



ISSN Print: 2664-844X
 ISSN Online: 2664-8458
 NAAS Rating: 4.97
 IJAFA 2025; 7(5): 368-372
www.agriculturaljournals.com
 Received: 23-03-2025
 Accepted: 29-04-2025

Sudeep Patil
 School of Food Technology,
 MIT Art, Design and
 Technology University, Loni
 Kalbhor, Pune, Maharashtra,
 India

Nitin G Suradkar
 Assistant Professor, School of
 Food Technology, MIT Art,
 Design and Technology
 University, Loni Kalbhor,
 Pune, Maharashtra, India

Sudhanshu Paygude
 School of Food Technology,
 MIT Art, Design and
 Technology University, Loni
 Kalbhor, Pune, Maharashtra,
 India

Soham Mahajan
 School of Food Technology,
 MIT Art, Design and
 Technology University, Loni
 Kalbhor, Pune, Maharashtra,
 India

Sunny Deshmukh
 School of Food Technology,
 MIT Art, Design and
 Technology University, Loni
 Kalbhor, Pune, Maharashtra,
 India

Sushrut Lamkhade
 School of Food Technology,
 MIT Art, Design and
 Technology University, Loni
 Kalbhor, Pune, Maharashtra,
 India

Corresponding Author:
Nitin G Suradkar
 Assistant Professor, School of
 Food Technology, MIT Art,
 Design and Technology
 University, Loni Kalbhor,
 Pune, Maharashtra, India

Quality evaluation of kokum (*Garcinia indica*)-Infused finger millet pasta

Sudeep Patil, Nitin G Suradkar, Sudhanshu Paygude, Soham Mahajan, Sunny Deshmukh and Sushrut Lamkhade

DOI: <https://www.doi.org/10.33545/2664844X.2025.v7.i5f.427>

Abstract

This study reports the development and comprehensive evaluation of pasta formulated by incorporating finger millet (*Eleusine coracana*) and kokum (*Garcinia indica*). Finger millet, known for its rich fiber, calcium, and iron content, was combined with kokum extract—a potent source of anthocyanins and hydroxycitric acid—to enhance the functional and sensory attributes of the product. A series of formulation trials (T₁-T₄) were conducted to optimize ingredient ratios and product characteristics. The optimized formulation (T₄) underwent proximate, bioactive, and microbial analyses along with sensory evaluation using a 9-point hedonic scale. The final product showed high consumer acceptability, favorable nutritional composition (Protein: 7%, fiber: 2.2%, energy: 350 kcal/100 g), and strong antioxidant potential (DPPH inhibition: 75%). Microbial analysis confirmed product safety with negligible counts. These findings demonstrate the potential of kokum-finger millet pasta as a clean-label, plant-based functional food suitable for health-conscious and gluten-intolerant consumers.

Keywords: Finger millet, kokum extract, pasta, functional foods, anthocyanins, sensory evaluation, antioxidant activity

Introduction

Kokum (*Garcinia indica*), a lesser-known tropical tree spice, is predominantly cultivated along the Western Ghats of India, especially in the states of Maharashtra, Goa, Karnataka, Kerala, and southern Gujarat. It also grows in parts of northeastern India, including Assam, Meghalaya, and West Bengal. Despite its widespread cultivation, kokum remains underutilized and lacks mainstream recognition, even though it possesses valuable medicinal and functional properties. Traditionally, kokum trees are grown alongside mango and cashew orchards, and are also found near areca nut and coconut plantations, as well as in kitchen gardens (Ranveer & Sahoo, 2017) ^[25].

Finger millet (*Eleusine coracana*), commonly known as ragi or mandua, is a highly nutritious cereal grain belonging to the Poaceae family. Native to Africa and widely cultivated in India, it is available in several color variants—ranging from white and tan to red, brown, and violet. Red cultivars are especially popular in Sri Lanka, Nepal, Madagascar, Malaysia, Uganda, Japan, and across the Indian subcontinent (Jagati *et al.*, 2021) ^[19]. Due to its dense nutritional profile, finger millet is often used in supplementary feeding programs. It is an excellent source of dietary fiber, iron, calcium, phosphorus, and antioxidants, and is associated with health benefits such as weight management, cholesterol reduction, and enhanced bone health (Karki *et al.*, 2020) ^[21].

Wheat, in contrast, is one of the most commonly consumed cereal grains globally due to its favorable processing characteristics, storage stability, and versatility in food applications. It continues to be a staple for the production of bread, pasta, noodles, biscuits, and other baked goods, retaining dominance in the global flour industry (Harke *et al.*, 2022) ^[17].

