

Development, Physicochemical and Sensory Evaluation of Vegan Paneer and Their Products Derived from Soy and Coconut Milk

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Abstract:

This study developed and evaluated vegan paneer from soy milk and coconut milk, with partial incorporation of buffalo milk to aid coagulation. Physicochemical analysis revealed that soy paneer had the highest moisture content (61.28 ± 0.29 g/100 g), crude fibre (4.2 ± 0.04 g/100 g), and mineral density, particularly magnesium (30.26 ± 0.05 mg/100 g), iron (5.4 ± 0.02 mg/100 g), and calcium (350 ± 4.80 mg/100 g). Coconut milk-based paneer exhibited superior protein (20.2 ± 0.16 g/100 g) and fat content (24.5 ± 0.13 g/100 g) and higher phosphorus (192.1 ± 0.12 mg/100 g). Sensory evaluation indicated higher acceptability for coconut milk-based paneer across colour, flavour, texture, and overall acceptability. Both soy and coconut paneer were successfully processed into value-added products, including snacks and gulab jamun, demonstrating functional versatility and suitability as plant-based dairy alternatives. The findings highlight the potential of these formulations for lactose-intolerant and health-conscious consumers, promoting nutritional adequacy and sustainable food innovation.

Keywords: Vegan paneer, soy milk, coconut milk, physicochemical analysis, sensory evaluation, plant-based dairy alternative, value-added products.

1. INTRODUCTION

The global demand for vegan and plant-based products has increased significantly due to rising concerns regarding sustainability, lactose intolerance, and changing dietary preferences toward veganism. However, the development of plant-based alternatives poses technological challenges, particularly in achieving desirable texture and protein network formation, which in dairy products is largely governed by casein gelation.

Paneer is one of the most widely consumed dairy products, especially in India. It is a soft, fresh acid-set cheese traditionally prepared by coagulating cow or buffalo milk using organic acids, followed by pressing and whey drainage. Paneer is characterized by its white appearance, spongy texture, and rubbery body, attributes imparted by the presence of casein and milk fat. It is a rich source of high-quality protein and essential micronutrients such as calcium. Paneer is extensively used in North Indian cuisine in popular dishes such as paneer butter masala, paneer 65, and various gravies.

With approximately 65–75% of the global population affected by lactose intolerance, there is an increasing demand for dairy-free alternatives. Plant-based products are gaining prominence as suitable substitutes, driven by health awareness and sustainability goals. Market projections indicate that by 2028, plant-based food products will constitute a substantial share of the global food market.

1.1 Soybean

Soybean (*Glycine max*) is an economically significant annual legume crop recognized for its high protein and oil content and is often referred to as a “miracle crop.” It is widely cultivated across diverse agro-climatic regions and plays an important role in improving soil fertility through biological nitrogen fixation. Due to its superior nutritional profile, soybean serves as a primary raw material for plant-based food products.

Table 1. Nutritional composition of raw mature soybean seeds (per 100 g)

Component	Quantity
Energy (kcal)	446
Carbohydrates (g)	30.16
Sugars (g)	7.33
Dietary fibre (g)	9.3
Fat (g)	19.9
Water (g)	8.5

(Source: USDA Nutrient Database)

1.2 Soy Milk

Soy milk is a lactose-free, plant-based protein alternative produced by soaking, grinding, and filtering soybeans with water. It provides essential nutrients such as calcium, B-complex vitamins, iron, phosphorus, and bioactive compounds including isoflavones. Soy milk also contains healthy fats that contribute to cardiovascular health. It is consumed directly as a beverage and is widely used as a base ingredient in the formulation of plant-based yogurt, cheese, and other dairy analogues.

1.2.1 Soy Paneer (Tofu)

Soy milk paneer, commonly known as tofu, is a plant-based dairy-free product obtained through the coagulation of soy milk. It is widely consumed among vegan populations and serves as a high-protein alternative to conventional paneer. Tofu contains beneficial fats and is a good source of calcium, which supports bone health and neurological functions.

