International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 19-04-2026, Accepted: 20-05-2026, Published: 04-06-2026
Volume 11, Issue 2, 2026, Page No. 193-196

Development and evaluation of raw banana incorporated vegan yoghurt

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DOI: https://doi.org/10.66856/ijfsn.2026.11.2.11075

Abstract
This study conducted to develop and quality evaluation of vegan yoghurt made from soy milk incorporated with raw banana flour as a functional ingredient at ratios 95:5 (T_1), 90:10 (T_2), 85:15 (T_3), 80:20 (T_4), 75:25 (T_5). The goal was to create a plant-based, lactose-free, nutrient dense yoghurt with enhanced microbial, physicochemical and sensory qualities. With better nutritional and sensory qualities than other formulations, T_3 demonstrated the highest level of overall acceptability among the treatments. Nutritional analysis revealed that it included carbohydrate ((19.24 g/100 g), protein (3.16 g/100 g), fat (1.71 g/100 g), crude fibre (2.82 g/100 g), ash (0.76 g/100 g), and energy value of 104.99 kcal. Calcium and potassium contents were 31.26 mg/100 g and 182.50 mg/100 g, respectively. The study found that adding raw banana flour to soy milk yoghurt improved its nutritional and functional qualities and could be a sustainable substitute for traditional dairy yoghurt.

Keywords: Vegan yoghurt, soy milk, raw banana, fermented food product, resistant starch, lactose free product

Introduction
Yoghurt is one of the most fermented dairy products in the world by considering its protein, calcium, vitamins and probiotics value. It is traditionally made from fermenting cow's milk by lactic acid bacteria namely, *Lactobacillus bulgaricus* and *Streptococcus thermophilus.* However, the demand for plant-based substitutes has increased due to growing concerns about lactose intolerance, milk allergies, cholesterol intake, and environmental sustainability. The lack of important bioactive components like plant-based antioxidants and dietary fiber further restricts the functional potential of regular yoghurt (Rashwan *et al.,* 2023) [17]. According to (Grasso *et al.,* 2020) [8] and (Vicent, 2024) [21], there has a notable surge in interest in plant based alternatives due to these limitations and growing consumer awareness of ethical and health issues. Soy milk provides the perfect foundation for creating nutritionally enhanced vegan yoghurt because its cholesterol free and cardioprotective properties.
Study by (Mehaya *et al.*,2023) [13] found that soy yoghurt made from soy milk is naturally lactose free and low in cholesterol. Soymilk based yoghurt has a weak gel structure and a distinct beany flavor, despite its advantages. Raw banana flour which is made from unripe bananas (Musa spp.) has become a promising ingredient because of its high resistant starch and dietary fiber content. According to studies, adding banana flour to soy yoghurt improves its viscosity, stability, and sensory qualities(Vicent, 2024) [21],and its prebiotic – resistant starch increases the viability of probiotic bacteria, resulting in symbiotic product with superior gut health benefits(Agustin *et al.*, 2024) [2].According to studies, eating raw banana flour enhances insulin sensitivity and lowers postprandial glucose levels, making it suitable for diabetic and weight management regiment(Sharma & Sharma, 2024:S. Shini *et al.*,2024) [18].
Guar gum, a galactomannan polysaccharide derived from *Cyamopsis tetragonoloba*; is used to increase the viscosity, water holding capacity and decreases syneresis without affecting the sensory quality of yoghurt (Rafiq *et al.,* 2020) [16]. According to studies published in Foods (Montemurro *et al.,* 2023) [14] plant-based yoghurt substitutes becoming more well liked since they are satisfying sustainability and nutritional needs. Soy yoghurt is well liked by customers and it helps to enhance protein consumption (Kalavathi *et al.,* 2024) [12]
Banana flour and soy milk are both readily available, reasonably priced, and sustainable materials. The resulting vegan yoghurt provides a nutritionally balanced dairy yoghurt, making it suitable for lactose intolerant people, vegans, and those looking for low cholesterol options.

Materials and Method
Materials and chemicals
Soybeans and raw banana (Nendran banana) were procured from local market in Pattambi, Kerala. The bacterial culture (*Streptococcus thermophilus* and *Lactobacillus bulgaricus* with *Lactobacillus acidophilus*) procured from KVASU (Kerala Veterinary and Animal Science University, Thrissur, Kerala. Other ingredients like sugar and food grade guar gum also obtained from commercial suppliers and stored in air tight container. All the chemicals used in in the analysis were the analytical grade

Methods
Raw material and vegan yoghurt manufacture
The soy beans were soaked in the water containing 0.3% of sodium bicarbonate for 10-12 hours and then dehulled manually. Dehulled soybeans blended with water to form slurry and it filtered through a muslin cloth to obtain soymilk. Then the soymilk boiled at 100℃ for 10 to 15 minutes by continuous stirring (Afroz *et al*., 2016) [3].
The unripe green banana washed, peeled and sliced into 5mm thickness and treated with 2% of sodium metabisulphite solution for 10minutes and washed with

water. The slices were dried in cabinet dryer at 70℃ for 3 – 4 hours. The dried slices were grounded into flour and sieved, then packed in airtight container and stored at room temperature (Thakur *et al.,* 2016) [20].

