Development and Quality Evaluation of Coconut Milk Products Enriched with Flaxseed Powder

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Abstract. Coconut milk is a lactose-free plant-based milk alternative widely consumed in Indonesia. This study developed coconut milk enriched with flaxseed powder to improve its nutritional and functional properties. Four formulations were prepared: control (0% flaxseed), A (3%), B (5%), and C (7%). Samples were analysed for proximate composition, physical properties (pH, colour, viscosity, total dissolved solids), antioxidant activity, total phenolic content, and sensory acceptance. Flaxseed addition significantly increased protein, fat, carbohydrate, viscosity, brightness (L*), yellowness (b*), ΔE, antioxidant activity, and total phenolics, while pH and redness (a*) decreased. Moisture and ash content were not significantly affected. The highest antioxidant activity (72.92%) and phenolic content (147.64 mg/L) were observed in Formula C. Sensory evaluation indicated that Formula A achieved the highest scores for overall liking, taste, aroma, and visual appeal, and was ranked most preferred (mean ranking 1.58). Higher flaxseed levels reduced acceptability due to increased bitterness and excessive thickness. Overall, incorporating 3% flaxseed powder into coconut milk produced a nutritionally enhanced beverage with optimal sensory acceptance, offering a promising lactose-free functional drink.

1 Introduction

Cow's milk is widely consumed worldwide, including in Indonesia, because it is a rich source of essential nutrients such as fat, protein, and carbohydrates, and calcium [1]. Nevertheless, persons who suffer from lactose intolerance as a result of a lack of lactase enzyme are restricted in their use of this substance. It is estimated that 21.3% of children aged 3–5 years, 57.8% of those aged 6–11 years, and 73% of those aged 12–14 years in Indonesia are affected by lactose intolerance [2]. This frequency of lactose intolerance increases with age in Indonesia.

Almond milk, soy milk, coconut milk, and rice milk are some examples of plant-based milk replacements that have been developed by the food industry in response to this problem. These products are gaining popularity because they provide needed macronutrients, such as carbohydrates, lipids, and proteins, as well as essential micronutrients, such as minerals and vitamins [3]. One of the most plentiful and nutrient-dense agro-industrial crops in Indonesia is coconut (*Cocos nucifera*). Rich in medium chain fatty acids, fiber and minerals, coconut

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production reached 2.86 million tons [4]. It is commonly processed into coconut milk, which is a white liquid that is produced from shredded coconut meat.

An abundance of oil, fibre, and bioactive compounds with antioxidant qualities are expected to be contained in flaxseed (*Linum usitatissimum*). These bioactive compounds include ALA, tocopherols, phenolics, lignans, and flavonoids. A high fibre content (60–80%) also contributes to the regulation of blood sugar levels. These characteristics make flaxseed an intriguing candidate for use as a functional food ingredient [5]. For the purpose of developing a more nutritious milk alternative, the aim of this study was to make fortified-coconut milk with flaxseed powder.

2 Materials and methods

2.1 Preparation of coconut milk fortified with flaxseed powder

Grated mature coconut was purchased from traditional market. Flaxseed powder (Organic Paradise, Indonesia) was purchased from online marketplace. Grated coconut and flaxseed powder were combined in four formulations: 0% (Control), 3% (Formula A), 5% (Formula B), and 7% (Formula C) as shown in Table 1. The mixture was then added with 1000 mL of water. The mixture was supplemented with 0.015% xanthan gum, 0.015% sodium benzoate, 5% fructose syrup, and 2% (w/v) Himalayan salt solution. It was blended until fully homogenized, then filtered through cheesecloth. The retained coconut pulp and flaxseed residue were squeezed to recover liquid, which was subsequently filtered through a 200-mesh nylon filter to obtain a smooth, clean coconut flax milk. The filtrate was pasteurized at 75–79 °C for 15 minutes, with the temperature monitored using a thermometer. The pasteurized product was stored in airtight containers for further analysis.

