

ORIGINAL RESEARCH ARTICLE

Development and Comprehensive Quality Characterization of Soybean-Coconut Composite Milk Yoghurt as a Functional Dairy Alternative

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ABSTRACT

This study investigated the proximate composition, mineral content, physicochemical characteristics, bacterial viability, and sensory attributes of soybean-coconut composite milk yoghurts formulated in different ratios (100:0, 75:25, 50:50, 25:75, and 0:100) of soybean to coconut milk, codename SCMY01 to SCMY05. The moisture content of approximately 86% with no significant difference among the samples, dominates the proximate results. A gradual reduction in protein (3.79–1.21%) was observed with higher coconut substitution. Sample SCMY05 had the highest fat content (6.48%). Ash, crude fibre, and carbohydrate were highest in sample SCMY01 (0.71, 0.41, and 7.11%). Mineral analysis revealed that soybean-dominant samples were richer in calcium, sodium, magnesium, iron, and zinc, whereas potassium levels were significantly higher in coconut-rich formulations (202.25 to 220.10mg/100g). Physicochemical assessment revealed a decline in pH (4.35–3.90) and an increase in titratable acidity (0.70–1.05%) as the coconut content increased, accompanied by a substantial improvement in total solids (12.00–21.25%). No significant difference was observed in total soluble solid results. Microbial counts ranged from (7.2–8.5 log₁₀ cfu/ml), with soybean-based samples supporting relatively higher microbial growth. Sensory analysis revealed that 100% coconut milk yoghurt was most favoured in terms of colour, taste, flavour, and overall acceptability, whereas soybean-based yoghurt, despite being nutritionally superior, was less accepted due to its pronounced beany flavour. This study highlight soybean-coconut composite yoghurt as a sustainable and health-promoting alternative to dairy yoghurt, with prospects for broader consumer acceptance and commercialization.

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1. INTRODUCTION

Yoghurt, traditionally produced by bacterial fermentation of cow's milk with *Lactobacillus bulgaricus* and *Streptococcus thermophiles*, is a widely consumed fermented dairy product valued for its nutritional composition, digestibility, and functional properties. Fermentation not only enhances flavour and texture, but also improves gut health, suppresses pathogens, and facilitates nutrient absorption (Akwasi et al., 2023). Despite these advantages, dairy yoghurt consumption is limited by the cost of animal milk, lactose intolerance, milk protein allergies, cholesterol-related concerns, and the environmental impact of dairy farming (Granato et al., 2010; Sethi et al., 2016)

The awareness of plant-based alternatives is increasing, with soybean (*Glycine max*) and coconut (*Cocos nucifera*) milks emerging as substitutes. While soybean milk is protein-rich and contains isoflavones with established cardiovascular and anticancer benefits, and suitable for fermentation (Akwasi et al., 2023), coconut milk, on the other hand, contributes a creamy texture, distinct flavour, and medium-chain triglycerides with antimicrobial effects (Adelodun and Abiodun, 2012; Akwasi et al., 2023). Soybean-based yoghurts often carry a beany aftertaste (Abd El-Gawad et al., 2015). Coconut milk lacks sufficient protein for adequate gel structure; therefore, combining the two plant milks could balance these limitations, enhance nutritional and sensory quality, and promote sustainable use of local crops.

Previous studies on plant-based yoghurt-like samples compete favorably with dairy yoghurt in terms of nutritional and sensory acceptability (Akwasi et al., 2023; Noman et al., 2025). However, evaluation of soybean-coconut composite milk yoghurts remains limited, particularly in terms of physicochemical, microbiological, and sensory attributes. This study, therefore, seeks to fill this gap by contributing to the development of nutritious, palatable, and sustainable plant-based yoghurt.

2. MATERIALS AND METHODS

2.1 Source of raw materials

Soybean seeds and Coconut were purchased from Jatu market, Etsako West Local Government Area of Edo State, Nigeria. Varietal identification and authentication were conducted at the Department of Crop Production Management, Auchi Polytechnic, Auchi (Nigeria).