The raw banana flour was incorporated into boiled soy milk at different ratios, along with a constant amount of sugar and stabilizer (Table 1). The mixture was allowed to cool at a temperature 40- 42℃ and inoculated with starter culture containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus.* Fermentation was carried out at 8 – 10hours until desired acidity and pH is obtained (Abdalla & Ahmed, 2019) [1].

Table 1: Ingredient composition different treatments of vegan yoghurt

Ingredients	Treatments					
	T_0 (Control)	T_1	T_2	T_3	T_4	T_5
Soy milk	100ml	95ml	90ml	85ml	80ml	75ml
Banana flour	Nil	5g	10g	15g	20g	25g
Sugar	8g	8g	8g	8g	8g	8g
Guar gum	0.1g	0.1g	0.1g	0.1g	0.1g	0,1g
Starter culture	1ml	1ml	1ml	1ml	1ml	1ml

Sensory evaluation

Sensory evaluation of developed vegan yoghurt samples was evaluated by using a 9- point hedonic scale with 15 untrained panelists. Product was evaluated on the basis of texture, color, taste, flavor, appearance and overall acceptability. Scores ranged from 1("dislike extremely") to (like extremely").

Physicochemical analysis

Measurement of pH and titrable acidity

According to (AOAC 2023), pH of yoghurt was measured by a using a digital pH meter. According to (AOAC 2023), titrable acidity is determined by titrating sample against 0.1N NaOH using phenolphthalein as an indicator.

Proximate analysis

Moisture content is commonly determined by hot air oven drying method according to (AOAC 2023). About 2g of sample weighed and dried in hot air oven at 105℃ until constant weight is obtained.

Carbohydrate content was determined by difference method. Percentage of fat, protein, ash, crude fiber and moisture were subtracted from 100 (FAO 2003). Protein content was commonly analyzed by Kjeldahl method using a conversion factor of 6.25 (AOAC 2023).

Fat content was obtained by Soxhlet extraction method (AOAC 2023). The sample was extracted with petroleum ether. Ash content was determined according to (AOAC 2023) by incinerating the sample in a muffle furnace at 550℃.

Crude fiber was determined by acid and alkali digestion method described by Chopra and Kanwar (1978). Energy was calculated using Atwater factors: protein and carbohydrateat4 Kcal/g, fat at 9Kcal/g.

Potassium and calcium content

Potassium content was determined by using a flame photometry by the method of Jackson (1973) [10]. Calcium content was determined by Perklin- Elmer (1982) by using Atomic Absorption Spectrophotometer.

Shelf life and microbial analysis

The selected vegan yoghurt sample(T_3) was analyzed for shelf life and microbial quality at a temperature 4℃. Total plate count, coliform and yeast and mold were determined using microbiological methods. Sensory quality was also evaluated during storage using 9-point hedonic scale.

Results

Sensory analysis

The table 2 shows the sensory evaluation scores selected treatment(T_3) on the basis of texture, flavor, color, appearance, taste and overall acceptability's total means core ranged fromfrom6.75(T_0) to 8.81(T_3), with T_3 showing the highest sensory acceptance. The sensory characteristics increased fromT_0 to T_3 and slightly decreased in $T_4$and T_5, indicating that T_3 was the most acceptable treatment.

Table 2: Sensory evaluation of selected treatment (T_3)

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability	Total mean score
T_0	6.8	6.9	6.7	6.8	6.6	6.7	6.75
T_1	7.2	7.3	7.1	7	7.2	7.1	7.15
T_2	7.8	7.7	7.9	7.8	7.7	7.8	7.78
T_3	8.8	8.9	8.7	8.8	8.9	8.8	8.81
T_4	7.5	7.4	7.3	7.5	7.4	7.4	7.41
T_5	6.9	7	6.8	6.9	6.7	6.9	6.86

Physicochemical analysis

The physicochemical composition changes of selected vegan yoghurt (T_3) was given in the Table 2. The product had a pH of.4, titrable acidity of 0.87%lactic acid and moisture content of 72.315%.The nutritional composition included carbohydrate((19.24 g/100 g), protein (3.16 g/100 g), fat (1.71 g/100 g), crude fibre (2.82 g/100 g), ash (0.76 g/100 g), and energy value of 104.99 kcal. Calcium and potassium contents were 31.26 mg/100 g and 182.50 mg/100 g, respectively.

