Research Article

Curcuma mangga Val. Powder Enhances Antioxidant and Nutritional Quality of Pasteurized Cow Milk

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Abstract | Milk is an animal product high in nutrients such as protein, fat, lactose, vitamins, and minerals. The addition of white turmeric (*Curcuma mangga* Val.), which contains bioactive compounds, is expected to increase the content of curcuminoids and phenolics, thereby enhancing antioxidant activity and enriching the functional value of milk. This study aims to evaluate the effect of adding white turmeric powder on the antioxidant activity, amino acid, and fatty acid profile of milk. This study used a completely randomized design with five levels of treatment (0, 1, 2, 3, and 4%) of powder. Total Plate Count (TPC) analysis was performed over six storage time points (0, 2, 4, 6, 8, and 10 days). The results showed that adding white turmeric powder starting from a concentration of 2% significantly increased the protein and ash content of milk, while the fat content reached its optimal value at the 3% treatment (31.54% db). White turmeric exhibited antibacterial activity, effectively maintaining the microbial quality of milk below the maximum threshold until day 8, with the lowest TPC value of 1.8×10^4 Colony Forming Unit (CFU)/mL observed at the 4% treatment level, which represents the peak of microbial inhibition before increasing on day 10. Sensory properties remained acceptable across these treatments. Antioxidant activity of milk using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and Ferric Reducing Antioxidant Power (FRAP) methods resulted in values of 4.14% radical scavenging activity (RSA) and 0.91 µg Ferro Ekivalen (FE)/mL, respectively. These values indicate a functional improvement compared to control milk, although they remain in the low-to-moderate range for antioxidant-enriched dairy products. The amino acid profile of the supplemented milk showed higher levels of alanine, arginine, aspartate, cysteine, glutamate, glycine, proline, and tyrosine compared to the control. The addition of white turmeric powder correlated with a shift in the lipid profile, specifically a reduction in total saturated fatty acids and a simultaneous increase in total polyunsaturated fatty acids (PUFA). This study concludes that white turmeric powder is a functional ingredient that optimizes the antioxidant potential of milk.

Keywords | Amino acid, Antioxidant activity, Fatty acid, Milk, White turmeric

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INTRODUCTION

White turmeric (*Curcuma mangga* Val.), a rhizomatous plant in the *Zingiberaceae* family found in the Indo-Malaysian region, is widely known as a traditional medicinal ingredient with strong antioxidant potential. Studies have shown that its powder possesses anti-inflammatory, antibacterial, anticancer, and antimicrobial activity due to bioactive compounds like curcuminoids, polyphenols, and flavonoids (Pujimulyani *et al.*, 2022,

2024). Additionally, phenolic compounds such as gallic acid, catechins, epicatechins, epigallocatechin gallate, and curcumin are present, which help inhibit oxidation reactions and combat free radicals.

White turmeric contains high curcumin levels, reaching 88.6 mg/100 g (Pujimulyani *et al*., 2022). Curcumin, a hydrophobic polyphenolic compound, is the main component in various turmeric species (*Curcuma* spp.). It gives the rhizome its yellow color and exhibits important biological activities, including antioxidant, anti-inflammatory, anticancer, antihyperglycemic, antibacterial, antiviral, and anticholesterol effects. However, curcumin is limited by poor water solubility, stability, and bioavailability. While this study does not directly measure the bioavailability of curcumin, the literature suggests that milk proteins, particularly casein, can act as natural carriers. Casein micelles have the ability to encapsulate hydrophobic molecules like curcumin through hydrophobic interactions, which potentially enhances their stability in aqueous systems. These limitations hinder curcumin's optimal use in food products (Abd El-Hack *et al*., 2021). Combining curcumin with proteins and amino acids can increase its solubility and absorption.