Table 1. Coconut milk formulation

Ingredients	Formulation (%)			
	Control	A	B	C
Grated coconut	11	8	6	4
Flaxseed powder	0	3	5	7
Water	81.98	81.98	81.98	81.98
Xanthan gum	0.01	0.01	0.01	0.01
Sodium benzoate	0.01	0.01	0.01	0.01
Fructose syrup	5	5	5	5
Himalayan salt solution	2	2	2	2

2.2 Physicochemical analyses

Physicochemical properties of coconut flax milk were assessed through proximate composition, physical characteristics, antioxidant, and total phenolic analysis. Proximate composition. Moisture, ash, fat, protein, carbohydrate, and crude fibre were determined according to AOAC method [6]. Moisture and crude fibre contents were measured using the gravimetric method, protein by the Kjeldahl method, fat by Soxhlet extraction, and carbohydrate content was calculated using by difference method. pH was measured using a

calibrated pH meter. Color parameters (L*, a*, b*, and ΔE) were obtained using a chromameter [7]. Viscosity was measured with a Brookfield Viscometer (DVELV). Total dissolved solids (TDS) were determined using a refractometer. Antioxidant activity was assessed using the DPPH radical scavenging method and total phenolic content using Folin-Ciocalteau method [8]. A 0.1 mM DPPH methanolic solution was reacted with 1 g of sample dissolved in 10 mL methanol, incubated in the dark for 30 minutes, and measured at 517 nm with a microplate spectrophotometer. Total phenolic content (TPC) was quantified using the Folin–Ciocalteu method, with results expressed as mg gallic acid equivalents (GAE) per liter.

2.3 Sensory analysis

Sensory evaluation was conducted with 100 untrained panelists. A 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) was used to assess overall liking, taste, aroma, thickness, and visual attributes. Samples (Control, Formula A, Formula B, Formula C) were served in random three-digit coded containers to avoid bias. A ranking test, adapted from was then performed to determine preference order, ranking from 1st (most preferred) to 4th (least preferred). Sample codes in the ranking test were different from those in the hedonic test to minimize bias.

2.4 Statistical analysis

Results were expressed as mean ± standard deviation. Proximate, physical, antioxidant, and hedonic test data were analysed using one-way analysis of variance (ANOVA) at a 5% significance level ($p<0.05$), followed by Tukey's HSD test for multiple comparisons. Ranking test results, being ordinal data, were analysed using the Friedman test, followed by the Wilcoxon signed-rank test for pairwise comparisons, as recommended for non-parametric sensory data.

3 Results and discussion

3.1 Physicochemical characteristics of coconut milk enriched with flaxseed powder

The data in Table 2 shows the proximate analysis results of the coconut milk.

Table 2. Physicochemical characteristics of coconut milk enriched with flaxseed powder

Parameters	**Control**	**A**	**B**	**C**
Moisture (%)	88.33 ± 3.32^{a}	87.33 ± 2.69^{a}	86.47 ± 2.62^{a}	85.87 ± 2.62^{a}
Ash (%)	0.30 ± 0.02^{a}	0.43 ± 0.11^{a}	0.49 ± 0.10^{a}	0.51 ± 0.15^{a}
Protein (%)	0.45 ± 0.12^{a}	0.98 ± 0.22^{b}	1.14 ± 0.24^{bc}	1.49 ± 0.33^{c}
Fat (%)	2.06 ± 0.01^{a}	3.22 ± 0.03^{b}	3.18 ± 0.04^{b}	3.47 ± 0.06^{c}
Carbohydrate (%)	3.58 ± 0.06^{a}	3.86 ± 0.31^{ab}	4.60 ± 0.06^{bc}	4.76 ± 0.03^{c}
Crude fiber (%)	5.13 ± 0.19^{c}	2.57 ± 0.22^{a}	3.72 ± 0.03^{b}	4.11 ± 0.13^{b}

Parameters	**Control**	**A**	**B**	**C**
pH	6.48 ± 0.01^{a}	6.03 ± 0.06^{b}	5.97 ± 0.04^{b}	6.05 ± 0.03^{b}
L*	63.67 ± 1.42^{a}	60.20 ± 3.46^{a}	67.49 ± 1.40^{b}	69.41 ± 2.42^{b}
a*	-0.36 ± 0.23^{a}	-1.88 ± 0.14^{b}	-2.13 ± 0.19^{c}	-1.89 ± 0.31^{b}
b*	-1.75 ± 0.15^{a}	5.75 ± 0.23^{b}	10.48 ± 0.79^{c}	13.71 ± 0.44^{d}
ΔE	0.00 ± 0.00^{a}	7.94 ± 0.37^{b}	12.98 ± 1.00^{c}	16.59 ± 0.43^{d}
Viscosity (cPs)	9.02 ± 0.07^{a}	13.78 ± 0.03^{b}	28.79 ± 0.03^{c}	59.72 ± 0.03^{d}
Total dissolved solids (%)	4.89 ± 0.29^{a}	5.63 ± 0.15^{b}	6.17 ± 0.08^{c}	6.65 ± 0.11^{d}
Antioxidant activity (%)	13.17 ± 0.98^{a}	61.66 ± 3.56^{b}	66.19 ± 5.87^{b}	72.92 ± 5.02^{c}
Total phenolic content (mg/L)	22.42 ± 2.97^{a}	69.30 ± 1.97^{b}	108.57 ± 2.48^{c}	147.64 ± 3.92^{d}

