

DEVELOPMENT AND QUALITY EVALUATION OF ROSELLE (*HIBISCUS SABDARIFFA* L.) LEAVES MATHRI ENRICHED WITH BLACK GRAM FLOUR: SENSORY, PHYSICO-CHEMICAL AND TECHNO-ECONOMIC ASSESSMENT

Sagar Rahul Mane^{1*}

¹Department of Food technology, Shramasakti College of Food Technology, Maldad, Sangamner, Maharashtra, India

*Corresponding author: sagar2010foodtech@gmail.com

Abstract—Mathri is a traditional deep-fried Indian snack that is usually prepared from refined wheat flour and is therefore low in protein and dietary fibre. This study aimed to develop a nutritionally improved mathri from a composite of semolina, wheat flour, corn flour and black gram flour, flavoured with roselle (*Hibiscus sabdariffa* L.) leaves, and to evaluate its consumer acceptability, physico-chemical properties and economic feasibility. An online market survey (n = 89) preceded product development. Four composite formulations (T1–T4; semolina 30–60%, wheat flour 15–30%, corn flour 15–30%, black gram flour 10%) and a 100% semolina control (T0) were evaluated on a 9-point hedonic scale. Formulation T4 (semolina : wheat flour : corn flour : black gram flour = 60 : 15 : 15 : 10) received the highest mean score for every attribute, including overall acceptability (8.8 vs. 8.3 for the control). The selected product weighed 1.8 g per piece, with a bulk density of 0.15 g cm⁻³, a true density of 1.25 g cm⁻³ and a porosity of 0.88. Proximate analysis gave 2.8% moisture, 18.5% fat, 11.2% protein, 4.6% crude fibre, 2.1% ash and 60.8% carbohydrate. At a production cost of ₹226.22 per kg and a selling price of ₹500 per kg (₹10 per 20 g pack), the benefit–cost ratio was 1.21 and the profit margin 54.76%. Roselle leaves mathri is therefore a technically and commercially promising, protein- and fibre-enriched snack; shelf-life and bioactive-compound studies are still required.

Index Terms—mathri, roselle leaves, black gram, composite flour, sensory evaluation, proximate composition, cost economics, nutritious snack

I. INTRODUCTION

Mathri is a popular savoury, flaky and crispy deep-fried snack of northern and western India, traditionally prepared from refined wheat flour (maida), water and ajwain. It was developed as a food that stays edible for several days, is stored at ambient temperature in jars and is widely carried while travelling or eaten with tea (Kusum *et al.*, 2023). Refined-flour products, however, are low in dietary fibre and are associated with a higher glycaemic response, which has stimulated interest in value-added snacks that incorporate millets and other functional ingredients (Kusum *et al.*, 2023).

Several recent studies have enriched mathri with alternative plant ingredients, including brown top millet (Kusum *et al.*, 2023), kodo millet (Kavya *et al.*, 2023), gurmar powder (Dwivedi, 2025), kalmegh powder (Dwivedi and Tripathi, 2025), dehydrated cauliflower stem powder (Sharma and Prasad, 2018) and iron-rich plant ingredients (Husain *et al.*). A common finding is that the level of incorporation is critical: acceptable sensory quality was retained at moderate levels, whereas higher levels reduced sensory scores (Kavya *et al.*, 2023; Dwivedi and Tripathi, 2025).

Each flour in a composite formulation can contribute a distinct function. Semolina, the coarsely milled endosperm of durum wheat, is easily digested, supplies energy and protein, and gives structure and a crisp bite (Bresciani *et al.*, 2022; Zingale *et al.*, 2023; Carpentieri *et al.*, 2024). Corn flour is gluten-free, starch-rich and contributes crispness and a golden colour, and yellow maize also carries carotenoids (Rooney and Serna-Saldivar, 2004; Rai *et al.*, 2012; Sun *et al.*, 2019). Black gram (*Vigna mungo* L. Hepper) flour is a protein-rich legume flour whose lysine content

complements lysine-poor cereals and which also supplies fibre, minerals and B vitamins (Salunkhe *et al.*, 1985; Wani *et al.*, 2013; Sen Gupta *et al.*, 2023; Indrani *et al.*, 2015).