Soybean proteins, particularly glycinin, undergo denaturation upon heating, and in the presence of coagulants such as citric acid, approximately 20% protein coagulation occurs, resulting in the formation of soy curd. The resultant soy paneer exhibits a mild flavour and relatively brittle texture, making it suitable for incorporation into curries, salads, and sandwiches.

1.3 Coconut

Coconut (*Cocos nucifera*), popularly known as Kalpa Vriksha (the tree of heaven), is valued for its extensive utility, as nearly every part of the plant is beneficial to humans. Kerala is the leading producer of coconuts in India, owing to favourable climatic conditions. Coconut is a rich source of lauric acid

(C₁₂H₂₄O₂), which contributes to characteristic flavour and texture in coconut-based food products. Additionally, coconut derivatives are widely used in cosmetic formulations due to their skin-soothing and antimicrobial properties. Studies have also reported anti-inflammatory effects and potential benefits in regulating blood glucose levels.

1.4 Coconut Milk

Coconut milk is a white, creamy liquid extracted from the grated flesh of mature coconuts. It serves as a plant-based milk alternative and is extensively used in culinary applications and beverages. Coconut milk is rich in saturated fats, which impart a desirable mouthfeel and enhance sensory quality. It also contains essential nutrients such as manganese.

Approximately 82% of coconut milk consists of water, which contributes to its limited shelf life. If stored beyond 72 hours, coconut milk is susceptible to rancidity due to lipolysis; therefore, it is recommended for fresh consumption.

1.5 Coconut Milk-Based Paneer

Coconut milk alone does not undergo coagulation suitable for paneer preparation due to the absence of casein-like proteins. However, when blended with buffalo milk in appropriate ratios, it results in paneer with improved texture and sensory acceptability. Such formulations offer potential benefits for lactose-intolerant consumers while partially reducing reliance on dairy ingredients.

Table 2. Comparative nutritional composition of selected milk sources (per 100 g)

Nutrient	Soya milk	Buffalo milk	Cow milk	Coconut milk
Moisture (%)	88.60	82.0	85.1	84.23
Fat (%)	2.12	5.0	3.5	5.02
Protein (%)	4.20	3.0	3.20	2.22
Ash (%)	0.46	0.60	0.50	0.68
Carbohydrates (%)	3.41	5.1	5.08	8.33

1.7 Objectives of Studies on Vegan Paneer Development

1. To develop plant-based paneer formulations
2. To optimize processing parameters
3. To evaluate physicochemical properties
4. To assess sensory attributes
5. To provide recommendations for future research

2. Review of Literature

Vegan paneer is a plant-based protein alternative developed to replace conventional dairy paneer, addressing the growing demand for lactose-free, cholesterol-free, and sustainable food products. Recent studies have highlighted the potential of vegan paneer in the dairy-free market due to its allergen-free profile and ability to mimic the texture and sensory properties of traditional paneer.

Pal et al. (2019) reported on the increasing popularity and consumption of paneer in India and described its traditional preparation using acid coagulation of milk. Paneer was identified as a rich source of protein, calcium, and phosphorus and widely used in vegetarian cuisines. The study also emphasized scope for innovation and value addition in paneer products. Rao et al. (2019) reviewed the effect of pH on paneer quality and reported that pH significantly influences sensory attributes, microbial stability, and shelf life, highlighting its importance in industrial paneer production.

Recent research has focused on vegan paneer formulations using plant-based ingredients. Adniya Yeshfeen et al. (2025) developed dairy-free paneer alternatives using soy, nuts, and millets, noting that soy-based paneer offers low cholesterol and lactose-free benefits, although achieving dairy-like sensory characteristics remains challenging. Subash Nallamuthu et al. (2024) evaluated paneer prepared using coconut milk blended with cow milk and reported enhanced nutritional and functional properties, including a fibre content of 1.4 g/100 g compared to zero fibre in conventional paneer. Ramesh Singh Pal et al. (2024) studied soya paneer produced using citric acid as a coagulant and found improved protein content and sensory acceptability, indicating its potential as a functional dairy alternative.