However, with growing awareness of health and sustainability, there is an increasing shift toward the consumption of underutilized grains and the adoption of innovative food processing technologies. Millets—particularly finger millet—are being increasingly valued for their nutrient density, resilience to climate variability, and health-promoting properties (Yadav *et al.*, 2021) ^[29]. Ragi's richness in fiber, iron, calcium, and natural antioxidants makes it a promising base for developing functional and health-oriented food products

(Chethan & Malleshi, 2007) [12].

Simultaneously, there is a growing consumer preference for natural, traditional ingredients that contribute not only to health benefits but also to sensory satisfaction. Kokum, recognized for its tangy taste and high levels of hydroxycitric acid (HCA) and anthocyanins, presents a unique opportunity for fortification in staple foods (Joshi *et al.*, 2013) [20]. The integration of kokum with finger millet in pasta formulation has the potential to create a gluten-free, antioxidant-rich, and consumer-appealing functional food.

The present study focuses on the development and evaluation of kokum-infused finger millet pasta as a nutritious, value-added alternative to conventional wheat-based products. The research aims to support the diversification of millet-based offerings, promote the use of traditional functional ingredients, and contribute to the growing domain of health-conscious food innovations. The following sections detail the methodology, results, and conclusions derived from this investigation.

Materials and Methods

Selection and Procurement of Raw Materials

All raw materials used in the development of the kokum-incorporated ragi pasta were sourced from local suppliers in Pune, Maharashtra. The primary ingredients included finger millet (ragi) flour, refined wheat flour, kokum (*Garcinia indica*) extract, water, and a spice blend composed of traditional Indian spices. The spice blend was formulated in-house using dried and powdered forms of turmeric, cumin, coriander, black pepper, red chili, and ginger to enhance both flavor and functionality. All ingredients were selected based on their freshness, quality, and suitability for food-grade applications.

Preparation Method for Kokum-Ragi Pasta

The preparation of kokum-infused finger millet pasta was carried out using a standardized extrusion-based method by modifying the method given by Alfiya, P. V. *et al* (2021) [1]. Each step in the process was carefully monitored to ensure uniformity and reproducibility across all formulation trials. Initially, all raw ingredients were accurately weighed using a digital kitchen balance with a sensitivity of 0.01 grams to maintain precision. The finger millet and refined wheat flours were then pre-blended and sifted to ensure uniform binding and achieve the desired texture. The weighed flours were mixed thoroughly with kokum extract and water to form a homogeneous dough. This mixture was fed into an automatic pasta-making machine, where it was kneaded and extruded through a pasta die to form short, cylindrical pasta shapes. The extruded pasta was then manually cut into uniform lengths for consistency in appearance and cooking behavior. Finally, the pasta samples were air-dried for 4 to 6 hours under ambient conditions (Approximately 28-30 °C) to reduce moisture content and stabilize the product for further analysis.

Table 1: Formulation of Pasta

Ingredients	T ₁	T ₂	T ₃	T ₄
Ragi Flour (g)	60	50	40	32
Maida (g)	30	30	27	16
Spice blend (g)	00	10	7	14
Kokum extract (ml)	00	00	26	16
Water (ml)	10	10	00	24

The inclusion of kokum extract aimed to enrich the pasta with natural antioxidants, improve its color appeal with anthocyanins, and introduce a subtle tangy flavor. Finger millet was used as the primary base to enhance the dietary fiber and micronutrient profile of the product.

Analytical Methods

To determine the physical and nutritional properties of the product, the following analytical procedures were employed:

Moisture Content

Approximately 10 g of the sample was accurately weighed in a pre-dried moisture dish and dried in a hot air oven at 105±2 °C to constant weight. After drying, the sample was cooled in a desiccator and reweighed. Moisture content was calculated as the percentage loss in weight. (AOAC International, 2019, Method 925.10).

Protein Estimation

One gram of the defatted sample was digested in concentrated sulfuric acid using a catalyst mixture (usually potassium sulfate and copper sulfate) in a Kjeldahl digestion unit. After digestion, the mixture was neutralized with sodium hydroxide and distilled using a Kjeldahl distillation unit. Ammonia was collected in a boric acid solution and titrated with 0.1 N hydrochloric acid. The nitrogen content was multiplied by a conversion factor of 6.25 to determine crude protein. (AOAC International, 2019, Method 2001.11).