Roselle (*Hibiscus sabdariffa* L., Malvaceae) is widely grown, and while its calyces are well known, its leaves are an under-utilised leafy vegetable that provides protein, fibre, vitamins and minerals, together with flavonoids and other phenolic compounds reported to have antioxidant, antihypertensive and antimicrobial activities (Edo, 2023; Zahari *et al.*, 2026; Mendonça *et al.*, 2021). The use of roselle leaves in traditional fried snacks remains little explored.

The present work therefore aimed to develop a convenient, low-cost and nutritionally improved mathri from semolina, wheat flour, corn flour and black gram flour with roselle leaves. The specific objectives were (i) to assess market demand through a survey, (ii) to standardise the formulation, (iii) to evaluate the sensory and physical properties of the product, (iv) to determine its proximate composition, (v) to assess its techno-economic feasibility, and (vi) to select suitable packaging and labelling.

II. MATERIALS AND METHODS

A. Raw materials

Semolina (rava), wheat flour, corn flour, black gram flour, roselle leaves, sesame seeds, turmeric powder, red chilli powder, ajwain, salt, a peri-peri/chaat masala seasoning and refined oil were procured from the local market of Sangamner, Maharashtra. The reported compositions of the main ingredients are given in Table I.

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

Parameter	Semolina	Wheat flour	Corn flour	Black gram flour	Roselle leaves
Energy (kcal)	340–370	340–365	370	341	43
Protein (g)	5–9	10–16	7.11	25.21	3.30
Fat (g)	1	0.97–2.28	1.75	1.64	0.30
Carbohydrate (g)	70–80	65–75	82.79	58.99	–
Fibre (g)	0.7 (dietary)	2.0–3.0 (crude)	3.9	18.3 (dietary)	10.0 (%) ^a
Ash (g)	0.2–0.6	0.4–0.7	–	–	1.00
Calcium (mg)	–	–	3	138	213
Moisture (g)	–	12–18	–	–	85.60

Sources: Fois *et al.* (2019) and Rajiv *et al.* (2015) for semolina; Leung *et al.* (1968), Duke and Atchley (1984) and Morton (1987) for roselle leaves (as cited by the authors); other values are typical literature values. ^aValue as reported in the source. –, not reported.

B. Market survey

Market demand was assessed through an online and an offline survey. The online survey used a Google Form with multiple-choice questions on respondent occupation and age group, the food category purchased most often, preferred protein-rich foods, preferred packaging, willingness to try new product types and preferred price range (n = 89 responses; majority aged 18–35 years). The offline survey was an interviewer-administered paper questionnaire given to retailers (n = NUMBER OF SHOPS SURVEYED) covering preferred product types, price ranges, local-product acceptance and willingness to stock a new product.

C. Formulation and preparation of roselle leaves mathri

Four composite flour formulations (T1–T4) were compared with a control (T0) made from semolina alone (Table II). The semolina content was increased from 30% to 60% while the wheat flour and corn flour fractions were reduced correspondingly, and black gram flour was held constant at 10%. The selected formulation was seasoned with (per 100 g flour blend) 2.5 g roselle leaves, 2.5 g turmeric powder, 1.7 g red chilli powder, 2.5 g salt, and sesame seeds and ajwain, and was deep-fried in refined oil (costed at 50 g per 100 g flour blend), followed by dusting with 10 g of peri-peri/chaat seasoning.

TABLE II
FLOUR COMPOSITION (%) OF THE MATHRI FORMULATIONS

Treatment	Semolina	Wheat flour	Corn flour	Black gram flour
T0 (control)	100	–	–	–
T1	30	30	30	10
T2	40	25	25	10
T3	50	20	20	10
T4	60	15	15	10

The process (Fig. 1) comprised selection of raw materials, sieving, preparation of dough with the spices and roselle leaves, resting of the dough for 10 min, sheeting, moulding, frying (conditions: frying temperature and time), sprinkling of seasoning, cooling, packing and labelling, and storage.