2.2 Soybean milk extraction

One kilogram of clean, moth- and mildew-free soybean grains was manually sorted to remove impurities and soaked in 3 L of warm distilled water for 24 h, with water replaced every 8 h to reduce the beany flavour. The soaked beans

were drained and treated with 6 L of boiled distilled water for 5 min to inactivate lipoxygenase and residual anti-nutritional factors. The beans were dehulled, rinsed, and ground into a paste, after which 3 L of water was added to form a slurry. Soy milk was extracted by filtration through a clean sieve cloth, while the residue was dried and used as animal feed. The extracted milk was pasteurized by boiling at 100 °C for 15 min to eliminate trypsin inhibitors, lectins, and other anti-nutritional factors (Liu, 1997), then cooled to 42–45 °C with surface scum removed (Akwasi et al., 2023).

2.3 Coconut milk extraction

Coconut milk was prepared according to Adelu et al. (2024) with slight modification. Six mature coconuts were cracked, and the coconut water was collected in a clean container with a lid and refrigerated at 4 °C. The kernel was separated from the endosperm, and the endosperm was then washed, weighed, and 1000g was grated before blending with the reserved coconut water and 1 L of distilled water to ease extraction. The slurry was further diluted with 1.5 L of distilled water and filtered through a double-layered muslin cloth. The filtrate (coconut milk) was pasteurized at 90 °C for 30 min, cooled to 43 °C, held for 12 h to allow physicochemical equilibration and condition milk for fermentation temperature, and finally cooled to room temperature (29 ± 2 °C).

2.4 Sample formulation

Soybean-coconut composite milk yoghurt was formulated into five different samples of varying soybean to coconut ratios as shown in **Table 1**.

Table 1. Composite milk Formulation ratio

Samples	Coconut milk (%)	Soybean milk (%)
SCMY01	0	100
SCMY02	25	75
SCMY03	50	50
SCMY04	75	25
SCMY05	100	0

2.5 Preparation and Inoculation of Soybean-coconut milk yoghurt

Soybean-coconut milk yoghurt was produced following the procedure of Adelodun and Abiodun (2012). The composite milk samples were pasteurized at 85 °C for 30 min, rapidly cooled to 45 °C, and inoculated with 2% (v/v) mixed starter culture of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (1:1). The inoculated samples were incubated at 40 - 45 °C for 24 h to obtain yoghurt, after which stabilizer (0.15% xanthan gum and 1% cassava starch), and sugar (7%), were incorporated.

2.6 Physicochemical Quality Parameters Analysis

AOAC (2019) analytical procedures were adapted with minor modifications for the physicochemical analysis. The pH of the yoghurt samples was measured directly using a pH 7 and pH 4 buffer calibrated digital pH meter (Mettler Toledo, Greifensee, Switzerland) at 20°C. Total solids were determined by oven-drying at 105 °C until constant weight was achieved. A portable digital refractometer was used to measure total soluble solids (TSS), with results expressed in °Brix (Ranganna, 1986). For titratable acidity (TA), 10 mL of yoghurt was titrated against 0.1 N NaOH using phenolphthalein as an indicator, and the outcome was expressed as lactic acid percentage (% lactic acid w/v) (Pearson, 1976).

2.7 Proximate Analysis of the yoghurt samples

The proximate composition of the yoghurt samples was analyzed according to the AOAC (2005) standard procedures. Moisture content was measured by oven-drying at 105 °C to a constant weight, while ash content was determined by incinerating the samples in a muffle furnace at 550 °C until a whitish residue was obtained. Crude protein was estimated using the Kjeldahl method with a nitrogen-to-protein conversion factor of 6.25. Crude fat was quantified through Soxhlet extraction with petroleum ether as the solvent. Crude fibre was assessed by sequential acid-alkali digestion. Carbohydrate content was then calculated by difference as: 100 – (% moisture + % protein + % fat + % ash + % fibre) (Pearson, 1976).

2.8 Mineral profile of yoghurt samples

The mineral contents (Ca, K, Na, Mg, Fe, and Zn) were analyzed using AOAC (2005) standard methods. Samples were dry-ashed in a muffle furnace at 550 °C, and the resulting ash was dissolved in dilute hydrochloric acid. Calcium, magnesium, iron, and zinc concentrations were measured using atomic absorption spectrophotometry (AAS) model AELABAA-7050, whereas sodium and potassium were determined with a flame photometer (model LEP-A11). The results were reported as milligrams per 100 grams of sample.