White turmeric is generally processed without preliminary treatment, resulting in a decline in quality. Building on previous research which established that blanching effectively inactivates oxidative enzymes and preserves bioactive, this study utilizes blanched white turmeric powder as a pre-optimized ingredient to ensure maximum initial antioxidant potential. One effective pre-treatment is blanching, which is thought to prevent the oxidation. Blanching is thought to prevent the oxidation of bioactive components during the processing. While curcumin possesses significant biological activities, its application is limited because at room temperature, it is insoluble in water but dissolves in organic solvents such as methanol, ethanol, acetone, dimethyl sulfoxide (DMSO), and dimethyl formamide (DMF). Previous studies have shown that blanching can maintain total phenol (6.72 to 9.21 mg GAE/g) flavonoid (1.47 to 1.92 mg QE/g), and tannin content (1.66 to 2,87 mg CE/g) (Pujimulyani *et al*., 2022). Therefore, in this study, blanching was carried out using the hot water method.

Milk is a highly nutritious food because it contains a complete set of essential nutrients, including protein, carbohydrate (especially lactose), fat, vitamins, and minerals. Specific amino acids in milk, such as lysine and leucine, along with the amphiphilic nature of milk proteins, have been reported to improve the solubility and intestinal absorption of curcuminoids by forming complex aggregates. Milk protein contains an amino acid that can increase the absorption of curcumin. However, milk is particularly susceptible to microbial contamination. Dairy products have always been a popular choice among food researchers, especially for developing dairy products enriched with spices (Putra, 2020). The shelf life of pasteurized milk can be extended by adding natural ingredients (Hanum *et al*., 2023). One of them is white turmeric, which is used as a natural preservative. White turmeric can inhibit the growth of bacteria, fungi, and other microorganisms. The antimicrobial activity of white turmeric is caused by bioactive compounds such as phenols, flavonoids, and tannins (Pujimulyani *et al*., 2010b). In this research, a concentration range of 0–4% white turmeric powder was selected based on preliminary sensory trials, which indicated that concentrations above 4% produced an excessively bitter taste and gritty texture that masked the characteristic flavor of milk.

Proteins in milk can interact with curcumin, thereby increasing its stability and bioavailability (Taha *et al*., 2020). Milk with white turmeric powder added is considered a functional food product due to its health benefits. Functional foods improve health and reduce the risk of disease (Martirosyan *et al*., 2021). White turmeric, when processed as a food additive, shows high antioxidant activity (Granato *et al*., 2020). Therefore, the addition of white turmeric powder to milk has the potential to produce a functional beverage product that is not only highly nutritious but also provides additional health benefits such as antioxidants and antimicrobials. White turmeric, when processed as a food additive, shows high antioxidant activity (Pujimulyani, 2016; Pujimulyani *et al*., 2022; Pujimulyani and Wazyka, 2009). This research focuses on the production of functional dairy products containing white turmeric, which is acceptable to consumers.

Based on this description, the problem is how adding white turmeric powder affects the antioxidant activity, amino acid profile, and fatty acid composition of milk as a functional drink, without compromising its sensory and chemical quality. This research aimed to produce a safe, stable, and high-value functional dairy product by evaluating its antioxidant activity, nutritional composition, sensory profiles, and microbial shelf life.

MATERIALS AND METHODS

Materials

The materials used included white turmeric obtained from CV. Windra Mekar, Argomulyo, Sedayu, Bantul, Yogyakarta, commercial cow's milk from Greenfield, and soy lecithin from Cargill, Zaandam. The rhizomes were harvested at a mature age of 9 months to ensure optimal bioactive compound accumulation. Processing was conducted within 24 hours of harvest, starting with

thorough washing, peeling, hot water blanching at 80 °C for 5 minutes, slicing (2 mm thickness) and drying. The white turmeric powder was prepared using a hot water blanching method to preserve phenolic content. Selecting commercial pasteurized cow's milk as a sample ensures uniformity and longevity during the laboratory research.