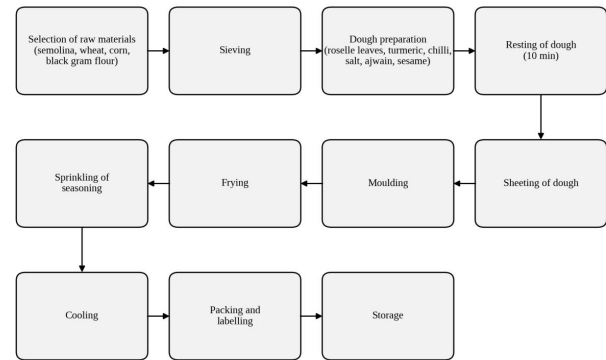


Fig. 1. Process flow chart for the preparation of roselle leaves mathri.

D. Sensory evaluation

Sensory quality was assessed by a panel of using a 9-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely; Peryam and Pilgrim, 1957) for appearance, colour, texture, taste and overall acceptability. Mean scores were calculated for each treatment.

E. Physical properties

The weight of randomly selected pieces was recorded on an electronic balance and the height with a Vernier caliper (AOAC, 2022). Bulk density was calculated as the mass of a known quantity of product (10 g) divided by the volume it occupied in a measuring cylinder. True density was determined by the toluene displacement method in a pycnometer using 10 g of finely ground sample. Porosity was calculated as:

$$\text{Porosity} = 1 - (\text{bulk density} / \text{true density})$$

F. Proximate composition

Proximate analysis followed AOAC (2022) methods. Moisture was determined by oven drying, as $(W_1 - W_2)/W \times 100$, where W_1 and W_2 are the weights of dish plus sample before and after drying and W is the sample weight. Ash was determined by incinerating 5 g of sample in a muffle furnace at 550 °C and expressed as the percentage of the original sample weight. Fat was extracted from about 10 g of dried, ground sample with petroleum ether (40–60 °C) for 6–8 h in a Soxhlet apparatus. Protein was determined by the micro-Kjeldahl method (digestion with a sodium/potassium sulphate–copper sulphate catalyst in sulphuric acid, steam distillation into 2% boric acid with mixed indicator, and titration with standard acid), and calculated as nitrogen (%) $\times 6.25$. Crude fibre was determined by sequential digestion of 5 g of sample with 1.25% sulphuric acid and 1.25% sodium hydroxide for 30 min each, followed by washing, drying at 105 °C and ashing at 550 °C. Carbohydrate was calculated by difference:

$$\text{Carbohydrate (\%)} = 100 - (\text{moisture} + \text{fat} + \text{protein} + \text{ash} + \text{crude fibre})$$

G. Techno-economic feasibility

Production cost per kilogram was calculated as the sum of raw material, processing, packaging and labelling, and

labour costs. The benefit, benefit–cost ratio (B/C) and profit margin were calculated as:

Benefit = selling price – production cost; B/C = benefit / production cost; Profit (%) = (benefit / selling price) × 100

III. RESULTS AND DISCUSSION

A. Market survey

The online respondents were mainly young consumers (18–35 years) with busy schedules who wanted quick, tasty and convenient foods. Snacks were by far the most frequently purchased category (58.4%), followed by ready-to-eat meals (18.0%), beverages (12.4%) and bakery products (11.2%) (Fig. 2a). Protein snacks (39.3%) and dairy products (38.2%) were the preferred protein sources, ahead of pulses/legumes (14.6%) and millets (7.9%) (Fig. 2b). These results support developing a convenient snack with enhanced protein. Notably, 71.9% of respondents preferred eco-friendly packaging (Fig. 2c), which is relevant to the packaging choice discussed in Section III-G.

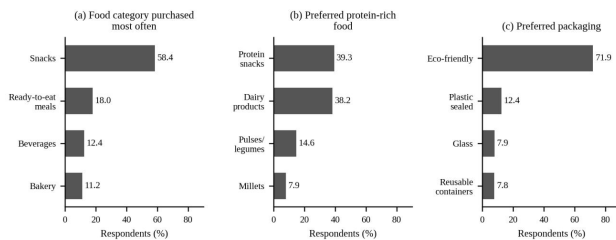


Fig. 2. Results of the online market survey (n = 89): (a) food category purchased most often; (b) preferred protein-rich food; (c) preferred packaging.

B. SWOT analysis

The strengths and weaknesses of the product and the external opportunities and threats are summarised in Table III.