2.9 Microbial Load Count (MLC)

Microbial load counts of the yoghurt samples was conducted using standard aseptic techniques (Akwasiam *et al.*, 2023). Ten millilitres of each sample were homogenized in 90 ml of peptonewater to prepare a stock suspension, which was then subjected to 10-fold serial dilutions. From the appropriate dilutions, 0.1 ml aliquots were inoculated onto nutrient agar and potato dextrose agar plates. Incubation was carried out at 37 ± 2 °C for 18–24 h (bacterial count) and 28 ± 2 °C for 48 – 72 h (fungi), colony counts were recorded and expressed as colony-forming units per millilitre (cfu/ml)

2.10 Sensory evaluation

The yoghurt samples were maintained at 6 ± 2 °C until evaluation. Sensory assessment was conducted by a 20-member panel comprising regular yoghurt consumers from the Department of Food Technology, Auchi Polytechnic. Panelists evaluated flavour, colour, taste, aftertaste, and overall acceptability according to Adelodun and Abiodun, (2012) with slight modification using a 5-point hedonic scale where 1 is dislike extremely to 5 is like extremely.

2.11 Statistical Analysis

Data were expressed as mean values, and differences among treatments were analyzed using analysis of variance (ANOVA). Statistical significance was considered at $p < 0.05$. Where significant differences occurred, means were separated using Duncan's Multiple Range Test (DMRT) with SPSS software (Version 21.0, IBM Corp., Armonk, NY, USA).

3. RESULTS AND DISCUSSION

3.1 Proximate analysis

The results of proximate composition of the formulated yoghurts is presented in **Table 2**. Moisture content which was most abundant as expected ranged between 85.95 and 86.00%, with no significant difference ($p > 0.05$) among the samples. This consistency reflects the high-water content typical of yoghurt and aligns with values reported for plant-based yoghurts (91.76 – 86.71%) by Olubamiwa and Abiodun, (2008). A general decrease with increasing coconut substitution, from 3.79% in SCMY01 (100% soya) to 1.21% in SCMY05 (100% coconut) was observed in the protein analysis. This trend could be attributable to the inherently higher protein content of soya milk compared to coconut milk (Chalupa-Krebszda, 2018; Noman *et al.*, 2025). Conversely, Crude fat content increased significantly ($p < 0.05$) with higher proportions of coconut milk, ranging from 2.02% in SCMY01 (100% soya) to 6.48% in SCMY05 (100% coconut). This could be attributed to fatty acid-rich nature of coconut milk, particularly its medium-chain triglycerides, which contribute to creaminess and mouthfeel (Marina *et al.*, 2009). Comparable fat enrichment in coconut-fortified yoghurts was also reported by Craigi *et al.* (2019). Ash content declined slightly from 0.71% in SCMY01 to 0.61% in SCMY05. Though the variation was modest, the trend suggests that soya milk contributed more minerals than coconut milk. This observation is corroborated earlier reports by Sethi *et al.* (2016), who observed higher ash values in soy-dominant plant-based blends. Crude fibre content was generally low (0.41–0.21%) and declined with increasing coconut substitution, this could be due to processing and fermentation losses (Noman *et al.*, 2025). Carbohydrate content, calculated by difference, decreased from 7.11% in SCMY01 to 5.53% in SCMY05. Similar findings was reported by Grasso *et al.* (2020).

Table 2. Proximate composition of yoghurt samples (%)

