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Nutritional and sensory impact of replacing milk with soy and pea protein in coconut sweetmeat: a vegan alternative

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Abstract
The booming demand for plant-based food alternatives has driven innovations in the development of dairy-free confections. This study aimed to develop a plant-based coconut sweetmeat as a vegan alternative to traditional dairy-based sweets by replacing milk solids with soy protein isolate (SPI) and Pea Protein Isolate (PPI). Several formulations were tested to optimize texture, taste, and overall acceptability while maintaining nutritional integrity. Sensory attributes were assessed by 60 untrained panelists using a 9-point hedonic scale, and the data was statistically analyzed using ANOVA. The evaluation revealed no significant differences in most sensory parameters between the two formulations, except for sweetness, where the SPI-based sweetmeat exhibited a superior score (p<0.05). Nutritional analysis demonstrated that plant-based variants exhibited higher protein content (8.48% for PPI and 7.09% for SPI) compared to the traditional variant (3.15%), while fat content was highest in the SPI-based formulation (20.35%), potentially due to protein-lipid interactions. The carbohydrate content was lower in plant-based variants due to increased protein incorporation. These findings suggest that SPI and PPI can be effectively incorporated into plant-based coconut sweetmeat, providing a viable vegan alternative with improved protein content while maintaining consumer acceptability. Further research may explore optimization strategies to enhance sensory attributes, particularly for PPI-based formulations, and evaluate the product's market potential.

Keywords: Plant-based coconut sweetmeat, soy protein isolate, pea protein isolate, sensory evaluation, nutritional analysis, vegan alternative

Introduction
The rising global and Indian shift toward plant-based diets is driven by health issues like lactose intolerance (affecting 68% of the global population) [51], religious beliefs, ethical concerns regarding animal welfare and industrial dairy farming [17], and environmental impacts of dairy such as greenhouse gas emissions, deforestation, and excessive water use [41]. In response to these concerns, there is growing interest in sustainable, dairy-free foods. As milk is a core component of many traditional Indian confections, this research explores dairy-free alternatives to develop nutritious and easily digestible sweets. Studies suggest that using plant proteins and functional ingredients like coconut and herbs can enhance micronutrient content and antioxidants while retaining traditional taste and sensory acceptability [54, 42, 40].

Coconut Burfi is a popular Indian confectionery known for its rich texture and mild sweetness, traditionally made with milk, sugar, and flavoring agents [49]. The inclusion of grated coconut, milk, sugar, and ghee contributes to its dense, creamy consistency, with dairy playing a key role in enhancing binding and mouthfeel [8, 22]. The presence of coconut imparts a mild sweetness and a characteristic nutty flavor attributed to its volatile compounds [21].

Coconut, a lactose-free primary ingredient in sweetmeat, provides dietary fiber, phytochemicals, proteins, carbohydrates, and healthy fats such as MCTs, MUFAs, and PUFAs, which aid metabolism and exhibit antimicrobial, cardioprotective as well as antiatherosclerotic benefits [38, 10]. It also contains essential micronutrients like potassium, magnesium, and vitamin C, enhancing its nutritional value [53]. The MCTs present in coconut are lauric acid, caprylic acid, and capric acid [13]. However, lauric acid oxidation causes ketonic rancidity, affecting product stability and the sensory quality of the product [24].

Soy Protein

Soy protein is a high-quality plant protein with 36-56% protein on a dry basis, a well-balanced amino acid profile, and high digestibility [28, 26]. Its PDCAAS score is between 0.91 to 1.0, making it nutritionally comparable to animal proteins [43]. It also contains bioactive compounds, such as isoflavones, which show antioxidant and hormonal benefits [32]. Soy protein offers various functional properties such as hydration, gelation, foaming, and emulsifying properties that are crucial for food formulation [25]. However, the inherent beany flavors due to volatile compounds such as aldehydes and ketones impact sensory properties [50]. Processing methods like high-temperature pre-treatment, enzymatic hydrolysis, fermentation, and flavor-masking agents have been explored to minimize these undesirable attributes and improve consumer acceptance [56, 52].

Soy Protein Isolate (SPI)

Soy protein isolate (SPI), with a protein content exceeding 90%, exhibits superior gelation, emulsification, and moisture retention properties, contributing to enhanced creaminess, improved texture, uniform fat distribution, and reduced phase separation. [28, 48]. It forms heat-induced gels that provide firmness and cohesiveness, mimicking dairy protein binding effects [6]. While SPI's foaming ability introduces air pockets, careful formulation is necessary to ensure optimal texture [25].