3. Materials and Methods

3.1 Materials:

- **Soy milk:**

White soybeans were selected for soy milk preparation, as seed colour significantly influences the appearance of the final product.

- **Coconut milk:**

Fresh coconut milk was extracted from mature coconuts. Due to its high fat content, coconut milk exhibits a thick consistency and contributes to texture and mouthfeel in paneer formulations.

- **Buffalo milk:**

Full-cream buffalo milk was used owing to its high protein, fat, and micronutrient content, essential for curd formation and texture development.

- **Citric acid:**

A 2% (w/v) citric acid solution was employed as the coagulating agent for paneer preparation.

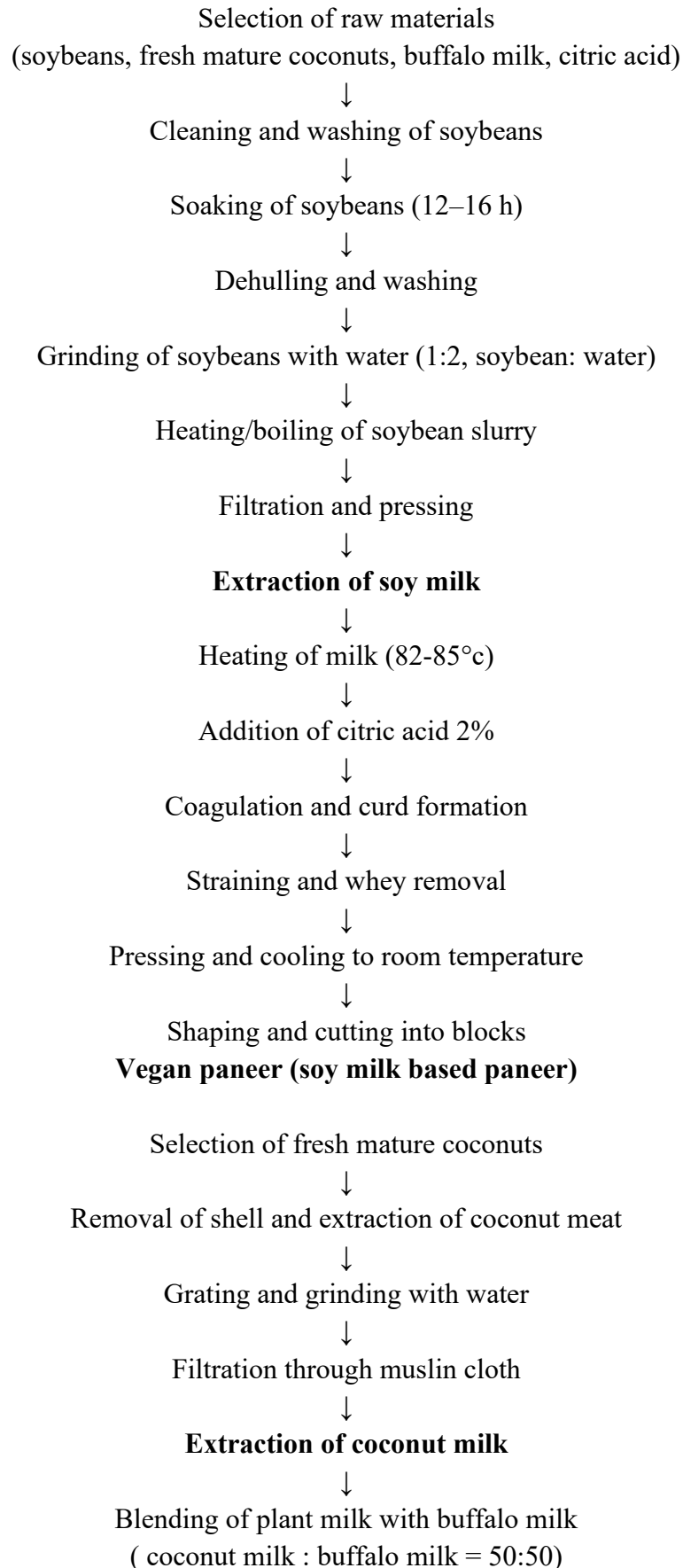
- **Utensils and glassware:**

Standard laboratory glassware including beakers, bowls, spatulas, volumetric flasks, and measuring cylinders were used for processing and proximate analysis.