Samples	Moisture	Protein	Crude fat	Ash	Crude Fibre	Carbohydrate (by diff.)
SCMY01	85.95 ^a ±0.07	3.79 ^a ±0.01	2.02 ^e ±0.02	0.71 ^a ±0.01	0.41 ^a ±0.01	7.11 ^a ±0.01
SCMY02	86.00 ^a ±0.01	3.16 ^b ±0.01	3.13 ^d ±0.01	0.69 ^a ±0.01	0.36 ^b ±0.01	6.71 ^b ±0.02
SCMY03	85.99 ^a ±0.01	2.51 ^c ±0.01	4.26 ^c ±0.01	0.66 ^b ±0.01	0.31 ^c ±0.02	6.31 ^c ±0.00
SCMY04	85.99 ^a ±0.03	1.86 ^d ±0.01	5.39 ^b ±0.01	0.62 ^c ±0.01	0.26 ^d ±0.01	5.91 ^d ±0.01
SCMY05	86.00 ^a ±0.01	1.21 ^e ±0.01	6.48 ^a ±0.04	0.61 ^c ±0.01	0.21 ^e ±0.02	5.53 ^e ±0.02

Values are means ± standard deviation. (n = triplicate). Different superscripts within a column indicate significant differences (p < 0.05).

Note: SCMY001 = 100% soybean milk
 SCMY002 = 25% coconut milk and 75% soybean milk
 SCMY003 = 50% each
 SCMY004 = 75% coconut milk and 25% soybean milk
 SCMY005 = 100% coconut milk

3.2 Minerals analysis

The mineral composition of the formulated yoghurts (**Table 3**) varied significantly (p<0.05). Calcium, sodium, magnesium, iron, and zinc levels were highest in the 100% soybean-based formulation (SCMY01) (25.15, 15.10, 25.01, 1.00, and 0.31% respectively) and declined progressively with increasing coconut substitution. In contrast, potassium content increased with greater coconut inclusion, ranging from 150.15 mg/100 g in SCMY01 to 220.10 mg/100 g in SCMY05. This pattern reflects the

intrinsic nutritional composition of the base ingredients (Smith *et al.*, 2022). Soybeans are richer in calcium, magnesium, and trace elements such as zinc and iron (Abd El-Gawad *et al.* 2015), whereas coconut is particularly abundant in potassium (Marina *et al.*, 2009; Messina and Messina, 2010). Coconut-rich formulations higher potassium content is beneficial for cardiovascular health and blood pressure regulation, while the declining sodium content with higher coconut substitution also presents an advantage for hypertensive individuals, as lower sodium-to-potassium ratios are associated with reduced cardiovascular risk (Sethi *et al.*, 2016).

Table 3. Mineral composition of Soy-Coconut milk yoghurt (mg/100g)

Samples	Ca	K	Na	Mg	Fe	Zn
SCMY01	25.15 ^a ±0.21	150.15 ^e ±0.21	15.10 ^a ±0.14	25.01 ^a ±0.01	1.00 ^a ±0.01	0.31 ^a ±0.01
SCMY02	22.78 ^b ±0.04	167.60 ^d ±0.14	14.26 ^b ±0.01	22.60 ^b ±0.14	0.87 ^b ±0.01	0.28 ^b ±0.01
SCMY03	20.51 ^c ±0.01	185.15 ^c ±0.21	13.52 ^c ±0.02	20.10 ^c ±0.14	0.76 ^c ±0.01	0.26 ^c ±0.01
SCMY04	18.26 ^d ±0.01	202.25 ^b ±0.35	12.78 ^d ±0.04	17.51 ^d ±0.01	0.63 ^d ±0.01	0.24 ^d ±0.01
SCMY05	16.11 ^e ±0.15	220.10 ^a ±0.14	12.01 ^e ±0.01	15.10 ^e ±0.14	0.51 ^e ±0.01	0.20 ^e ±0.01

Values are means ± standard deviation. (n = triplicate). Different superscripts within a column indicate significant differences (p < 0.05).

Note: SCMY001 = 100% soybean milk
 SCMY002 = 25% coconut milk and 75% soybean milk
 SCMY003 = 50% each
 SCMY004 = 75% coconut milk and 25% soybean milk
 SCMY005 = 100% coconut milk