Table 3: Physicochemical analysis of selected treatment (T_3)

Parameters	Composition (per 100g)
pH	4.4
Titrable acidity (%)	0.87% lactic acid
Moisture content (%)	72.31%
Protein (%)	3.16%
Carbohydrate (%)	19.24%
Fat (%)	1.71%

Crude fiber (%)	2.82%
Ash content (%)	0.76%
Calcium (mg/100g)	31.26mg/100g
Potassium (mg/100g)	182.mg/100g
Energy (Kcal)	104.99Kcal

Shelf-life study

The sensory scores and shelf-life data of selected vegan yoghurt(T_3) during refrigerated storage was given in the Table 4. The total mean score gradually decreased from8.82 at0 days to7.70 at 15 days.

Table 4: Shelf-life study of selected treatment (T_3)

Treatment	Sensory Attributes	0 days	5 days	10 days	15 days
T_3	Appearance	8.8	8.5	8.1	7.8
	Colour	8.9	8.6	8.2	7.9
	Taste	8.9	8.5	8	7.6
	Texture	8.8	8.4	8	7.7
	Flavour	8.7	8.3	7.9	7.5
	Overall acceptability	8.8	8.4	8	7.7
	Total mean score	8.82	8.45	8.03	7.7

Microbial analysis

The microbial analysis of selected vegan yoghurt treatment (T_3) during storage was given in the Table 5. The total plate count increased gradually from2.5×10^6 CFU/g to 5.4×10^6 CFU/g during 15days of storage. Yeast, mold and coliform counts were not detected initially but showed slight growth at later days of storage.

Table 5: Microbial analysis of selected treatment

Treatment	Storage period	Total Plate Count (TPC) (CFU/g)	Yeast and mould Count (CFU/g)	Coliform Count (CFU/g)
T_3	0^{th} day	2.5×10^6	Not detected	Not detected
	5^{th} day	3.8×10^6	Not detected	Not detected
	10^{th} day	4.7×10^6	8	Not detected
	15^{th} day	5.4×10^6	14	1

Discussion

The different formulation of soymilk and raw banana flour had significant effect on sensory evaluation and acceptability of developed vegan yoghurt. Among all treatments T_3 (85ml soymilk and 15g raw banana flour) showed the highest sensory acceptability with superior scores for appearance, taste, color, flavor, texture and overall acceptability. The improved sensory quality ofT_3 was due to optimum incorporation of soy milk and raw banana flour, which improve the smoothness, viscosity and mouthfeel. Similar findings were reported by (Vicent, 2024) [21] which corporation of banana flour improve the texture and general acceptability of soy based yoghurt.

The sensory scores increased gradually from T_0 to T_3 and declined slightly in T_4 and T_5, indicating the excessive use of banana flour may affect the texture and overall acceptability. Similar observations were reported by (Agustin *et al.*, 2024) [2], who found that higher banana concentration could reduce sensory acceptability due to slight graininess and its consistency.

The physiochemical analysis of the selected treatment (T_3) showed desirable nutritional quality with moisture content of 72.31%, pH 4.4, and titratable acidity of 0.87% lactic acid. The product contained carbohydrate (19.24 g/100 g), protein (3.16 g/100 g), fat (1.71 g/100 g), crude fibre (2.82 g/100 g), ash (0.76 g/100 g), energy (104.99Kcal) calcium (31.26mg/100g) and potassium 182.50mg/100g, it indicating the incorporation of raw banana flour increase the nutritional composition of soy based vegan yoghurt. Similar observations were reported by (Jayalalitha, 2015) and (Gupta *et al.*, 2022) [9, 11].

The microbial analysis during storage shows a gradual increase in total plate count from 2.5×10^6 CFU/g to 5.4×10^6 CFU/g over 15 days of refrigerated storage. Coliform, yeast and Mold have no initial growth on the storage days but showed slight growth of yeast and Mold were observed after 10 days. Similar changes in sensory and microbial quality during storage of plant based yoghurt product were observed by (Arukwe *et al.*, 2026) [5].

Conclusion

From the results and discussion of the present study, the incorporation of raw banana flour improved the sensory, physical, nutritional and microbial quality of soy milk based vegan yoghurt. Among all treatments T_3(85ml soymilk& 15g banana flour) showed the higher sensory acceptability and desired nutritional composition. Also remained microbiologically acceptable during refrigerated storage days. There for the study suggest that soy milk and raw banana flour incorporated can be utilized for the development of vegan yoghurt with good nutritional and storage stability.

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