

UTILIZATION OF SORGHUM AND FINGER MILLET FLOURS IN THE DEVELOPMENT OF NUTRITIOUS MUFFINS: FORMULATION, SENSORY EVALUATION, PROXIMATE COMPOSITION AND COST ECONOMICS

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Abstract—Bakery products are widely consumed by children and adults, but most are made from refined wheat flour, which is low in dietary fibre and minerals. This study aimed to develop a nutritious muffin by partially or wholly replacing refined wheat flour with sorghum (*Sorghum bicolor*) flour and finger millet (ragi, *Eleusine coracana*) flour. Five formulations were prepared: a control (T0, 100 % refined wheat flour) and four treatments (T1–T4) in which refined wheat flour was reduced from 60 to 0 % while sorghum flour was raised from 20 to 80 % and finger millet flour was held at 20 %. A market survey, conducted online and offline in supermarkets, showed that consumers are health-conscious and look for nutritionally enriched, attractively packaged foods. Sensory evaluation on a hedonic scale identified T3 (20 % refined wheat flour, 60 % sorghum flour, 20 % finger millet flour) as the most acceptable sample, with a score of 9 for appearance, colour, flavour, aroma, taste and overall acceptability. The T3 muffin contained 21.84 % moisture, 24 % fat, 4.98 % protein, 2 % ash, 6 % fibre, 41.18 % carbohydrate and 239 mg calcium. Each muffin weighed 8 g. The total production cost was ₹611.56 per kg (125 muffins), against a selling value of ₹1,250, indicating that the product is economically viable. The study shows that sorghum and finger millet flours can replace up to 80 % of refined wheat flour in muffins while keeping consumer acceptability high.

Index Terms—millet muffin, sorghum flour, finger millet, ragi, bakery product, sensory evaluation, proximate composition, cost economics

I. INTRODUCTION

Bakery products are becoming more popular because consumers want quick and convenient foods. Muffins are small, round, soft, sweet baked products that are usually eaten warm and are liked by both children and adults. The word “muffin” is derived from the French word *moufflet*, meaning soft bread, although the product itself originated in Britain.

Most commercial bakery products are made from refined wheat flour (maida) alone or in combination with whole wheat flour. Refined wheat flour is produced from the endosperm of the wheat grain, with the germ and bran removed. It is rich in starch and contains the gluten proteins that form an extensible, viscous dough on kneading with water and give baked goods their structure [1]. However, the removal of bran and germ leaves it low in dietary fibre, minerals and other bioactive components.

Millet is a nutrient-dense cereal that can improve the nutritional quality of baked products. Sorghum (jowar) is the fifth most widely grown cereal crop in the world and is a traditional food grain of Africa and Asia. Its starch is digested slowly, particularly after cooking, which gives sustained energy and may help control blood glucose in people with type 2 diabetes. Sorghum also contains phenolic compounds with antioxidant activity [2]. Finger millet (ragi, nachni) is one of the important millets of India and has the highest calcium content among cereals, together with good amounts of protein, iron and antioxidants. It is usually consumed without dehulling and is reported to have benefits for bone health, weight management, blood cholesterol and anaemia [3], [4].

Previous work has shown that millet and other non-wheat flours can be incorporated into bakery products, including muffins, cupcakes, buns and biscuits, with acceptable sensory quality [5]–[11]. Building on this, the present work developed a ready-to-eat muffin from a blend of refined wheat, sorghum and finger millet flours, sweetened with jaggery in place of refined sugar.

The objectives of the study were:

1. To conduct a market survey to understand consumer demand.
2. To develop nutritious muffins using a blend of sorghum, ragi and refined wheat flours.
3. To characterise the physical and chemical properties and sensory quality of the developed muffins.
4. To calculate the cost economics of the developed product.

II. MATERIALS AND METHODS

A. Study plan

The work was carried out between May and November 2025. Group discussions and the market survey were held from 27 May to 24 June 2025. Raw-material information collection, standardisation trials and sensory selection of the optimum formulation were done from 25 June to 20 July 2025. Raw-material purchase, production, physical and chemical analysis and record keeping were done from 21 July to 29 September 2025, and documentation and report preparation from 27 September to 7 November 2025.

B. Market survey

An online survey and an offline survey, in which supermarkets were visited, were conducted to find out consumer needs and expectations of food products. Consumer priorities and expectations were recorded and used to guide product development.

C. Raw materials and their functions

Refined wheat flour, sorghum flour, finger millet (ragi) flour, jaggery powder, milk, curd, refined oil, baking powder, baking soda, vanilla extract and salt were procured from the local market. Primary ingredients were refined wheat flour, sorghum flour, ragi flour, jaggery, curd and milk. Secondary ingredients were baking powder, baking soda, vanilla extract, salt and oil. The function of each ingredient is given in Table I, and the reported nutritional composition of the main ingredients is given in Table II.