Table 3. Raw materials and formulation levels

Material	Quantity
Soy milk	500 mL
Buffalo milk	500 mL
Coconut milk	500 mL
Citric acid	2% (w/v)

Figure 1: Consolidated Process Flow Diagram for Vegan Paneer Development



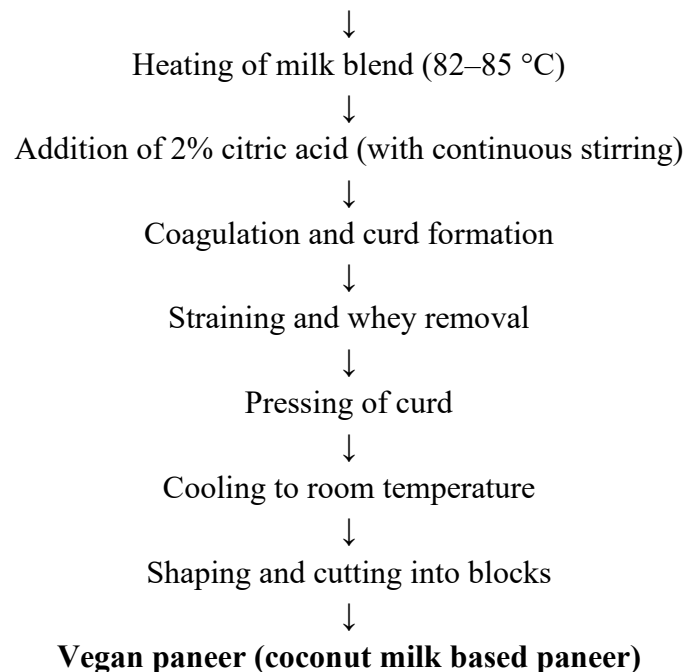


Figure 1 illustrated that the consolidated process flow diagram for the development of vegan paneer from soy and coconut milk. The process includes extraction of plant-based milks, blending with buffalo milk, heat-induced coagulation using citric acid, followed by pressing, cooling, and shaping to obtain paneer blocks with desirable quality attributes.

3.2 Proximate Analysis

All analyses were performed in **triplicate** following **AOAC standard methods**.

3.2.1 Moisture Content

Approximately 2.5–3.0 g of homogenized sample was weighed in a flat-bottom dish and dried at 102 °C for 3 h or until constant weight, following AOAC 925.23 (milk) or AOAC 948.12 (cheese products). Moisture content was calculated as the percentage weight loss.

3.2.2 pH Analysis

A calibrated pH meter (pH 4 and 7 buffers at 25 °C, AOAC 981.12) was used. Homogenized paneer samples were measured after 1 min electrode stabilization, and results were reported to two decimal places.

3.2.3 Protein Content

Crude protein was determined using the Kjeldahl method (AOAC 991.20). Samples (1–5 g) were digested with concentrated H₂SO₄, potassium sulphate, and copper catalyst. The digested solution was distilled with NaOH, and liberated ammonia was titrated. Nitrogen content was multiplied by a factor of 6.38 to calculate protein.

3.2.4 Total Fat Content

Fat content was estimated using the Gerber method (AOAC 2000.18). Samples were treated with H₂SO₄ and isoamyl alcohol, centrifuged, and fat percentage was read directly from the butyrometer.

3.2.5 Carbohydrate Content

Total carbohydrates (%) were calculated by difference: Carbohydrates (%) = 100 – (Moisture + Protein + Fat + Ash + Crude Fiber)

3.2.6 Crude Fiber

Crude fibre was determined following AOAC 962.09. Defatted samples were sequentially digested with

1.25% H₂SO₄ and 1.25% NaOH, then ashed at 550 °C. Fiber content was calculated based on the residue weight.