Pea Protein

Pea protein is hypoallergenic, neutral-tasting, and rich in BCAAs [7], though slightly lower in methionine, a sulfur-containing amino acid [47]. With 20-25% protein content [53], it serves as an alternative for soy or dairy-sensitive consumers. Pea protein is recognized for its high digestibility and functional properties, including emulsification properties. While it has lower solubility, gelation, and water-holding capacity than soy [46, 27], these challenges can be addressed using hydrocolloids and emulsifiers such as lecithin or guar gum [31, 20]. Unlike soy, pea protein's minimal foaming ability helps achieve a denser, traditional Burfi-like texture [46].

Pea Protein Isolate (PPI)

Pea protein isolate (PPI), with 80-90% protein, can bring nutritional benefits along with improvement in the texture and stability of vegan sweets [46]. Its slightly earthy or bitter taste can be mitigated through fermentation, enhancing sensory quality [58].

The table below summarizes the key nutritional and functional properties of soy and pea proteins, highlighting their advantages and challenges in dairy-free Sweetmeat formulations.

Table 1: Comparison of nutritional and functional properties of soy and pea proteins

Property	Soy Protein	Pea Protein
Protein Content	36–56% (dry basis)	20–25%
PDCAAS	~1.0	~0.89
Amino Acid Profile	Complete protein, rich in lysine	Good, but low in methionine
Emulsification	High	Moderate
Gelling Properties	Strong, forms smooth gel	Moderate, requires stabilizers
Solubility	High, good water-binding	Moderate, needs modification
Flavor	Beany requires masking	Earthy, slightly bitter
Allergenicity	Common allergen	Hypoallergenic

Health benefits of soy and pea proteins

Soy protein supports cardiovascular health by lowering serum cholesterol levels, reducing heart disease risk [2, 44]. Its isoflavones help reduce inflammation and oxidative stress, promoting heart health [32]. These compounds also aid hormonal balance in postmenopausal women by mimicking estrogen, alleviating symptoms like hot flashes and bone density loss [45]. Additionally, soy protein enhances muscle recovery and growth, making it popular among athletes [55]. It also supports bone health, increasing bone mineral density and reducing osteoporosis risk [5].

Pea protein, abundant in branched-chain amino acids (BCAAs), plays a crucial role in muscle development and recovery, positioning it as a valuable protein source for plant-based diets and athletic nutrition [7, 23]. It is hypoallergenic, free from common allergens, and suitable for sensitive individuals [18]. Pea protein also promotes digestive health by providing prebiotic fibers that support gut bacteria [57]. Additionally, its high protein and fiber content aids in weight management by increasing satiety and reducing calorie intake [1].

While coconut-based sweets are well-known, limited research has been conducted on developing vegan versions using plant protein integration. Traditional Indian sweets like coconut burfi heavily rely on milk solids, which poses a challenge when attempting to develop acceptable plant-based alternatives. The challenge lies in maintaining the sensory characteristics (such as texture, taste, and appearance) while improving the nutritional quality. Previous studies have demonstrated the potential of soy and pea protein to mimic dairy functionalities however, their application in coconut-based vegan sweets remains underexplored.

Research Hypothesis

This study hypothesizes that the complete replacement of milk with soy and/or pea protein in coconut burfi can enhance the nutritional profile while maintaining or improving sensory acceptability. It also assumes that synergistic combinations of plant proteins and coconut meat can yield a product that meets consumer expectations for taste, texture, and overall quality.

The primary objectives of this research are:

- To develop coconut sweetmeat formulations by replacing milk with soy protein and pea protein.
- To compare the nutritional profiles of coconut sweetmeat made with milk, soy protein, and pea protein.
- To evaluate the sensory acceptability of the developed plant-based coconut sweetmeat alternative among consumers.

- To explore the implications of such substitutions in the context of vegan, lactose-free, and health-conscious product development.

The scope of this study is limited to formulation development, nutritional evaluation, and sensory analysis of the coconut sweetmeat samples. The findings aim to contribute to the body of knowledge supporting plant-based innovations in traditional Indian sweets, catering to evolving dietary trends and preferences.