Notes: different superscript letter indicates significant difference ($p<0.05$)

The addition of flaxseed powder slightly reduced the moisture content of coconut milk, although the differences among samples were not statistically significant. All values complied with the moisture limits set by CODEX STAN 240, with formulas A, B, and C classified as coconut milk (≤87.3% moisture) and the control as light coconut milk (87.3–93.4% moisture). Moisture content influences key quality attributes such as viscosity, colour, texture, and flavour, with lower levels generally associated with higher viscosity. Ash content showed a gradual increase with flaxseed addition, reflecting its mineral richness, particularly in potassium, calcium, magnesium, and phosphorus—although differences were not significant. As an indicator of total mineral content, ash is important for nutrition labelling, quality evaluation, and product stability. Protein content increased significantly in proportion to flaxseed concentration, ranging from 0.45 ± 0.12% in the control to 1.49 ± 0.33% in formula C. This increase aligns with flaxseed's high protein content (18.29%) and its complete profile of essential amino acids, including alanine, histidine, lysine, leucine, isoleucine, arginine, and glycine [9]. Fat content also rose significantly, from 2.06 ± 0.01% in the control to 3.47 ± 0.06% in Formula C, consistent with the high proportion of polyunsaturated fat (73%) in flaxseed and previous findings by Siva et al. (2019) [18, 19]. Carbohydrate content followed the same trend, increasing from 3.58 ± 0.06% in the control to 4.76 ± 0.03% in Formula C, despite flaxseed containing only about 1 g carbohydrate per 100 g; similar increases have been reported [10]. Interestingly, crude fibre content was highest in the control (5.13 ± 0.19%) and lowest in formula A (2.57 ± 0.22%), likely due to the removal of the fibre-rich seed coat during dehulling and filtration. Nonetheless, fibre levels increased with higher flaxseed concentrations, reaching 3.72 ± 0.03% in Formula B and 4.11 ± 0.13% in Formula C, particularly at 5% and 7% additions [11].

The control sample exhibited the highest pH value (6.48 ± 0.01), whereas all flaxseed-enriched samples showed lower pH values, with no significant differences among them. The slight decrease in pH is attributed to active compounds in flaxseed mucilage that can interact with proteins and minerals in milk. However, increasing flaxseed concentration did not further reduce pH. All samples remained within the typical pH range for plant-based milk (6.33–6.97), which is close to neutral [12].

The incorporation of flaxseed powder affected various physicochemical and functional characteristics of coconut milk. The L* (brightness) parameter for colour increased with higher flaxseed concentrations, with Formula C (7% flaxseed) exhibiting the highest value (69.41 ± 2.42), significantly differing from the control and Formula A, while no differences were noted between the control and Formula A or between Formulas B and C. The increase in brightness was ascribed to the inherent light-yellow hue of flaxseed powder and its elevated fat content. The a* (redness) parameter diminished with the incorporation of flaxseed, with Formulas A and C exhibiting much lower values than the control and Formula B, presumably due to the fat in flaxseed attenuating red colour intensity [13]. The b* (yellowness) measure exhibited a substantial rise across all samples, indicating the yellow hue of flaxseed. The total colour difference (ΔE) increased with elevated flaxseed concentrations, ranging from 7.94 ± 0.37 in Formula A to 16.59 ± 0.43 in Formula C, attributed to the vibrant, yellowish pigment of flaxseed [13]. Viscosity significantly escalated with flaxseed concentration, rising from 9.02 ± 0.07 cPs in the control to 59.72 ± 0.03 cPs in Formula C, attributable to the mucilage and gum constituents of flaxseed, which function as water binders, gelation agents, and thickeners; fibre–protein interactions further reinforced the milk structure. Total dissolved solids (TDS) exhibited a comparable trend, increasing from 4.89 ± 0.29% in the control to 6.65 ± 0.11% in Formula C, indicating elevated levels of soluble proteins and carbohydrates. Antioxidant activity markedly increased in Formula C relative to the control, attributed to the phenolic compounds in flaxseed, particularly secoisolariciresinol diglucoside (SDG), γ-tocopherol, and sulphur-rich proteins [14]. The total phenolic content increased markedly across all formulations, peaking in Formula C (147.64 ± 3.92 mg/L), attributed to the presence of lignans, hydroxycinnamates, and phenolic acids, including ferulic and coumaric acids; and probably roasting further amplifies these compounds by enhancing seed porosity and extraction efficiency.