3.3 Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale to assess appearance, taste, texture, flavour, and overall acceptability. The evaluation panel consisted of twenty-five semi-trained panelists aged between 24 and 30 years. Samples were coded and served under controlled conditions, and mean scores were calculated.

4. Results

The prepared products were analysed and showed the results of the proximate composition of soya paneer, coconut milk-based paneer, and dairy-based paneer (Table 5) showed notable variations in moisture content, macronutrient profile, and pH. Soya paneer recorded the highest moisture content (61.28 ± 0.29 g/100 g), followed by dairy paneer (53.6 ± 0.01 g/100 g) and coconut milk-based paneer (52.1 ± 0.26 g/100 g). The pH of the samples ranged from 5.1 to 5.7, with soya paneer exhibiting the highest pH (5.7 ± 0.04), indicating a comparatively less acidic nature than dairy-based paneer (5.1 ± 0.01).

Protein content was significantly higher in coconut milk-based paneer (20.2 ± 0.16 g/100 g), followed by dairy paneer (17.5 ± 0.97 g/100 g), whereas soya paneer showed a relatively lower protein content (12.6 ± 0.16 g/100 g). Carbohydrate levels varied marginally among the samples, with coconut milk-based paneer showing the highest value (5.5 ± 0.10 g/100 g), followed by soya paneer (5.2 ± 0.08 g/100 g) and dairy paneer (3.5 ± 0.97 g/100 g). Fat content differed markedly, being highest in coconut milk-based paneer (24.5 ± 0.13 g/100 g), moderate in soya paneer (8.2 ± 0.09 g/100 g), and lowest in dairy paneer (1.25 ± 0.004 g/100 g). Crude fibre was detected only in soya paneer (4.2 ± 0.04 g/100 g) and was absent in both coconut milk-based and dairy paneer.

The mineral composition also showed (Table 6) significant differences among the paneer types. Soya paneer contained the highest levels of magnesium (30.26 ± 0.05 mg/100 g) and iron (5.4 ± 0.02 mg/100 g), indicating superior micronutrient density. Calcium content was highest in soya paneer (350 ± 4.80 mg/100 g), followed by coconut milk-based paneer (336.2 ± 0.12 mg/100 g) and dairy paneer (326.5 ± 0.96 mg/100 g). In contrast, phosphorus content was maximum in coconut milk-based paneer (192.1 ± 0.12 mg/100 g), followed by dairy paneer (158.2 ± 0.82 mg/100 g), while soya paneer recorded the lowest phosphorus level (101.12 ± 0.10 mg/100 g).

Figure 2 illustrates freshly prepared coconut milk-based paneer with a smooth, compact, and uniform appearance. The paneer exhibits a soft and cohesive curd structure with a clean white colour, indicating effective coagulation and minimal whey separation. The moist surface texture reflects the inherent fat content of coconut milk, contributing to its creamy consistency. Overall, the visual attributes indicate good structural integrity and freshness, confirming its suitability for further culinary and analytical applications.



Figure 2: Coconut Milk–Based Paneer

Figure 3 illustrates gulab jamun prepared using coconut milk–based paneer and immersed in sugar syrup. The jamuns display a uniform spherical shape with evenly developed golden-brown to deep brown coloration, indicating proper frying and controlled heat treatment. The smooth surface and intact structural integrity suggest effective binding and desirable textural stability of the coconut milk–based paneer matrix. Overall, the visual attributes reflect favorable sensory characteristics, confirming the suitability of coconut milk–based paneer for the development of traditional Indian sweet products such as gulab jamun.



Figure 3: Coconut milk-based paneer gulab jamun

Figure 4 shows freshly prepared soya milk paneer (tofu) with a compact and uniform structure. The product exhibits a firm yet fine-grained curd matrix with a light cream to off-white colour, indicating effective protein coagulation. The smooth and cohesive surface suggests good moisture retention and structural stability. Overall, the visual attributes reflect the freshness and suitability of soya milk paneer for further processing and value-added food product development.