Materials and Methods

Materials

Three formulations were developed for this study: a traditional variant serving as the control and two experimental variants, where milk was entirely replaced with soy and pea protein isolates, respectively. Desiccated coconut was utilized as the primary ingredient, while protein isolates were incorporated to enhance the nutritional profile, providing a highly purified and concentrated protein source. To maintain the vegan nature of the product, soy and pea protein isolates were selected as alternatives to milk, and vanaspati was used as a binding agent instead of ghee, ensuring the exclusion of animal-derived ingredients. Cardamom was incorporated as a flavoring agent, while powdered cane sugar was employed as a sweetening agent.

Methodology

The traditional formulation, serving as the control, was prepared following conventional methods, while the experimental formulations were developed using a standardized process. For preparation, desiccated coconut was dry-roasted in an open pan over medium heat, stirring continuously until it developed a golden color and characteristic aroma, enhancing flavor and texture. Vanaspati ghee was melted separately, while pea protein isolate (PPI) and soy protein isolate (SPI) were lightly roasted to eliminate any raw taste and improve solubility. The roasted desiccated coconut was then combined with protein isolates, ensuring uniform distribution. Powdered sugar and cardamom powder were added for sweetness and flavor enhancement. The mixture was continuously stirred, and filtered water was gradually incorporated in order to prevent clumping while ensuring a smooth consistency. The mixture was cooked over medium heat and stirred constantly until the mass thickened and started leaving the sides of the pan, indicating proper binding. The prepared mixture was then transferred into greased molds, shaped, and allowed to set at room temperature before undergoing nutritional and sensory evaluation.