Fat Estimation

About 5 g of ground sample was extracted with petroleum ether (boiling point 40-60°C) using a Soxhlet extraction apparatus for 6 hours. After extraction, the solvent was evaporated, and the residue was dried at 100±2 °C, cooled in a desiccator, and weighed. (AOAC International, 2019, Method 922.06).

Ash Content

Approximately 5 g of sample was weighed into a pre-weighed crucible, charred on a low flame, and then incinerated in a muffle furnace at 550±25 °C for 5-6 hours until a white or gray ash was obtained. The crucible was cooled in a desiccator and weighed. (AOAC International, 2019, Method 923.03).

Crude Fibre

Approximately 2 g of the dried, defatted sample was digested sequentially with 1.25% sulfuric acid followed by 1.25% sodium hydroxide solution under controlled conditions using a fiber estimation apparatus. The residue was then dried, weighed, incinerated in a muffle furnace at 550±25 °C, cooled in a desiccator, and reweighed. The difference in weights before and after ashing was used to calculate crude fiber content. (AOAC International, 2019, Method 962.09).

Carbohydrate Estimation

The carbohydrate content of the sample was calculated by difference using the formula:

$$\text{Carbohydrates (\%)} = 100 - [\text{Moisture (\%)} + \text{Protein (\%)} +$$

Fat (%) + Ash (%) + Crude Fiber (%)]. (Food and Agriculture Organization [FAO], 2003).

Energy Value Calculation

The energy content of the sample was calculated using the Atwater general factors:

Energy (kcal/100g) = [Protein (%) × 4] + [Carbohydrates (%) × 4] + [Fat (%) × 9].

(USDA Handbook No. 74, Merrill & Watt, 1973) ^[24].

Ascorbic Acid (Vitamin C) Estimation

The sample was extracted with 4% oxalic acid solution and filtered. An aliquot was titrated against a standard 2,6-dichlorophenolindophenol (DCPIP) dye solution until a persistent pink endpoint was observed. The ascorbic acid content was calculated from the volume of dye consumed. (AOAC International, 2019, Method 967.21).

Total Anthocyanin Content (TAC) Determination

The total anthocyanin content was determined according to the method described by Suradkar *et al.* (2017) ^[28]. Anthocyanins were extracted using acidified ethanol, and the absorbance of the clear extract was measured at 535 nm using a UV-Vis spectrophotometer. The anthocyanin content was calculated using the absorbance value, dilution factor, molar absorptivity, and molecular weight of cyanidin-3-glucoside, and expressed as mg cyanidin-3-glucoside equivalents per 100 g of fresh sample.

Total Phenolic Content (TPC)

TPC was determined using the Folin-Ciocalteu method. Two grams of powdered sample were extracted with 80% methanol, and 0.5 ml of the extract was mixed with 2.5 ml of 10% Folin-Ciocalteu reagent and 2 ml of 7.5% sodium carbonate. The mixture was incubated for 30 minutes in the dark, and absorbance was measured at 765 nm. The results were expressed as mg gallic acid equivalents (GAE) per 100 g of sample. (Singleton & Rossi, 1965) ^[27].

Total Flavonoids

Flavonoid content was determined by the aluminum chloride colorimetric method. One ml of the methanolic extract was mixed with 4 ml distilled water and 0.3 ml of 5% sodium nitrite solution. After 5 minutes, 0.3 ml of 10% aluminum chloride was added, followed by 2 ml of 1 M sodium hydroxide. The absorbance was measured at 510 nm, and results were expressed as mg quercetin equivalents (QE) per 100 g of sample. (Chang *et al.*, 2002) ^[11].

Antioxidant Activity (DPPH Radical Scavenging)

Antioxidant activity was assessed using the DPPH assay. One ml of the extract was mixed with 2 ml of 0.1 mM DPPH solution prepared in methanol. The mixture was kept in the dark for 30 minutes, and the absorbance was read at 517 nm. The percent inhibition of DPPH was calculated to determine antioxidant potential. (Brand-Williams *et al.*, 1995) ^[10].

Iron Content Estimation

Iron content was estimated using the colorimetric method. One gram of sample was digested with a mixture of nitric acid and perchloric acid. The digested sample was filtered

and reacted with 1, 10-phenanthroline reagent under acidic conditions to develop a red-colored complex. The absorbance was measured at 510 nm, and the iron content was calculated from a standard curve. (AOAC International, 2019, Method 944.02).