3.2 Sensory acceptance of products

Organoleptic evaluation was conducted with 100 untrained panellists. As shown in Table 3, overall acceptability scores revealed that formula C (7% flaxseed) had the lowest rating (4.59 ± 2.02), significantly lower than the control, formula A, and formula B, which did not differ significantly from each other.

Table 3. Sensory acceptance results of coconut milk enriched with flaxseed powder

Attributes	Samples			
	Control	A	B	C
Overall	6.09 ± 1.65^{b}	6.51 ± 1.76^{b}	5.94 ± 1.75^{b}	4.59 ± 2.02^{a}
Taste	6.03 ± 1.83^{bc}	6.53 ± 1.87^{c}	5.83 ± 1.90^{b}	5.02 ± 1.97^{a}
Aroma	6.04 ± 1.94^{ab}	6.36 ± 1.73^{b}	6.06 ± 1.74^{ab}	5.53 ± 20^{a}
Thickness	5.39 ± 2.12^{b}	6.40 ± 1.78^{c}	5.72 ± 2.03^{bc}	4.30 ± 2.50^{a}
Visual	5.30 ± 2.12^{a}	6.58 ± 1.67^{b}	6.64 ± 1.67^{b}	5.85 ± 2.14^{a}
Ranking	2.32 ± 1.16^{b}	1.58 ± 0.91^{a}	2.39 ± 0.93^{b}	3.71 ± 0.94^{c}

Notes: different superscript letter indicates significant difference ($p<0.05$)

This indicates that formula C was the least preferred sample, with the lowest scores in taste, aroma, and thickness. In the taste attribute, significant differences were observed among formulations, with formula A (6.53 ± 1.87) rated highest and formula C (5.02 ± 1.97) lowest. Higher flaxseed levels tend to impart a bitter taste, lowering consumer preference, while the nutty flavour of flaxseed mucilage can become undesirable at elevated concentrations. For aroma, formula A scored highest (6.36 ± 1.73) and formula C lowest, with high flaxseed concentrations potentially reducing aroma perception due to the hydrocolloid properties of flaxseed, which can mask volatile compounds. Thickness ratings also differed significantly, with formula A having the highest score (6.40 ± 1.78) and formula C the lowest (4.30 ± 2.50), suggesting that excessive thickness was not favoured. Regarding visual appearance, formulas A and B scored significantly higher than both the control and formula C, with higher flaxseed levels producing a darker yellow colour and decreasing visual acceptance, consistent with previous findings [15].

The ranking test result further confirmed the findings from the hedonic evaluation. Formula A (3% flaxseed) achieved the best ranking score (1.58 ± 0.91), indicating it was the most preferred sample overall, followed by the control (2.32 ± 1.16) and formula B (2.39 ± 0.93), which did not differ significantly from each other. Formula C (7% flaxseed) received the highest ranking score (3.71 ± 0.94), indicating it was the least preferred. These results suggest that moderate flaxseed addition (3%) can enhance consumer preference without compromising key sensory attributes, while higher levels (7%) may negatively impact overall acceptance.

4 Conclusion

The addition of flaxseed powder (BBR) to coconut milk improved its nutritional and functional properties by significantly increasing protein, fat, carbohydrate, and crude fiber contents, as well as enhancing the L*, b*, and total color parameters, viscosity, total dissolved solids, antioxidant activity, and total phenolic content. Conversely, higher flaxseed levels reduced the a* color parameter and pH values, while moisture and ash contents remained unaffected. Sensory evaluation indicated that coconut milk with 3% flaxseed powder (Formula A) achieved the highest overall, flavor, aroma, and thickness scores (overall: 6.51 ± 1.76) and was the most preferred formulation in the ranking test (1.58 ± 0.91). These findings suggest that 3% flaxseed powder enrichment can enhance both the nutritional value and consumer acceptability of coconut milk, whereas higher levels may negatively affect sensory attributes.

Open Data Statement. The data obtained in this study are included within the article.

Author contributions. Jason Rayadi Lawoto: conceptualization, formal analysis, investigation, data collection, writing manuscript. Andreas Romulo: editing, writing, reviewing manuscript

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