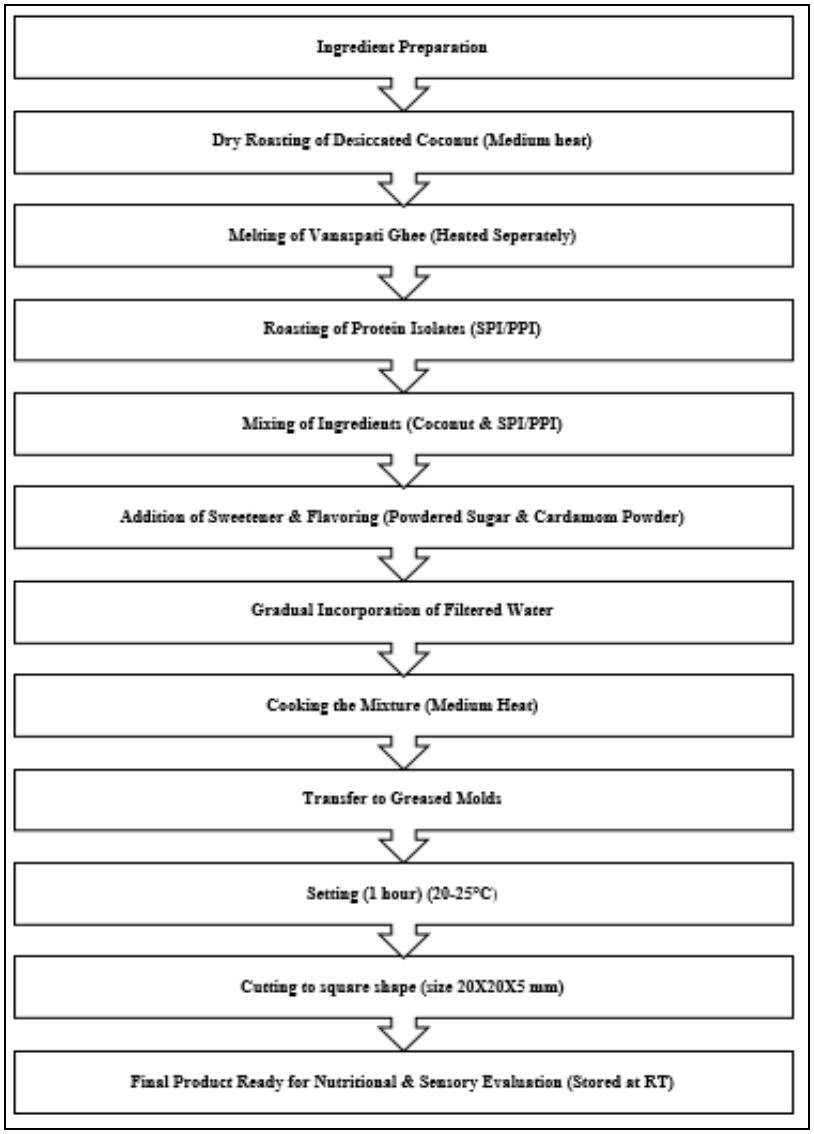

Fig 1: Flow diagram for plant-based coconut sweetmeat production

Sensory Evaluation and Statistical Analysis

Sensory evaluation was conducted to assess color, texture, sweetness, aroma, taste, and overall acceptability using a 9-point hedonic scale (1="dislike extremely" to 9="like extremely") [39]. Sixty untrained panelists, randomly selected from students and staff familiar with Indian sweets, participated. To minimize bias, coded samples were presented in a randomized order on white plates at room temperature, with panelists rinsing their palates with water between samples. The obtained sensory data was analyzed using one-way ANOVA to identify significant differences (p<0.05), with results expressed as mean ± standard deviation (SD) [35]. Statistical analysis was performed using Microsoft Excel's Data Analysis ToolPak [33].

Proximate analysis

Physicochemical properties were analyzed using standardized methods:

- **pH (AOAC 981.12) [3, 4]:** Measured using a digital pH meter.
- **Total Soluble Solids (TSS) (Milwaukee Corporation, n.d.) [34]:** Determined using a digital Brix refractometer.
- **Moisture Content (AOAC 925.10) [3, 4]:** Estimated via oven-drying at 105°C.
- **Ash Content (AOAC 942.05) [3, 4]:** Determined through dry ashing in a muffle furnace at 550°C.
- **Fat Content (AOAC 920.39) [3, 4]:** Measured using Soxhlet extraction with petroleum ether.
- **Protein Content (FSSAI, Kjeldahl Method C13) [15]:** Determined via digestion, distillation, and titration.
- **Crude Fiber (AOAC 962.09) [3, 4]:** Assessed through sequential acid and alkali digestion.
- **Free Fatty Acids (FFA), (FSSAI Manual-Oils and Fats, 2016) [16]**
- **Carbohydrate Content:** Calculated by difference method:
  Energy (kcal/100g) = (Carbohydrate X 4) + (Protein X 4) + (Fat X 9).

Results

Product Development and Formulation Trials

The study aimed to develop a plant-based coconut sweetmeat by replacing dairy milk with soy protein isolate (SPI) and pea protein isolate (PPI). Tables 2 and 3 contain various trials that were conducted to formulate the plant-based coconut sweetmeat by modifying ingredient proportions to optimize texture, taste, and overall acceptability.

Table 2: Formulation trials for Pea PPI variant

Formulation	Desiccated Coconut	Pea Protein Isolate (PPI)	Sweetener (Sugar powder)	Binding agents (Vanaspati)
P1	35	5	50	10
P2	35	7	49	9
P3	37	10	45	8

Table 3: Formulation trials for SPI variant

Formulation	Desiccated Coconut	Soy Protein Isolate (SPI)	Sweetener (Sugar powder)	Binding agents (Vanaspati)
S1	35	5	50	10
S2	35	7	49	9
S3	37	10	45	8

Based on sensory feedback, Formulations P3 (PPI-based) and S3 (SPI-based) were selected as optimal, offering a good balance between protein enrichment and desirable sensory attributes. Figures 2 and 3 represent the final product, which was prepared following a standardized procedure, ensuring consistency in texture and taste

Fig 2: Pea Protein Variant

Fig 3: Soy Protein Variant

Sensory evaluation

The final plant-based sweetmeat formulations were assessed by 60 untrained panelists using a 9-point hedonic scale

Table 4: Sensory scores of final product variants

Sensory Attributes	Pea protein (Variant 1)	Soy protein (Variant 2)
Colour & Appearance	7.45 ± 1.10	7.63 ± 0.71
Texture	7.38 ± 1.33	7.57 ± 1.27
Aroma	7.37 ± 1.69	7.57 ± 1.40
Sweetness	7.65 ± 1.32	8.05 ± 0.93
Taste	7.70 ± 0.96	7.95 ± 1.0
Overall Acceptability	7.76 ± 0.80	7.97 ± 0.72