Microbial Analysis

Microbial quality was assessed by determining Total Plate Count (TPC), Yeast and Mould count, and the presence of coliforms, *E. coli*, and *Salmonella*. For TPC and Yeast & Mould, 1 g of pasta sample was aseptically homogenized in 9 ml of sterile saline and serially diluted. Aliquots were plated on Plate Count Agar and Potato Dextrose Agar, respectively, and incubated at 35±2 °C for 48 hours (bacteria) and 25±1 °C for 5 days (Fungi). Coliforms and *E. coli* were tested using Violet Red Bile Agar and Eosin Methylene Blue Agar. *Salmonella* detection was done using pre-enrichment in Buffered Peptone Water, selective enrichment in Rappaport-Vassiliadis broth, followed by plating on XLD agar. (ICMSF, 2002; FSSAI Manual of Methods for Food Microbiology, 2016).

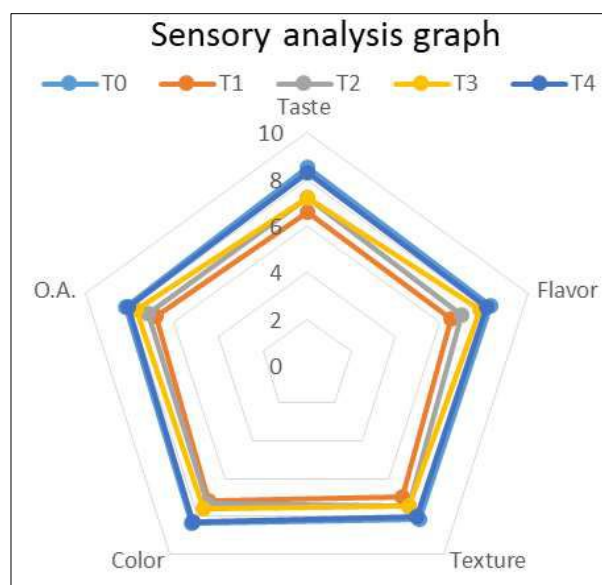
Results and Discussion

Sensory Evaluation

Sensory analysis was carried out by a semi-trained panel of 20 individuals aged between 20 and 50 years. Evaluation criteria included appearance, aroma, texture, flavor, and overall acceptability. A 9-point hedonic scale was used for scoring.

Table 2: Sensory evaluation of Pasta

Sample	Taste	Flavor	Texture	Color	O.A.
T ₀	8.5	8.3	8.2	8.4	8.2
T ₁	6.6	6.5	7.0	7.2	6.8
T ₂	7.2	7.0	7.5	7.3	7.2
T ₃	7.2	7.8	7.5	7.6	7.7
T ₄	8.3	8.1	8.0	8.3	8.1



Graph 1: Sensory evaluation of Pasta

The sensory evaluation clearly shows that Trial T₄, which included an optimal combination of kokum extract and spice blend, achieved the highest score in all attributes among the experimental formulations. It was particularly appreciated for its tangy taste, vibrant color, and well-balanced sensory

profile. The presence of anthocyanins from kokum imparted an attractive reddish-purple hue (Joshi *et al.*, 2013) ^[20], while the spice blend enhanced both flavor and aroma, contributing to a highly acceptable product.

Trial T₀, used as a reference, was a market-available pasta made entirely from maida (Refined wheat flour). As expected, it scored the highest overall (O.A. 8.2), primarily due to consumer familiarity and the refined texture typical of commercial wheat pasta. However, despite being slightly lower in scores, T₄'s performance was comparable, showing that a gluten-free, millet-based pasta can compete favorably in terms of sensory attributes.

Trial T₃ also showed high acceptability, particularly in flavor (7.8) and color (7.6), likely due to a slightly higher kokum concentration. Nevertheless, its marginally lower taste and texture scores suggest that excessive kokum may affect the balance of sensory appeal.

Trial T₁, the initial modified trial with kokum and spices, scored the lowest among the experimental versions, indicating an imbalance in the spice-to-kokum ratio. However, a steady improvement in sensory scores from T₁ to T₄ reflects the positive impact of progressive formulation refinement and optimization.

These findings confirm that the incorporation of kokum and spices, when optimized, significantly enhances the sensory quality of finger millet pasta. This aligns with earlier studies by Chethan & Malleshi (2007) ^[12] and Yadav *et al.* (2021) ^[29], which emphasize the effectiveness of composite formulations in improving both nutrition and acceptability in millet-based food innovations.