TABLE III
SWOT ANALYSIS OF ROSELLE LEAVES MATHRI

Factor	Internal	External
Positive	Strengths: low production cost; good appearance, texture and taste; raw materials, spices and oil readily available locally; customers satisfied with quantity and taste	Opportunities: lower price than comparable mathri; novel product; better nutritional profile than refined-flour snacks
Negative	Weaknesses: limited manpower; weak marketing; low awareness of a new product	Threats: intense competition and price wars; changing consumer preferences; consumers who prefer other health foods

C. Formulation and sensory evaluation

The five formulations (Fig. 3) were evaluated for sensory quality (Table IV, Fig. 4). Mean scores ranged from 7.5 to 8.8 for all treatments, meaning that every sample was liked moderately to very much. Treatments T1–T3 scored lower than the control for most attributes, whereas T4 (60% semolina, 15% wheat flour, 15% corn flour, 10% black gram flour) scored highest for every attribute: appearance (8.7), colour (8.6), texture (8.6), taste (8.7) and overall acceptability (8.8), compared with 8.3 for the control. T4 was therefore selected for further characterisation. The higher semolina proportion in T4 is consistent with the

contribution of semolina to a crisp, firm texture and attractive appearance, while the black gram flour added a nutritional benefit without lowering acceptability. Because the scores are means without a reported measure of variability, the differences between treatments should be regarded as indicative rather than statistically established.

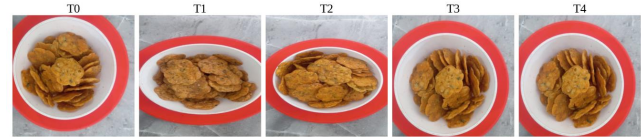


Fig. 3. Roselle leaves mathri prepared with different formulations (T0–T4).

TABLE IV
MEAN SENSORY SCORES (9-POINT HEDONIC SCALE) OF ROSELLE LEAVES MATHRI

Treatment	Appearance	Colour	Texture	Taste	Overall acceptability
T0	8.5	8.1	8.0	8.6	8.3
T1	8.0	7.8	7.6	7.6	7.8
T2	7.9	7.8	7.7	7.5	8.0
T3	8.0	8.0	8.1	7.7	7.8
T4	8.7	8.6	8.6	8.7	8.8

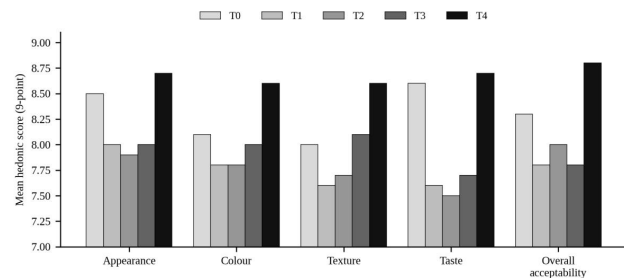


Fig. 4. Mean sensory scores of the control (T0) and composite formulations (T1–T4).

D. Physical properties

The physical properties of the selected product are given in Table V. Each piece weighed 1.8 g and measured 3.5 cm in height. The bulk density was low (0.15 g cm⁻³) relative to the true density (1.25 g cm⁻³), giving a high porosity of 0.88. This indicates a highly open, air-filled structure, consistent with the light, crisp and brittle texture of the product; the low bulk density also implies that the product occupies considerable pack volume, which is relevant to packaging design and transport.

TABLE V
PHYSICAL PROPERTIES OF ROSELLE LEAVES MATHRI (T4)

Parameter	Value
Weight per piece (g)	1.8
Height (cm)	3.5
Bulk density (g cm ⁻³)	0.15
True density (g cm ⁻³)	1.25
Porosity	0.88

E. Proximate composition

The proximate composition of the selected mathri is shown in Table VI. The low moisture content (2.8%) is favourable for maintaining crispness and limiting microbial growth during storage. The fat content (18.5%) is

attributable mainly to oil uptake during frying and is typical of fried snack products. The protein content (11.2%) is mainly due to the black gram flour, which supplies high-quality plant protein and complements cereal proteins; the crude fibre (4.6%) reflects the contributions of black gram flour and roselle leaves, and the ash content (2.1%) indicates the mineral contribution of the flours and leaves. Carbohydrate, mostly from semolina, wheat flour and corn flour, was 60.8%, making the snack a good energy source. Earlier work on millet-enriched mathri likewise reported higher protein, fat, fibre and calcium than wheat-based controls (Kusum *et al.*, 2023; Kavya *et al.*, 2023). In the present study, however, the control was not analysed chemically, so improvement relative to conventional mathri is inferred from the ingredient composition rather than measured directly.