TABLE I
FUNCTIONS OF INGREDIENTS IN THE MUFFIN FORMULATION

Ingredient	Function in muffins
Sorghum flour	Adds dietary fibre, protein and minerals; reduces gluten; improves nutritional value and texture
Finger millet (ragi) flour	Provides calcium, iron and antioxidants; improves nutritional quality; gives a slightly nutty flavour
Refined wheat flour	Provides gluten structure that helps muffins rise and hold shape
Jaggery	Natural sweetener; adds flavour, colour and moisture retention
Milk	Contributes tenderness and moistness; dissolves dry ingredients and adjusts batter consistency
Curd	Provides acidity that reacts with baking soda for leavening; adds moisture and softness
Oil	Improves softness, moistness and shelf life
Baking powder	Chemical leavening agent; releases carbon dioxide to make muffins light and fluffy
Baking soda	Reacts with acidic ingredients (curd, jaggery) for additional leavening and browning
Vanilla extract	Adds aroma and flavour
Salt	Balances sweetness and enhances flavour

TABLE II
NUTRITIONAL COMPOSITION OF THE MAIN INGREDIENTS (PER 100 G)

Constituent	Refined wheat flour	Sorghum flour	Finger millet flour	Jaggery powder	Milk	Curd
Moisture / water (g)	10.9	11.0	10.89	–	87.0	–
Protein (g)	10.62	8.4	7.3	0.4	3.5	3.1–3.5
Fat (g)	0.86	3.3	1.3	0.1	3.7	3–6
Ash / total minerals (g)	1.45	1.3	3.0	1.0	0.7	–
Dietary / crude fibre (g)	0.35	–	3.6	–	–	–
Carbohydrate (g)	76.61	73.0	72.6	80	–	4–5
Lactose (g)	–	–	–	–	4.9	–
Calcium (mg)	–	–	–	–	–	136
Energy (kcal)	356.64	366	–	383	–	97–100

A dash indicates that the value was not reported. Values compiled from the literature cited in the text.

D. Formulation

Five formulations were prepared. The control (T0) contained 100 g refined wheat flour. In treatments T1–T4 refined wheat flour was progressively replaced with sorghum flour, with finger millet flour held constant at 20 g per 100 g of flour (Table III). All other ingredients were kept constant across treatments (Table IV).

TABLE III
FLOUR COMPOSITION OF THE TREATMENTS (G PER 100 G OF FLOUR BLEND)

Treatment	Refined wheat flour	Sorghum flour	Ragi flour
T0 (control)	100	–	–
T1	60	20	20
T2	40	40	20
T3	20	60	20
T4	0	80	20

TABLE IV
COMPLETE FORMULATION OF MUFFIN TREATMENTS (G PER 100 G OF FLOUR BLEND)

Raw material	T0	T1	T2	T3	T4
Refined wheat flour	100	60	40	20	0

Raw material	T0	T1	T2	T3	T4
Sorghum flour	–	20	40	60	80
Ragi flour	–	20	20	20	20
Curd	80	80	80	80	80
Milk	80	80	80	80	80
Jaggery	80	80	80	80	80
Oil	40	40	40	40	80
Baking powder	4	4	4	4	4
Baking soda	2	2	2	2	2
Vanilla extract	4	4	4	4	4
Salt	2	2	2	2	2

E. Preparation of muffins

The process followed these steps: (1) selection of good-quality raw materials; (2) preheating of the oven to 180 °C; (3) sieving of refined wheat, sorghum and finger millet flours; (4) weighing of the raw materials; (5) addition of the wet ingredients (milk, curd, oil and vanilla extract); (6) thorough mixing; (7) resting of the batter for about 10 min; (8) transfer of the batter into moulds; (9) baking at 180 °C for 15–20 min; (10) cooling; (11) packaging and labelling; and (12) storage.

F. Sensory evaluation

Sensory evaluation is the scientific discipline used to analyse and measure human responses to the composition of food. The muffins were evaluated for appearance, colour, texture, flavour, aroma, taste and overall acceptability on a hedonic rating scale (maximum score 9). The treatment with the highest scores was selected for large-scale production and further analysis.

G. Physical analysis

Weight was measured on a digital balance as the average of five individual muffins. Length and thickness were measured with a vernier calliper [12].