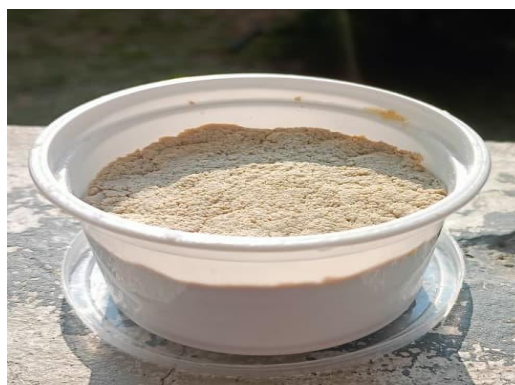


Figure 4: Fresh soymilk paneer (tofu)

Figure 5 illustrates value-added snack products developed from soya milk paneer. The snacks exhibit a uniform round shape with an evenly fried golden-brown colour, indicating proper dough formulation and controlled frying conditions. The crisp outer surface and intact structure suggest good binding and textural stability of the soya milk paneer matrix. Overall, the visual attributes demonstrate the suitability of soya milk paneer for the development of acceptable and appealing ready-to-eat snack products.



Figure 5: Soymilk paneer was made into soya snacks

Table 5: Macronutrient Content of Soy Paneer, Coconut Milk Based Paneer and Cow Milk Paneer

Macronutrient Content of Soy Paneer, Coconut Milk Based Paneer and Cow Milk Paneer			
Attributes (g / 100 gm)	Soya paneer	Coconut milk-based paneer	Dairy based paneer
Moisture content (%)	61.28±0.29	52.1±0.262	53.6±0.012
pH	5.7±0.0410	5.3±0.249	5.1±0.008
Protein (g)	12.6±0.163	20.2±0.16	17.5±0.967
Carbohydrates (g)	5.2±0.084	5.5±0.096	3.5±0.967
Fat (g)	8.2±0.09	24.5±0.131	1.25±0.004
Crude fiber (g)	4.2±0.043	-	-

Table 6: Mineral Content of Soy Paneer, Coconut Milk Based Paneer and Cow Milk Paneer

Micronutrients Per 100 gm	Soya paneer	Coconut milk-based paneer	Dairy based paneer
Magnesium (mg)	30.26±0.052	6.34±0.008	14.6±0.057
Iron (mg)	5.4±0.016	3.12±0.016	0.6±0.008
Calcium (mg)	350±4.80	336.2±0.12	326.5±0.96
Phosphorous (mg)	101.12±0.0967	192.1±0.124	158.2±0.816

The graph (figure 6) presents a comparative analysis of the proximate composition of soya paneer, coconut milk-based paneer, and dairy-based paneer. Soya paneer exhibited the highest moisture content, while coconut milk-based and dairy paneer showed comparatively lower values. Protein content was highest in coconut milk-based paneer, followed by dairy paneer and soya paneer. A marked difference was observed in fat content, with coconut milk-based paneer recording substantially higher fat levels compared to soya

and dairy paneer. Carbohydrate content showed marginal variation among the samples, whereas crude fibre was present only in soya paneer and was absent in coconut milk-based and dairy paneer. Overall, the graph highlights distinct nutritional differences among plant-based and dairy-based paneer variants.