3.4 Physicochemical analysis

The physicochemical evaluation of soybean–coconut milk composite yoghurts revealed distinct trends across formulations, driven by the relative ratios of the two plant-based substrates (**Table 4**). pH values declined from 4.35 in the sample (SCMY01) to 3.90 in (SCMY05), accompanied by a progressive increase in titratable acidity (from 0.70 to 1.05%). This indicates more extensive lactic fermentation in

coconut-rich blends, which could be attributed to higher fermentable carbohydrate content of coconut due to sugar added. These results corroborate earlier findings that coconut-based yoghurts undergo faster acidification compared to soybean-based counterparts (Dey *et al.*, 2022; Marlapati *et al.*, 2024). While moderate acidity enhances microbial safety and shelf stability, excessive sourness may reduce consumer acceptability if not balanced with appropriate formulation strategies (Granato *et al.*, 2010). Total soluble solids were relatively stable across

formulations (2.25, 2.35, 1.90, 2.25 and 2.40^oBrix, respectively), suggesting limited impact of blending on sugar content. In contrast, total solids rose significantly with an increase in coconut milk concentration, ranging from 12.00% in SCMY01 to 21.25% in SCMY05. This trend reflects the inherently higher dry matter of coconut milk (Marina *et al.*, 2009; Sethi *et al.*, 2016), which contributes to improved viscosity, mouthfeel, and creaminess. Similar

enhancements in texture and palatability was reported in recent studies on hybrid plant-based yoghurts (Noman *et al.*, 2025). In general, soy-based formulations provide higher protein density, calcium, and isoflavones for muscle health and metabolic regulation (Messina and Messina, 2010), while coconut-rich formulations deliver higher potassium and total solids, offering cardiovascular benefits and greater satiety, albeit with higher energy density

Table 4. Physicochemical Properties of Soya and Coconut Composite Milk Yoghurt

Samples	pH	Titrateable acidity (TTA) (%)	Total soluble solids (^o Brix)	Total solid content (%)
SCMY01	4.35 ^a ±0.01	0.70 ^b ±0.07	2.25 ^a ±0.35	12.00 ^d ±1.41
SCMY02	4.05 ^b ±0.01	0.90 ^a ±0.07	2.35 ^a ±0.35	14.88 ^c ±0.18
SCMY03	3.99 ^b ±0.02	0.95 ^a ±0.07	1.90 ^a ±0.14	16.33 ^c ±0.25
SCMY04	3.93 ^b ±0.01	1.00 ^a ±0.07	2.25 ^a ±0.07	18.63 ^b ±0.53
SCMY05	3.90 ^b ±0.01	1.05 ^a ±0.07	2.40 ^a ±0.14	21.25 ^a ±0.35

Values are means ± standard deviation. (n = triplicate). Different superscripts within a column indicate significant differences (p < 0.05).

Note: SCMY01 = 100% soybean milk
 SCMY02 = 25% coconut milk and 75% soybean milk
 SCMY03 = 50% each
 SCMY04 = 75% coconut milk and 25% soybean milk
 SCMY05 = 100% coconut milk

3.5 Microbial Load Count (TVC)

The bacterial load count of the soybean–coconut composite milk yoghurts ranged from 7.2 to 8.5 log₁₀ cfu/ml, indicating substantial bacterial viability across all formulations (**Table 5**). The 100% soybean-based sample (SCMY01) exhibited the highest viability (8.5 log₁₀ cfu/ml), while the 100% coconut-based sample (SCMY05) recorded the lowest (7.2 log₁₀ cfu/ml). Intermediate blends (SCMY02–SCMY04) demonstrated counts between 7.6 and 8.2 log₁₀ cfu/ml, reflecting a progressive decline in microbial proliferation as coconut proportion increased. There was no growth on the potato dextrose agar plate. These results suggest that soybean milk provided a more favorable growth medium for the starter culture, which could be due to its higher protein, mineral, and nitrogen content. Whereas, coconut milk, despite contributing desirable sensory and lipid characteristics, was comparatively less supportive of microbial growth, possibly due to its medium-chain fatty acids with mild antimicrobial effects (Sindelar *et al.*, 2023). Haiping Li *et al.*, (2012) reported (9.00 cfu/ml) in fermented soymilk produced with single culture of six probiotics strains, a level consistent with substantial bacterial proliferation in plant-based yoghurt systems. The decline in counts with increasing coconut substitution underscores the need for careful formulation to maintain microbial viability throughout the soybean-coconut milk yoghurt shelf life.