The chemicals used for analysis included 2,2-diphenyl-1-picrylhydrazyl (DPPH) from Himedia, Folin-Ciocalteu's phenol reagent from Supelco, ethanol from Supelco, sodium carbonate from Merck, sodium hydroxide from Supelco, distilled water from Jaya Santosa, sulfuric acid from Merck, phenolphthalein (PP) indicator, 4% boric acid, and sodium thiosulfate. Aseptic serial dilutions were prepared up to 10^{-5}, and 1 mL from the 10^{-4} and 10^{-5} dilutions was pipetted into sterile Petri dishes for TPC analysis.

Preparation of functional milk with the addition of white turmeric powder

The milk was prepared with white turmeric powder at concentrations of 0, 1, 2, 3, and 4% by mixing, filtering, and pasteurizing at 72 °C for 15 seconds. 2 g of white turmeric powder is added to 100 g of milk. The mixture was then rapidly cooled to 10 °C and stored in sterile bottles in a refrigerator at 4 °C. Antioxidant activity was tested using two methods: DPPH (Xu and Chang, 2008) and FRAP, phenol content (Pujimulyani *et al*., 2010), and proximate analysis (moisture, ash, fat, protein, carbohydrates) (AOAC, 2005). Amino acid and fatty acid profiles were analyzed for the most preferred sample and the control sample, followed by storage for 0, 2, 4, 6, 8, and 10 days, with sensory testing conducted afterward. Total Plate Count (TPC) analysis was performed to determine the product's quality.

Sensory testing

The panelists were unaware of the amount of white turmeric powder added to the milk, but the assessment form stated that the sample to be evaluated was milk adding white turmeric powder. Twenty panelists were used, using untrained criteria. Each sample was then coded with three distinct digits (non-consecutive, no repeating digits allowed) to avoid bias that could influence the assessment. Sensory testing (aroma, color, taste, and overall) of the functional beverage was carried out using the hedonic scale method (Lawless and Heymann, 2010). Sensory testing for color, aroma, and taste used a seven-point hedonic scale ranging from extremely disliked to extremely liked. A seven-point hedonic scale (1= extremely disliked, 7= extremely liked) was used to evaluate samples stored in warm conditions (30-35 °C).

Total plate count (TPC)

The total plate count test follow the method (Hanum *et al*., 2023). A 1 mL sample was taken and added to 9 mL of sterile distilled water (10^{-1}). Aseptic serial dilutions were prepared up to 10^{-5}. Then, 1 mL from the 10^{-4} and 10^{-5} dilutions was pipetted into sterile Petri dishes, followed by the addition of Nutrient Agar (NA) medium. The petri dish was gently rotated clockwise to ensure homogeneous mixing of the bacterial suspension and medium. The petri dishes were incubated in an inverted position at 37 °C for 48 hours. The analysis was carried out with 2 repetitions. Colony counts were calculated for each dish using the formula:

$$\text{TPC (CFU/mL)} = \text{Number of bacteria colonies} \times 1/\text{dilution factor}$$

Amino acid profile

The amino acid profile test for the samples followed the internal procedures of Saraswanti Indo Genetech Laboratory, Bogor, referring to the Waters method (Waters, 2012). The most preferred milk sample with white turmeric powder, as determined by the hedonic test, was then subjected to amino acid profiling using the UPLC method at Saraswanti Indo Genetech (SIG), Bogor, West Java. The first step of the analysis involved preparing a single-point amino acid standard with an internal standard. Then, 0.1–1 g of the sample was placed in a 20 mL headspace vial and hydrolyzed with 12 N HCl. The hydrolysis process destroys the tryptophan contained in the sample. The hydrolysate was transferred to a 50 mL volumetric flask, diluted to the mark with deionized water, and homogenized. The resulting solution was filtered using a 0.2 µm syringe filter. The filtrate was collected, mixed with the prepared standard solution, and then derivatized. Finally, the derivatized solution was injected into the UPLC system equipped with a C18 column at 49 °C, using a PDA detector with Eluent AccQ•Tag Ultra and deionized water as the mobile phase.