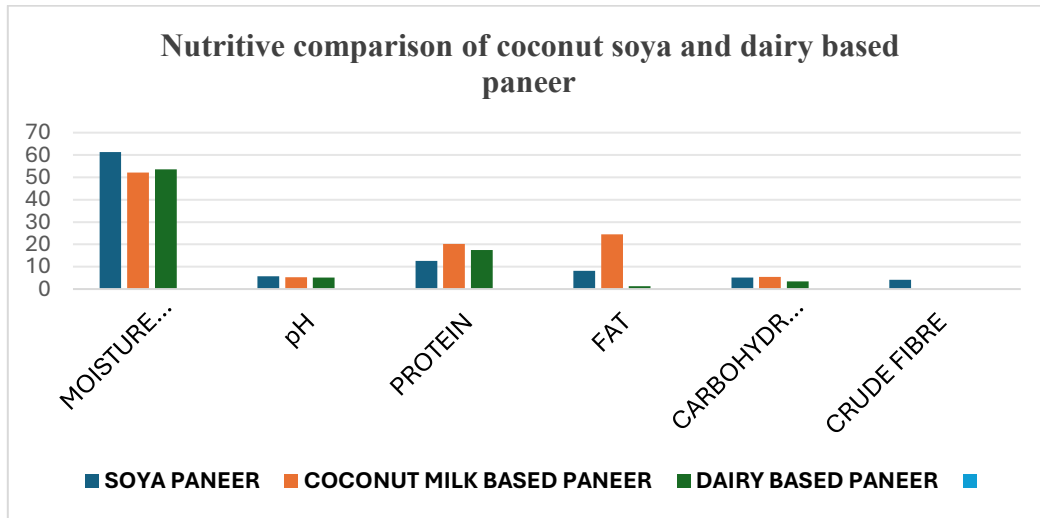


Figure 6: Graph of nutritive comparison of coconut soya and dairy based paneer

The graph (figure 7) illustrates the comparative micronutrient composition of soya paneer, coconut milk-based paneer, and dairy-based paneer. Soya paneer exhibited the highest magnesium and iron contents, indicating superior mineral density among the samples. Calcium content was highest in soya paneer, followed by coconut milk-based paneer and dairy paneer. In contrast, phosphorus content was maximum in coconut milk-based paneer, with dairy paneer showing intermediate values and soya paneer the lowest. Overall, the graph highlights distinct variations in mineral profiles between plant-based and dairy-based paneer alternatives.

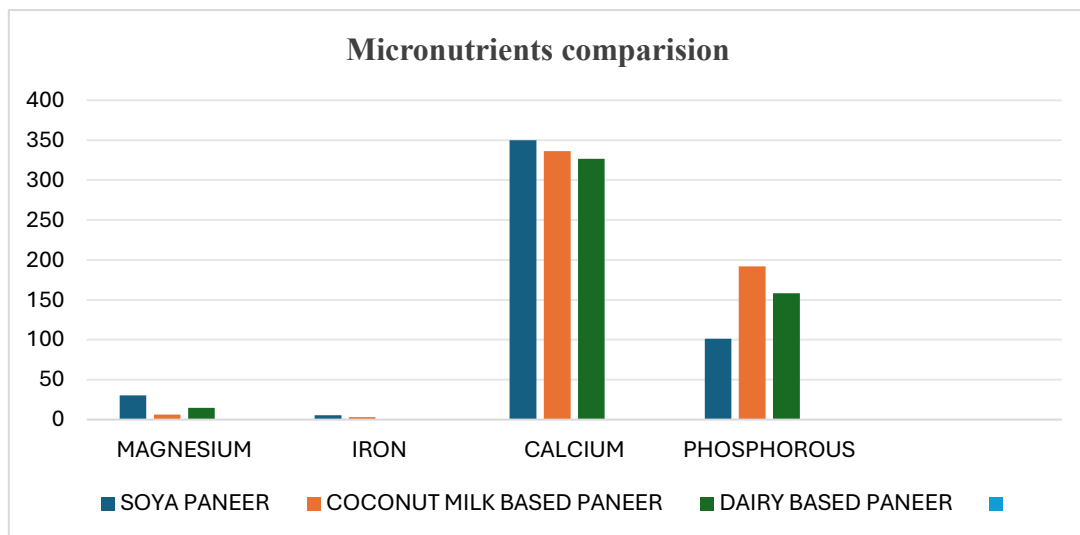


Figure 7: Graph of Micronutrients comparison.