H. Chemical analysis

Moisture. Five grams of sample were weighed in a petri dish and dried for 6 h in an oven at 105 °C, cooled in a desiccator and reweighed [9].

$$\text{Moisture (\%)} = \frac{[(\text{weight of original sample} - \text{weight of dried sample}) / \text{weight of original sample}] \times 100}{1}$$

Crude fat. Five grams of moisture-free sample in a pre-weighed thimble were extracted with 100 mL petroleum ether (b.p. 60–80 °C) in a solvent-extraction unit at 90 °C for 1 h. The temperature was then raised to 110 °C to recover the solvent. The beakers containing the fat were dried in a hot-air oven at 60 °C to constant weight, cooled in a desiccator and weighed [9].

$$\text{Fat (\%)} = \frac{[(\text{weight of beaker with fat} - \text{weight of empty beaker}) / \text{weight of sample (g)}] \times 100}{1}$$

Protein. Protein was estimated by the method of Lowry et al. (1951). Standard protein solutions and the sample were made up to 1 mL with distilled water, with a water-only tube as blank. Alkaline copper reagent (5 mL) was added to each tube and left for 10 min at room temperature, followed by 0.5 mL of diluted Folin–Ciocalteu reagent with rapid mixing. After 30 min of incubation in the dark, absorbance was read at 660 nm, and the sample protein concentration was read from the standard curve.

Ash. Five grams of oven-dried sample were weighed in a silica crucible, charred until smoke-free and then placed in a muffle furnace at 550 °C for 5–6 h until white ash was obtained. The crucible was cooled in a desiccator and weighed [9].

$$\text{Ash (\%)} = (\text{weight of ash} / \text{weight of sample}) \times 100$$

Calcium. Calcium was determined by the oxalate–permanganate titration method on an ash solution prepared by wet ashing with tri-acid mixture ($\text{HNO}_3 : \text{H}_2\text{SO}_4 : \text{HClO}_4 = 9 : 3 : 1$). A 20 mL aliquot was treated with 10 mL saturated ammonium oxalate and methyl red indicator, adjusted to a faint pink colour with ammonia and acetic acid, boiled once and left for up to 4 h. The calcium oxalate precipitate was filtered, washed free of oxalate, dissolved in hot dilute H_2SO_4 (1 + 4) and titrated with potassium permanganate [14].

Calcium (mg/100 g) = [titre $\times$ N of $\text{KMnO}_4 \times 20 \times$ total volume of ash solution] / [volume of ash solution taken for estimation $\times$ weight of sample taken for ashing]

Carbohydrate content corresponds to the remainder after the other constituents are subtracted from 100 %.

I. Cost economics

The raw-material cost was calculated from the quantity and market price of each ingredient. Labour cost was taken as 10 % of the raw-material cost. Total production cost was calculated as raw-material cost + processing cost + packaging and labelling cost + labour cost. The number of packets per kilogram and the selling price per packet were used to calculate the return.

III. RESULTS AND DISCUSSION

A. Market survey

The market survey showed that consumers give priority to the cleanliness of food products, followed by price, quality, quantity, variety, packaging and non-seasonal availability. Consumers are increasingly health-conscious about their eating habits, prefer nutritious food, look for nutritionally enriched products and expect proper and attractive packaging. These findings supported the development of a millet-based, nutrient-rich muffin presented in suitable packaging.

B. Sensory evaluation

The mean hedonic scores of the five treatments are given in Table V.

TABLE V
SENSORY SCORES OF MUFFINS (HEDONIC SCALE)

Treatment	Appearance	Colour	Texture	Flavour	Aroma	Taste	Overall acceptability
T0	8.5	8.5	8.5	8.5	8.7	8.6	8.5
T1	7.5	7.5	8.0	8.0	8.0	8.0	8.0
T2	8.0	7.5	8.0	8.5	8.5	8.0	8.3
T3	9.0	9.0	8.5	9.0	9.0	9.0	9.0
T4	8.0	8.0	9.0	8.0	9.0	7.5	9.0

The control (T0) scored 8.5 for most attributes, which shows good consumer acceptance of the conventional product. Partial replacement of refined wheat flour at the lowest level (T1) slightly lowered scores for appearance and colour (7.5), and T2 gave intermediate values. Sample T3 recorded the highest scores for appearance, colour, flavour, aroma and taste (9.0) and a texture score of 8.5, and was therefore selected for large-scale production. T4, which contained no refined wheat flour, was scored highest for texture (9.0) and equal to T3 for aroma, but had the lowest taste score (7.5). The overall acceptability value of 9.0 reported for T4 is higher than would be expected from its individual attribute scores and should be verified against the original score sheets.

The acceptability of T3 shows that up to 80 % of the flour blend (60 % sorghum and 20 % finger millet) can be supplied by millets without a loss of sensory quality, even though gluten is reduced. Gluten is the main structure-forming protein in wheat, so the moderate level of refined wheat flour retained in T3 probably still gave sufficient structure, while the millet flours contributed colour, flavour and nutrition. Jaggery, curd and milk added moisture, softness and a pleasant flavour.