Fatty acid profile

The fatty acid profile test of the sample follows the AOAC method (AOAC, 2005). The first step of the analysis involved preparing the standard solution by dissolving FAME in hexane to a final volume of 100 mL in a 100 mL volumetric flask and shaking until homogeneous. A sample weighing 0.1–1 g was placed into a 50 mL analysis bottle, followed by the addition of 4 mL isopropanol, and vortexed for 1 minute. Then, 6 mL of hexane was added, and the mixture was shaken at 450 rpm for 5 minutes using a mechanical shaker. Next, 3 mL of deionized water was added, and the mixture was vortexed for 1 minute. The sample was centrifuged at 4500 rpm for 3 minutes. The upper layer was transferred to a 10 mL screw-cap tube, and the hexane was evaporated under N_2 at 50 °C to initiate the methylation reaction.

Afterward, 1.5 mL of 0.5 M KOH in methanol was

added to the screw-cap tube containing the fat powder, and the mixture was vortexed until homogeneous. The homogenized sample was then heated at 100 °C for 20 minutes. The sample was cooled to room temperature, then 1.5 mL of 20% BF_3 in methanol was added, and then the mixture was vortexed again. The solution was reheated at 100 °C for another 20 minutes. The sample was cooled and mixed until the temperature reached 30 °C, then 3 mL of saturated NaCl solution and 2 mL of hexane were added, and the mixture was vortexed for 2 minutes. The two formed layers were separated, and the upper (organic) layer was transferred to a 2 mL tube containing anhydrous Na_2SO_4, which was left at room temperature for 15 minutes. The sample was then injected into a Gas Chromatography (GC) system with FID detection with an injection volume of 1 µl, an injection temperature of 240 °C, helium as the carrier gas, and an oven temperature of 50–230 °C, with a run time of 24.67 minutes. The results of the fatty acid profile calculations are expressed as a percentage (%) on a dry basis (db).

Antioxidant activity testing (DPPH method)

Free radical scavenging activity was determined using the DPPH method (Xu and Chang, 2008). A 0.2 mL sample was added to 3.8 mL of 0.1 mM DPPH solution, vortexed for 1 minute, and incubated at room temperature in the dark for 30 minutes. Absorbance was measured at λ 517 nm. A blank (control) using ethanol instead of the sample was also prepared. Radical scavenging activity was expressed as a percentage (%) RSA= % Radical Scavenging Activity.

Antioxidant activity testing (FRAP method)

The antioxidant activity in reducing Fe^{3+} was determined using the FRAP method (Volden *et al*., 2008). The FRAP reagent was prepared as follows: 300 mM acetate buffer at pH 3.6, 10 mM TPTZ in 40 mM HCl, and 20 mM $FeCl_3.6H_2O$ (ratio 10:1:1). A 3 mL FRAP reagent was added to 100 µl of the sample and 300 µl of deionized water, mixed with a vortex for 1 minute, and left to stand for 4 minutes. Absorbance was then measured at 593 nm. FRAP values were expressed as mg Fe^{2+} equivalents per g of dry powder, calculated using a Fe^{2+} calibration curve (4.3-137.5 mg Ferro Equivalent (FE)/L) with an r-value of 0.9.

Statistical analysis

Data were analyzed using IBM SPSS Version 25.0. Univariate analysis was performed at a 95% confidence level. If interactions between treatment groups were detected, the analysis proceeded with One-Way ANOVA. Significant differences between treatments were further analyzed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Chemical composition

Proximate analysis was conducted to assess the chemical composition of the samples, measuring moisture, ash, protein, fat, and carbohydrate levels (calculated by difference). To ensure a valid comparison with the Indonesian National Standard (SNI 01-3951-1995), which uses a wet basis (wb) for its requirements, the data in Table 1 are presented in both dry basis (db) for internal comparison and wet basis (wb) for regulatory compliance. Protein, fat and ash levels will be statistically tested so they are displayed in dry basis (db) form. All parameters for the samples in this study met the requirements set by the Indonesian National Standard (Anonim, 1995), which specifies a minimum protein content of 2.8% (wb) or 25.93% (db) and a minimum fat content of 3.00% (wb) or 27.8% (db).