5. Sensory Evaluation:

The radar chart (Figure 8) presents the sensory evaluation of soya paneer and coconut milk-based paneer based on colour, flavour, appearance, texture, and overall acceptability (OAA). Coconut milk-based paneer recorded higher mean scores across all sensory attributes, particularly in colour, flavour, and overall

acceptability, indicating superior consumer preference. Soya paneer showed comparatively lower but acceptable scores for all parameters. Overall, the sensory results suggest that coconut milk–based paneer possesses enhanced sensory appeal compared to soya paneer.

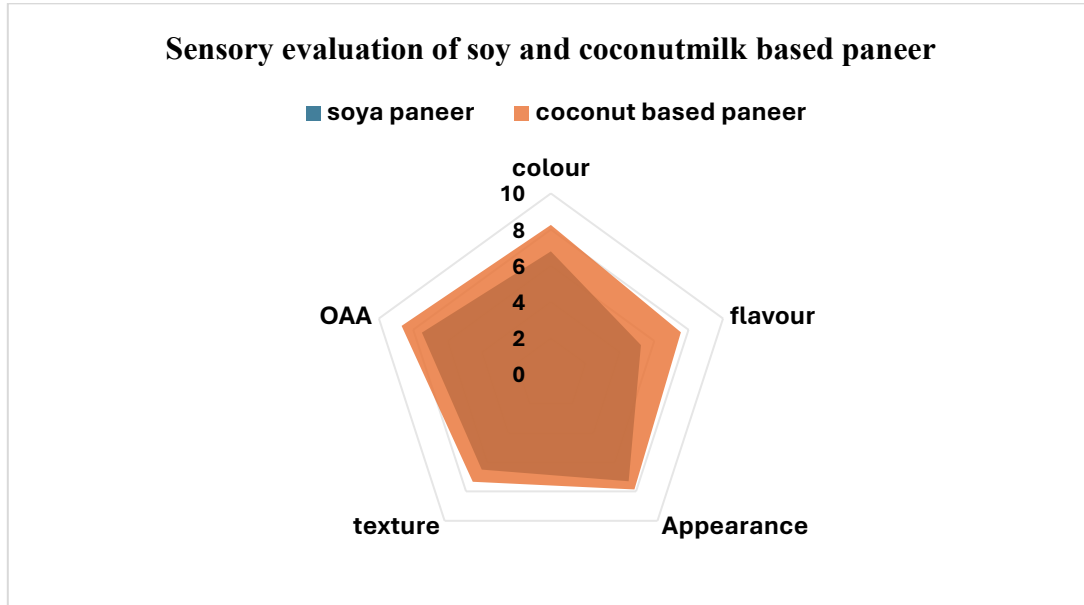


Figure 8: The radar chart presents sensory evaluation of soya paneer and coconut milk–based paneer based on colour, flavour, appearance, texture, and overall acceptability (OAA).

6. Conclusion

The present study successfully demonstrated the development and evaluation of vegan paneer formulations derived from soy milk and coconut milk, with partial incorporation of buffalo milk to facilitate coagulation and improve textural quality. Significant variations were observed in the physicochemical and nutritional properties of soya paneer, coconut milk–based paneer, and dairy-based paneer. Coconut milk–based paneer exhibited higher protein and fat content, while soya paneer showed superior moisture retention, crude fibre, and micronutrient density, particularly magnesium, iron, and calcium. Sensory evaluation revealed higher acceptability scores for coconut milk–based paneer, indicating enhanced sensory appeal compared to soya paneer.

The successful conversion of coconut milk–based paneer into value-added products such as gulab jamun, and soya paneer into snack items, further confirmed the functional versatility and processing suitability of these plant-based paneer alternatives. Overall, the findings suggest that soy and coconut milk–based paneer can serve as nutritionally rich, sensory-acceptable alternatives to conventional dairy paneer, particularly for lactose-intolerant and health-conscious consumers. The study highlights the potential of plant-based paneer products in promoting dietary diversification, sustainability, and innovation in the functional food sector. Future research may focus on complete dairy-free formulations, shelf-life studies, and large-scale commercialization.

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