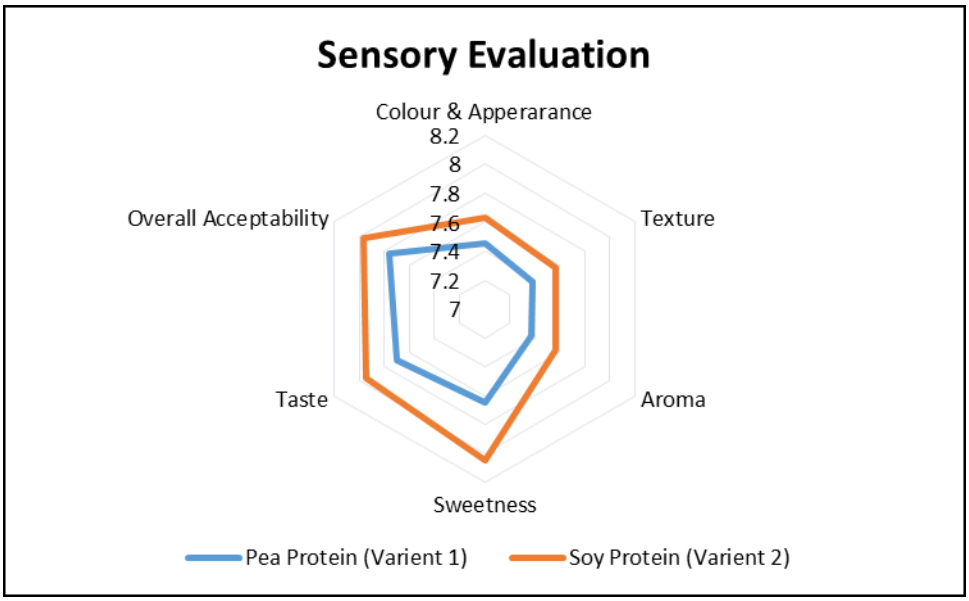

Fig 4: Sensory analysis of sweetmeat variants

The findings illustrated in table 4 and figure 4 suggest that both the variants showed high acceptability, with the soy-based version scoring slightly higher across all attributes, especially in sweetness and taste. Soy protein's milder flavor and better sugar solubility likely contributed to its improved sensory profile. However, PPI also demonstrated acceptable scores (>7.0), indicating potential with further optimization.

Statistical Analysis

As presented in Table 5, only sweetness showed a statistically significant difference ($p < 0.05$), favoring the soy-based variant. All other attributes were comparable between the two, indicating PPI as a viable alternative in plant-based sweets.

Table 5: ANOVA results for sensory attributes

Attribute	F-Value	P-Value	Significance
Color & Appearance	1.11	0.293	Not significant
Texture	0.77	0.379	Not significant
Aroma	0.77	0.380	Not significant
Sweetness	4.27	0.041	Significant
Taste	1.91	0.168	Not significant
Overall Acceptability	1.59	0.208	Not significant

Proximate Analysis

A proximate analysis was conducted to evaluate the nutritional and compositional improvements resulting from the substitution of milk with Soy Protein Isolate (SPI) and Pea Protein Isolate (PPI) in coconut sweetmeat formulations. The aim was to determine how the inclusion of these plant-based protein isolates influenced the nutritional quality and suitability of the product. A traditional coconut sweetmeat served as the control for comparative evaluation and the results obtained are compiled in Table 6.

Table 6: Proximate composition of coconut sweetmeat variants

Test	Traditional Variant	Pea Protein Variant	Soy Protein Variant
Ph	5.93	6.14	6.21
Total Soluble Solids (TSS) (°Bx)	46°Bx	52°Bx	51°Bx
Moisture (%)	9.70	12.50	10.70
Ash (%)	1.03	1.20	1,00
Fat (%)	15.60	18.50	20.35
Protein (%)	3.15	8.48	7.09
Fiber (%)	12.60	12.64	12.37
Carbohydrate (%)	57.92	46.68	48.49
Energy (kcal/100g)	384.68	387.14	405.47
Free Fatty Acids (%)	0.52	0.53	0.42

pH

The pH values of the formulations ranged from 5.93 (traditional) to 6.21 (soy-based), with the pea protein variant (6.14) falling in between. The higher pH in plant-based formulations suggests a reduction in acidity compared to the traditional dairy-based variant. This could be attributed to the absence of lactic acid from milk solids and the buffering capacity of protein isolates, particularly soy protein, which tends to have a slightly alkaline nature [25].