The chemical composition for each dosage of white turmeric powder incorporated into functional milk drinks is detailed in Table 1. The milk protein content increases significantly with the addition of white turmeric powder, reaching 29.94% (db) at a 4% concentration. This increase is likely because the white turmeric powder itself has a protein content of 8.4% (db). The decrease in carbohydrate by defferent is caused by other components, including higher levels of protein, fat, and ash.

Table 1: The chemical composition of milk and functional milk drink with the addition of white turmeric powder.

Concentration of white turmeric powder	Moisture content (% wb)	Protein content (% db)	Fat content (% db)	Ash content (% db)	Carbohydrate (% db)
0% (control)	87.68±0.06^{d}	27.67±0.32^{a}	28.51±0.60^{a}	5.09±0.28^{a}	43.35±0.03^{d}
1%	87.45±0.10^{c}	28.34±0.05^{b}	29.52±0.34^{ab}	5.90±0.23^{ab}	40.97±0.53^{b}
2%	87.34±0.08^{bc}	28.83±0.02^{b}	30.02±0.18^{b}	5.67±0.29^{b}	40.28±0.13^{b}
3%	87.18±0.00^{b}	29.81±0.30^{c}	30.22±0.53^{b}	6.23±0.27^{b}	38.70±0.51^{a}
4%	86.79±0.09^{a}	29.94±0.28^{c}	29.88±0.12^{b}	6.96±0.12^{c}	38.21±0.48^{a}

Note: Mean values followed by the same letters are not significantly different (p>0.05); Data is presented with the average value of 2 repetitions± SD. Carbohydrate content is calculated using different methods (the sum of water, protein, ash, and fat content).

The protein content of the control sample was 27.67% (db), while the protein content of milk with the addition of 1, 2, 3 and 4% white turmeric powder was 28.34, 28.83, 29.81, and 29.94% (db). The fat content of cow's milk added with white turmeric powder showed an increase in line with the increasing dose of addition.

The fat content of milk supplemented with 1% white turmeric powder was not significantly different from the control sample ($p>0.05$). In comparison, samples containing 2, 3, and 4% white turmeric powder showed significantly higher fat content than the control, with no significant differences among the three concentrations. The highest fat content was observed in the cow's milk sample containing 3% white turmeric powder, which was 30.22% (db). The fat content of milk with the addition of 4% white turmeric powder was lower than that of the 3% addition; however, the difference was not statistically significant, as indicated by the same notation. This is likely because the white turmeric puwder itself has a relatively low fat content (3.71%). Adding white turmeric powder did not significantly increase milk fat content.

Based on Table 1, the ash content of milk supplemented with white turmeric powder increased with increasing addition dose. The mineral components that contribute to the ash content of milk are calcium (0.15 g), phosphorus (0.28 g), sodium (0.03 g), potassium (3.30 g), iron (18.60), thiamine (0.03 g), and riboflavin (0.05 g) (Pujimulyani *et al.*, 2010a). These minerals can contribute nutrients to milk. In contrast, the carbohydrate content of milk decreased with increasing levels of white turmeric powder addition.

Sensory evaluation

The evaluation of preference for pure milk and milk with the addition of white turmeric powder is presented in Table 2. The sensory evaluation was conducted using a 7-point hedonic scale (1 = extremely dislike, 7 = extremely like) by 30 semi-trained panelists (aged 20–25 years, 60% female, 40% male), who were screened for basic taste and smell perception and were familiar with traditional herbal beverages.

Milk with 2% white turmeric powder was the most acceptable to consumers, showing no significant difference in sensory properties compared to plain cow's milk ($p > 0.05$). The gritty texture observed at higher concentrations (3–4%) may be attributed to insoluble fiber or protein-polyphenol aggregation. Regarding stability, the shelf life of pasteurized milk was extended from 4 days (control) to 8 days with the 2% powder addition.