Table 5. Bacteria Count analysis of yoghurt samples

Sample (code)	Estimated (log ₁₀ cfu/ml)
SCMY01	8.5 ± 0.02 ^a
SCMY02	8.2 ± 0.01 ^b
SCMY03	8.0 ± 0.01 ^b
SCMY04	7.6 ± 0.01 ^c
SCMY05	7.2 ± 0.02 ^d

Values are means ± standard deviation (n = triplicate). Different superscripts within a column indicate significant differences (p < 0.05).

Note: SCMY01 = 100% soya milk
 SCMY02 = 75% soya milk and 25% coconut milk
 SCMY03 = 50% each
 SCMY04 = 75% coconut milk and 25% soyabean milk
 SCMY05 = 100% coconut milk

3.6 Sensory analysis

The sensory attributes of the soybeans–coconut composite milk yoghurts as displayed in **Table 6** varied significantly (p < 0.05) across formulations. Overall acceptability scores ranged from 2.20 in the soybeans-only sample (SCMY01) to 4.50 in the coconut-only sample (SCMY05), while colour ratings increased progressively with coconut substitution, with SCMY05 (4.70) rated highest, reflecting the appealing creamy-white appearance imparted by coconut milk

compared to the more opaque, duller tone of soy-based products. Taste and flavour were also markedly rated higher in coconut-rich formulations, with SCMY05 receiving the highest scores (4.60 each), while SCMY01 was least preferred (1.90). Aftertaste followed a similar trend, with coconut-dominant blends (SCMY04 and SCMY05) scoring higher than soybean dominant formulations. Soy milk, while nutritionally superior, has been associated with lower consumer acceptability due to its inherent beany taste and

less appealing colour (Messina and Messina, 2010; Abd EI-Gawad *et al.* 2015). Importantly, the 50:50 blend (SCMY03) achieved intermediate scores, suggesting that balanced formulations can mitigate soy's sensory limitations while retaining its nutritional value. The result of the sensory evaluation in the present study has shown that soybean-coconut yoghurt could become more acceptable when appropriate quantity of coconut milk is added to yoghurt premixes.

Table 6. Sensory Evaluation of Soya and Coconut Composite Milk Yoghurt

Samples	Colour	Taste	Flavour	Aftertaste	Overall acceptability
SCMY01	2.90 ^b ±1.60	2.00 ^b ±0.94	1.90 ^c ±0.99	2.70 ^b ±1.16	2.20 ^c ±1.03
SCMY02	3.20 ^b ±1.55	2.60 ^b ±1.35	2.70 ^{bc} ±0.95	3.60 ^{ab} ±1.08	2.70 ^{bc} ±0.95
SCMY03	3.80 ^{ab} ±1.03	2.80 ^b ±1.23	3.40 ^b ±1.17	3.20 ^{ab} ±1.32	2.70 ^{bc} ±0.95
SCMY04	4.40 ^a ±0.84	3.10 ^b ±1.37	2.50 ^{bc} ±1.35	3.50 ^{ab} ±1.43	3.40 ^b ±0.70
SCMY05	4.70 ^a ±0.48	4.60 ^a ±0.52	4.60 ^a ±0.52	4.30 ^a ±0.82	4.50 ^a ±0.53

Values are means ± standard deviation (n = triplicate). Different superscripts within a column indicate significant differences (p < 0.05).

Note: SCMY01 = 100% soybean milk
SCMY02 = 75% soybean milk and 25% coconut milk
SCMY03 = 50% each
SCMY04 = 75% coconut milk and 25% soybean milk
SCMY05 = 100% coconut milk

CONCLUSION

The findings of this study indicate that soybean-coconut composite milk yoghurts possess complementary nutritional and functional properties, with the 100% coconut milk (SCMY05) recorded the highest sensory attributes preference. In general, the results indicate that appropriately balanced formulations can reduce the sensory limitations associated with soybean milk while maintaining nutritional quality, adequate viable bacterial counts, and improved consumer acceptability.

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CONFLICT OF INTEREST

Authors declare that no conflicts of interest influenced the report in this manuscript.

ETHICS STATEMENT

Not applicable. But, consents of all participants in the sensory analysis were obtained.

DATA AVAILABILITY

The data supporting the findings of this study are available upon request from the corresponding author.

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