TABLE VI
PROXIMATE COMPOSITION OF ROSELLE LEAVES MATHRI (T4)

Component	Content (%)
Moisture	2.8
Fat	18.5
Protein	11.2
Crude fibre	4.6
Ash	2.1
Carbohydrate (by difference)	60.8

F. Techno-economic feasibility

The raw-material cost of 1 kg of mathri was ₹185.65 (Table VII). Adding processing (₹9), packaging and labelling (₹13) and labour at 10% of the raw-material cost (₹18.57) gave a total production cost of ₹226.22 per kg. One kilogram yields 50 packs of 20 g; at ₹10 per pack the total sale value is ₹500, so the benefit is ₹273.78 per kg, the B/C ratio 1.21 and the profit margin 54.76%. The product can therefore be produced profitably at a price accessible to the snack consumers identified in the survey. These figures are for small-scale production and exclude overheads such as rent, utilities, equipment depreciation and marketing, so the net margin at commercial scale will be lower.

TABLE VII
RAW-MATERIAL COST FOR THE PRODUCTION OF ROSELLE LEAVES MATHRI

Raw material	Quantity per 100 g (g)	Quantity per kg (g)	Rate (₹ kg ⁻¹)	Cost per 100 g (₹)	Cost per kg (₹)
Semolina	60	600	42	2.52	25.20
Wheat flour	15	150	30	0.45	4.50
Corn flour	15	150	50	0.75	7.50
Black gram flour	10	100	136	1.36	13.60
Turmeric powder	2.5	25	300	0.75	7.50
Red chilli powder	1.7	17	300	0.51	5.10
Salt	2.5	25	20	0.05	0.50
Oil	50	500	160	8.00	80.00
Roselle leaves	2.5	25	10	0.025	0.25
Peri-peri/chaat masala	10	100	400	4.00	40.00
Total				18.57	185.65

G. Packaging and labelling

Packaging protects food from moisture, light, oxygen and physical damage, and also acts as a marketing tool that conveys brand and product information (Marsh and Bugusu,

2007; Ghoshal, 2018). Fried mathri is a low-moisture, high-fat food that is prone to moisture uptake, rancidity and loss of crispness, so a good water-vapour and grease barrier is needed. Polypropylene (PP), particularly biaxially oriented PP (BOPP), offers good clarity, printability, heat-sealability, grease resistance and a low water-vapour transmission rate, but only a moderate oxygen barrier; metallised BOPP/cast PP (MET-BOPP/PP) laminates improve oxygen and light protection (Marsh and Bugusu, 2007; Coles *et al.*, 2003; Alavi *et al.*, 2020). Nitrogen flushing can further delay rancidity. PP laminate pouches of 20 g were therefore selected. Because 71.9% of survey respondents preferred eco-friendly packaging, the use of recyclable mono-material PP laminates rather than metallised multilayer films is worth considering, since metallised films are harder to recycle. The pack label carries the brand name, product name, net weight and price, and should also list ingredients, allergens, nutrition information, manufacturing and expiry dates and storage instructions, as clear labels support informed purchase and consumer trust (Polonsky *et al.*, 1998).

IV. CONCLUSION

A crisp, acceptable mathri enriched with black gram flour and flavoured with roselle leaves was successfully developed. Of the formulations tested, T4 (semolina : wheat flour : corn flour : black gram flour = 60 : 15 : 15 : 10) obtained the highest sensory scores for all attributes (overall acceptability 8.8). The product was light and porous and contained 11.2% protein, 4.6% crude fibre and 2.8% moisture, with 18.5% fat from frying. Its production cost of ₹226.22 per kg, B/C ratio of 1.21 and profit margin of 54.76% indicate good small-scale commercial potential, supported by survey evidence of consumer demand for convenient, protein-rich snacks.

Limitations include the absence of replicated statistical analysis of sensory data, of a chemical analysis of the control, and of shelf-life, microbiological and antioxidant/phenolic assessments of the final product. Future work should address these points, evaluate lower-fat processing such as baking or air-frying, and test the acceptability of the product with a larger consumer panel.

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