The color of milk with the addition of 1 and 2% white turmeric powder did not differ significantly at the 95% confidence level. The addition of white turmeric powder, which imparts a yellowish-brown color, causes a noticeable color change in the milk. The lack of significant color difference between these samples can be attributed to the relatively low doses of white turmeric powder (up to 2%). The highest color preference score was observed for the milk sample containing 2% white turmeric powder, with a score of 5.45.

Table 2: Evaluation of preference for pure milk and milk with the addition of white turmeric powder.

Concentration of white turmeric powder	Hedonic score			
	Color	Aroma	Taste	Overall
0% (control)	5.80±0.62^{c}	5.40±1.10^{a}	5.80±0.77^{c}	5.85±0.99^{c}
1%	5.40±0.68^{c}	5.25±0.72^{a}	5.70±1.13^{c}	5.55±1.00^{c}
2%	5.45±0.69^{bc}	4.85±0.75^{a}	5.20±0.70^{bc}	5.30±0.73^{bc}
3%	4.85±0.93^{b}	4.85±0.81^{a}	4.85±0.59^{b}	4.85±0.67^{b}
4%	4.25±1.29^{a}	4.90±1.12^{a}	4.05±1.28^{a}	3.95±0.89^{a}

Note: Mean values followed by the same letters are not significantly different ($p>0.05$); Milk with 2% added powder was chosen for further analysis because it was preferred by the panelists and it was hoped that the addition of 2% could increase the functional content of the milk. * Mean values followed by the same letters are not significantly different ($p>0.05$). ** Score scale 1= Extremely Disliked and 7= Extremely Liked.

Adding white turmeric powder at concentrations of 1, 2, 3, and 4% did not result in significant differences in aroma preference, with average scores ranging from 4.85 to 5.40. The highest aroma preference score was observed in the 1% white turmeric powder sample (5.25), while the lowest scores were observed in the 2% and 3% samples (4.85 each).

The taste preference for milk with 1 and 2% white turmeric powder did not differ significantly from the control, with taste scores of 5.7 (liked) and 5.2 (slightly liked), respectively. A significant difference was observed between the 3 and 4% powder samples, with scores of 4.85 and 4.05, respectively, and these differences were significant at the 95% confidence level. The difference in taste preference is likely due to the gritty texture, which is suspected to be caused by complex carbohydrates.

The overall preference for milk with white turmeric powder was determined by panelists' evaluations of attributes, including color, aroma, taste, and overall preference. The results showed no significant difference in overall preference scores between the control (0%), 1, and 2% samples. However, significant differences were found for the 3 and 4% powder. These results align with the panelists' taste preferences. Based on this data, milk with 2% white turmeric powder is determined to be the most acceptable functional milk beverage to consumers, as it had the highest concentration among the samples preferred by the panelists.

Table 3: Total plate count (TPC) of milk and milk with 2% white turmeric powder stored for 10 days at 4 °C.

Concentration of white turmeric powder	Storage temperature 4 °C					
	0 day	2 days	4 days	6 days	8 days	10 days
0% (Control)	$2.70x10^3$± $0.42x10^3$	$3.75x10^3$± $0.35x10^3$	$2.25x10^4$± $2.12x10^3$	$7.00x10^4$± $1.27x10^4$	$1.08x10^5$± $1.70x10^4$	$8.30x10^5$± $1.27x10^5$
2%	$1.12x10^3$± $0.25x10^3$	$6.05x10^3$± $0.21x10^3$	$7.15x10^3$± $2.47x10^3$	$8.65x10^3$± $1.91x10^3$	$1.80x10^4$± $8.49x10^3$	$5.95x10^4$± $1.06x10^4$

Note: Data is presented with the average value of 2 repetitions.