Table 3: Proximate Analysis of Pasta (T₄)

Parameter	Value
Moisture (%)	11.0
Protein (%)	7.0
Fat (%)	2.0
Ash (%)	1.2
Crude Fiber (%)	2.2
Carbohydrates (%)	76.6
Energy (kcal/100 g)	350

The high carbohydrate content (76.6%) confirms pasta's role as an energy-dense food, aligning with findings by Maske and Yadav (2022) ^[23], who reported 73.8% carbohydrates in beetroot-based pasta. Protein content was 7%, slightly lower than the 9.95% reported by Singh and Emmanuel (2022) ^[26] in ragi-rice pasta but still sufficient for a plant-based product. The fiber content (2.2%) contributes to digestive health and satiety, which is comparable to 4% observed in moringa-based pasta by Getachew and Admassu (2020) ^[16]. The low fat (2.0%) and ash content (1.2%) are ideal for individuals seeking low-fat diets.

Table 4: Bioactive Composition of Pasta (T₄)

Parameter	Value
Total Phenolic Content	150 mg GAE/100 g
Flavonoids	30 mg QE/100 g
Anthocyanins	22.5 mg C3G/100 g
Antioxidant Activity (DPPH)	75% inhibition

The presence of 22.5 mg/100 g anthocyanins, derived from kokum extract, significantly enhances the nutraceutical value of the product. Anthocyanins are known for their antioxidant, anti-inflammatory, and anti-cancer potential

(Joshi *et al.*, 2013) ^[20]. Total phenolic content (150 mg GAE/100g) and flavonoids (30 mg QE/100 g) further strengthen the antioxidant profile, similar to values reported by Suradkar *et al.* (2017) ^[28] in other fruit-based functional products. The DPPH radical scavenging activity of 75% indicates potent antioxidant potential, promoting health benefits such as protection from oxidative stress and degenerative diseases.

Table 5: Microbial analysis of Pasta (T₄)

Parameter	Value
Total Plate Count (cfu/g)	<10 ³
Yeast & Mould (cfu/g)	<10 ²
Coliforms	Absent
<i>E. coli</i> , <i>Salmonella</i>	Absent

The microbial load values fall well within acceptable safety limits (ICMSF, 2002), confirming the hygienic preparation and stability of the air-dried pasta. The absence of coliforms, *E. coli*, and *Salmonella* indicates safe handling and processing, critical for consumer health.

Table 6: Vitamin C Content of Pasta

Parameter	Value
Kokum extract	20 mg/100 g
Pasta (T ₄)	4.5 mg/100 g

Though some loss of vitamin C occurred during processing, the final product retained a moderate amount (4.5 mg/100 g). This retention is consistent with established patterns of thermal degradation of vitamin C, as described in food processing literature (Fennema, 2008; Lee & Kader, 2000) ^[14, 22].

Table 7: Iron Content of Pasta

Parameter	Value
Ragi flour	3.75 mg
Spice blend	0.75 mg
Pasta (T ₄)	4.5 mg/100 g

Iron content in the final pasta (4.5 mg/100 g) mainly originated from finger millet (ragi), known for its naturally high iron levels (Karki *et al.*, 2020) ^[21]. This makes the pasta beneficial for individuals at risk of anemia, especially in regions where dietary iron intake is low.

Comparative Advantage and Functional Relevance

The integration of kokum and finger millet offers dual benefits: kokum contributes antioxidants like anthocyanins and vitamin C, while ragi enhances fiber and mineral content. Compared to conventional wheat pasta, this variant provides enhanced bioactivity, lower glycemic index, and improved micronutrient profile. The product aligns well with current consumer trends for gluten-free, plant-based, and functional foods (Yadav *et al.*, 2021) ^[29].

Conclusion

The successful development of kokum-infused finger millet pasta represents an innovative and nutritious adaptation of a familiar food product. By integrating the health-promoting properties of finger millet—known for its high fiber, iron, and calcium content—with the antioxidant-rich kokum, this formulation offers a compelling alternative to traditional wheat-based pasta. The combination not only enhances the

nutritional profile but also introduces unique sensory attributes, such as tangy flavor and appealing color, which were well received in sensory evaluations. The results of proximate, bioactive, and microbial analyses further support the product's potential as a functional food, suitable for health-conscious consumers and individuals with specific dietary needs, such as gluten intolerance. This research underscores the potential of leveraging underutilized indigenous ingredients to develop modern, value-added foods that align with contemporary health and sustainability trends. It highlights the importance of blending nutritional science with culinary innovation to meet the growing demand for clean-label, plant-based, and functional food products. With appropriate market positioning and consumer education, kokum-ragi pasta could contribute meaningfully to improved dietary habits and the promotion of millets as climate-resilient, nutrient-rich grains.

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