C. Physical characteristics

The T3 muffin had a length of 4.5 cm, a thickness of 5.5 cm and a weight of 8 g (Table VI).

TABLE VI
PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SELECTED MUFFIN (T3)

Parameter	Value
Physical	
Length	4.5 cm
Thickness	5.5 cm
Weight	8 g
Chemical	
Moisture	21.84 %
Fat	24 %
Protein	4.98 %
Ash	2 %
Fibre	6 %
Carbohydrate	41.18 %
Calcium	239 mg per 100 g

D. Chemical composition

The T3 muffin had a moisture content of 21.84 %, which is typical of a soft, moist baked product and reflects the contribution of milk, curd and jaggery. The fat content of 24 % is relatively high and is attributable mainly to the 40 g of oil used per 100 g of flour; reducing the oil level in future trials would lower the fat and energy content. The protein content was 4.98 %, derived from the millet flours, milk and curd. The ash content of 2 % indicates a useful mineral content, in line with the high ash content of finger millet flour (3.0 g per 100 g) and sorghum flour (1.3 g per 100 g). The fibre content of 6 % is considerably higher than the 0.35 g per 100 g reported for refined wheat flour, which supports the claim that the muffin is a good source of fibre. Calcium was 239 mg, and finger millet flour and dairy ingredients are the principal contributors. The carbohydrate content was 41.18 %. The components sum to 100 %, which is consistent with carbohydrate being obtained by difference.

E. Cost economics

The raw-material cost of the selected formulation (T3) was ₹48.7 per 100 g of flour basis, equal to ₹487.2 for the 1 kg scale (Table VII). Jaggery (₹96), sorghum flour (₹72), vanilla extract (₹80) and curd (₹64) were the largest cost items.

TABLE VII
RAW-MATERIAL COST OF THE T3 MUFFIN FORMULATION

Raw material	Quantity for 100 g (g)	Quantity for 1 kg (g)	Price for 100 g (₹)	Price for 1 kg (₹)
Sorghum flour	60	600	7.20	72.0
Finger millet flour	20	200	2.40	24.0
Refined wheat flour	20	200	1.40	14.0
Jaggery	80	800	9.60	96.0
Milk	80	800	4.16	41.6
Curd	80	800	6.40	64.0

Raw material	Quantity for 100 g (g)	Quantity for 1 kg (g)	Price for 100 g (₹)	Price for 1 kg (₹)
Oil	40	400	6.00	60.0
Baking powder	4	40	2.40	24.0
Baking soda	2	20	1.12	11.2
Vanilla extract	4	40	8.00	80.0
Salt	2	20	0.04	0.4
Total			48.7	487.2

TABLE VIII
PRODUCTION COST AND RETURN (PER KG OF MUFFINS)

Item	Amount (₹)
Raw-material cost	487.40
Processing cost	6.34
Packaging and labelling cost	69.08
Labour cost (10 % of raw-material cost)	48.74
Total production cost	611.56
Number of packets (1000 g ÷ 8 g)	125
Selling price per packet	10.00
Total selling value (125 × ₹10)	1,250.00
Net return (selling value – production cost)	638.44

The production cost works out to about ₹4.89 per 8 g packet, against a selling price of ₹10, giving a gross return of about ₹5.11 per packet and a benefit–cost ratio of about 2.04. The product is therefore economically viable at the proposed price.

F. Packaging and labelling

Packaging protects the food and supports its distribution, marketing and storage. The muffins were packed in polypropylene (PP) containers, chosen because they are lightweight and easy to handle, resistant to chemicals and moisture, easy to mould and shape, and cost-effective. The packs carried a label, which responds to the consumer demand for attractive and informative packaging identified in the market survey.

IV. CONCLUSION

Nutritious and organoleptically acceptable muffins were successfully produced from blends of sorghum flour, finger millet flour and refined wheat flour. Among the five formulations, T3 (20 % refined wheat flour, 60 % sorghum flour and 20 % finger millet flour per 100 g blend) obtained the highest sensory scores and was selected for large-scale production. The selected muffin contained 6 % fibre and 239 mg calcium, together with 4.98 % protein and 2 % ash. Production cost was ₹611.56 per kg against a selling value of ₹1,250, showing good commercial potential. Replacing a large part of refined wheat flour with millets raises the nutritional value of a familiar bakery product and may help to address nutritional disorders such as fibre and calcium deficiency.

Limitations and future scope. The study evaluated a single replication of each formulation without statistical analysis, and the sensory panel size is not reported here. Future work should include statistical analysis of sensory data (e.g. ANOVA), reduced-oil formulations, texture profile analysis, analysis of the control sample for comparison, and shelf-life studies under different storage and packaging conditions.

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