Total Soluble solids

The TSS values were highest in the pea protein variant (52°Bx), followed by the soy protein variant (51°Bx) and the traditional variant (46°Bx). The increase in TSS in plant-based formulations suggests a higher concentration of dissolved solids, possibly due to the higher protein content

and its interaction with sugars.

Moisture Content
The moisture content was highest in the pea protein variant (12.50%), followed by the soy protein variant (10.70%), and the traditional variant had the lowest moisture (9.70%). The higher moisture levels in plant-based variants could be attributed to the water-binding capacity [46] of plant proteins, particularly pea protein, which has a higher hydrophilic nature compared to dairy proteins.

Ash Content
The ash content, representing the total mineral content, was highest in the pea protein variant (1.20%), followed by the traditional variant (1.03%), and the soy variant had the lowest (1.00%). The higher ash content in pea protein and soy protein formulations could be due to higher inherent mineral composition, particularly sodium, phosphorous, calcium, magnesium, and iron, commonly found in these proteins [29]. A higher mineral content can contribute to improved nutritional value, enhancing its potential as a functional food.

Fat Content
The fat content was highest in the soy protein variant (20.35%), followed by the pea protein variant (18.50%), and the traditional variant had the lowest fat (15.60%). Despite using equal quantities of fat sources, the higher fat content in plant-based variants may be due to the protein-lipid interaction, which affects the retention of fat within the matrix [19]. Soy protein, known for its higher emulsification capacity [36], may have led to better fat incorporation and retention in the final product.

Protein Content
The protein content was significantly higher in plant-based formulations, with the pea protein variant containing 8.48%, and the soy protein variant 7.09%, compared to only 3.15% in the traditional formulation. This increase is attributed to the addition of protein isolates (SPI and PPI) as milk replacers, demonstrating the nutritional enhancement of plant-based alternatives. Pea protein displayed a higher protein yield, possibly due to a higher protein dispersibility index (PDI), suggesting better protein solubility and retention during processing [30].

Fiber Content
The fiber content remained nearly constant across all formulations, with traditional (12.60%), pea (12.64%), and soy (12.37%). Since coconut is the primary source of fiber, the small variations may be due to different hydration properties and protein interactions during processing. Pea protein exhibited a slightly higher fiber content, which may be due to its higher retention of insoluble components during formulation. Fiber is essential for texture modification, water retention, and improved digestibility [12], making these plant-based formulations nutritionally beneficial.

Carbohydrate Content
The carbohydrate content was highest in the traditional variant (57.92%), while plant-based formulations had lower carbohydrate levels, with pea protein at 46.68% and soy protein sat 48.49%.

Energy
The energy content was highest in the soy protein variant (405.47 kcal/100g), followed by the pea protein variant (387.14 kcal/100g), while the traditional variant had the lowest energy (384.68 kcal/100g). The increase in caloric value of plant-based variants is primarily due to higher fat and protein content, contributing to a more energy-dense product, making it a better option for individuals requiring high-protein, high-calorie diets.

Free Fatty Acids (FFA)
FFA values were highest in the pea protein variant (0.53%), followed by the traditional variant (0.52%), while the soy protein variant had the lowest (0.42%). The Free fatty acids (FFAs) are unesterified fatty acids that are not bound to glycerol in triglyceride molecules. They are formed as a result of the hydrolysis of triglycerides catalyzed by lipolytic enzymes or chemical reactions during processing and storage. The concentration of FFAs is an important indicator of lipid quality, as elevated levels are associated with oxidative rancidity and the development of undesirable off-flavors [11, 14], with lower values generally indicating better lipid stability in food products [9, 37].

Conclusion
The present study demonstrated the successful development of a plant-based coconut sweetmeat by replacing dairy milk with soy protein isolate (SPI) and pea protein isolate (PPI). Both formulations were well-accepted in sensory evaluations, with the soy variant showing slightly higher scores, especially for taste and sweetness. Nutritional analysis revealed significant improvements in protein content and energy value in both variants compared to the traditional formulation, with SPI providing better fat retention and FFA stability and PPI offering higher mineral content.
These findings support the feasibility of using SPI and PPI as functional milk alternatives in traditional Indian confections. The developed products meet consumer demands for vegan, protein-rich, and lactose-free sweets, offering a promising avenue for healthier, plant-based dessert innovations.

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