 4.1, respectively (Table 2). Among the treatment T3 scored minimum than other treatments for all the sensory attributes viz., for color (3.5), texture (3.0), aroma (3.0), taste (3.0), appearance (3.5) and over all acceptability (3.3). The acceptability decreases gradually as the amount of black gram flour increases. All treatments showed significant differences in texture, taste, appearance, and overall acceptability, whereas no significant differences were observed for color and aroma (Table 2).

Table 2: Sensory evaluation of Ragi laddu

Parameter	Product code			C.D. @ 5%	S.Em	S/NS
	T1	T2	T3			
Color	4.0±0.57	3.8±0.53	3.5±0.52	0.50	0.17	NS
Texture	4.1±0.73	3.8±0.67	3.0±0.62	0.62	0.22	S
Aroma	4.1±0.61	4.0±0.74	3.0±0.92	0.71	0.24	NS
Taste	4.1±0.69	3.7±0.78	3.0±70	0.67	0.23	S
Appearance	4.3±0.63	3.8±0.67	3.5±0.57	0.58	0.20	S
Overall acceptability	4. 1±0.61	3.8±0.67	3.3±0.63	0.59	0.20	S

Values are the mean±SD

*S- Significant, NS- Non significant

Nutritional Composition of Ragi Laddu

The nutrient composition and mineral contents of ragi laddu treatments are presented in Tables 3 and 4. Nutritional analysis showed that the T1 sample contained 11.15% moisture, 16.5% fat, 10.73% crude protein, 55.41% carbohydrate, 1.68% ash, and 4.52% crude fiber. The T2 sample exhibited 10.28% moisture, 16.5% fat, 11.29% crude protein, 55.68% carbohydrate, 1.64% ash, and 5.1% crude fiber, while the T3 sample had 10.07% moisture, 15.6% fat, 11.87% crude protein, 55.72% carbohydrate, 1.40% ash, and 5.3% crude fiber. According to Puri Avadhut P *et al*. (2022), ragi laddu contained 67.4 g/100 g carbohydrate, 10.5 g/100 g protein, 9.2 g/100 g moisture, 10.5 g/100 g fat, and 1.8 g/100 g ash.

The calcium content of ragi laddu treatments (T1, T2, and T3) ranged from 180.2 to 199.02 mg/100 g (Table 4), with T1 showing the highest level of 199.02 mg/100 g, followed by T2 and T3. The iron content in ragi laddu treatments (T1, T2, and T3) varied from 3.73 to 4.50 mg/100 g (Table 4), with T1 having the highest content of 4.50 mg/100 g, followed by T2 and T3. Mishra and Kulkarni (2022) reported that ragi and urad laddu contained 11.74 g of protein, 21.54 g of fat, 1170.93 mg of calcium, 4.14 mg of iron, and 2.08 g of ash per 100 g of laddu.

Table 3: Nutritional Composition of Ragi Laddu

Nutrients	Product code			C.D. @ 5%	S.Em	S/NS
	T1	T2	T3			
Moisture	11.15±0.30	10.28±0.54	10.07±0.31	0.81	0.23	S
Crude protein	10.73±0.30	11.29±0.27	11.87±0.61	0.85	0.25	S
Ash	1.68±0.03	1.64±0.09	1.40±0.17	0.23	0.07	S
Crude fat	16.5±0.5	15.9±0.20	15.56±0.66	0.99	0.29	NS
Crude fibre	4.52±0.34	5.1±0.15	5.3±0.20	0.49	0.14	S
Carbohydrate by difference	55.41±0.42	55.68±0.28	55.72±0.70	1.0	0.29	NS

Values are the mean±SD

Table 4: Mineral content of Ragi Laddu

Minerals	Product code			C.D. @ 5%	S.Em	S/NS
	T1	T2	T3			
Calcium	199.02±0.02	188.84±0.29	180.2±0.26	0.46	0.13	S
Iron	4.50±0.43	4.30±0.06	3.73±0.24	0.58	0.17	S

Values are the mean±SD

Conclusion

Ragi (finger millet) is a nutrient-rich millet, high in calcium, iron, protein, and other essential minerals, making it a valuable dietary option to address widespread deficiencies such as iron deficiency anemia and calcium insufficiency in India. The study demonstrated that ragi laddu, particularly the T1 formulation, was highly acceptable in sensory evaluation and nutritionally rich, with significant levels of calcium and iron. Incorporating ragi into traditional snack foods like laddus provides a culturally appropriate, affordable, and sustainable strategy to improve mineral intake among vulnerable populations, including children, adolescents, and women, highlighting the potential of millet-based functional foods to combat micronutrient deficiencies while promoting the use of locally available, nutrient-dense ingredients.

Conflict of Interest

Not available

Financial Support

Not available

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