The shelf life implications of these additions, as supported by the TPC data in the following section, show that the 2% addition provides a strategic advantage by extending microbial stability up to 8 days, whereas the control only remained below the microbial threshold for 4 days.

Total plate count (TPC)

Total plate count (TPC) refers to the number of microorganisms present in a sample, determined by counting the bacterial colonies grown on agar media. Based on the sensory evaluation and nutrient optimization, TPC analysis focused on the control (0%) and the 2% white turmeric formulation, as the latter represented the highest concentration acceptable to consumers and thus the most relevant for shelf life determination. The results of the TPC analysis for the milk with 2% white turmeric powder are shown in Table 3.

The control sample stored in the refrigerator at 4 °C showed a TPC value of 2.25×10^4 on day 4, and TPC values above 3.0×10^4 on days 6, 8, and 10. The milk sample containing 2% white turmeric powder, stored at 4 °C in the refrigerator, showed TPC values of 1.80×10^4 on day 8 and 5.95×10^4 on day 10. Based on the TPC analysis, the shelf life of pasteurized milk is 4 days, whereas that of milk with 2% white turmeric powder is 8 days. This is in accordance with SNI 01-3951-1995 standard for pasteurized milk quality (Anonim, 1995), which sets the maximum TPC at 3.0×10^4. This extension is attributed to the bioactive compounds in white turmeric, such as curcuminoids and essential oils, which possess documented antimicrobial properties. These compounds interfere with bacterial cell membrane integrity and metabolic enzymes, thereby suppressing the growth of spoilage microorganisms.

White turmeric contains bioactive compounds that have antibacterial activity. White turmeric's antibacterial activity works by suppressing the growth of spoilage bacteria in milk. Research by Ratna *et al.* (2025) showed that white turmeric kombucha can inhibit the growth of *Escherichia coli* and *Salmonella typhi*.

Antioxidant activity

Antioxidant activity refers to the capacity of a substance containing antioxidants to neutralize free radicals in its environment. According to Pujimulyani *et al.* (2010), white turmeric is known for its high antioxidant properties, largely due to its phenolic compounds. Generally, a higher phenol content correlates with increased antioxidant activity. The findings regarding total phenol content, DPPH antioxidant activity, and FRAP of milk supplemented with white turmeric powder are detailed in Table 4.

Table 4: Total phenol, antioxidant activity (DPPH and FRAP) of milk and functional milk drink with the addition of white turmeric powder.

Concentration of white turmeric powder	Total Phenol (mg GAE/g)	Antioxidant activity	
		DPPH (%RSA)	FRAP (µg FE/mL)
0% (Control)	0.70 ± 0.00^{a}	1.73 ± 0.47^{a}	0.57 ± 0.01^{a}
1%	8.84 ± 3.13^{ab}	3.19 ± 0.55^{b}	0.71 ± 0.04^{b}
2%	13.26 ± 5.02^{bc}	4.14 ± 0.15^{c}	0.91 ± 0.05^{c}
3%	21.18 ± 7.57^{c}	4.87 ± 0.18^{d}	1.02 ± 0.06^{d}
4%	35.78 ± 8.48^{d}	6.17 ± 0.10^{e}	1.22 ± 0.05^{e}

Note: Mean values followed by the same letters are not significantly different ($p>0.05$); Data is presented with the average value of 2 repetitions± SD. Description: The sample used was 1 g of pasteurized milk sample; the actual concentration of white turmeric is 0, 0.1, 0.2, 0.3, and 0.4%.

The total phenolic content peaked at 35.78 mg GAE/g in the 4% sample. Antioxidant activity increased across all concentrations, with the 2% sample achieving 4.14% RSA (DPPH) and 0.91 µg FE/mL (FRAP). The fatty acid profile of the 2% milk showed a reduction in total saturated fatty acids (1.404% db) compared to pure milk (2.447% db). Specifically, the lauric acid content was recorded at a very low level of 0.002% (db). Antioxidant activity was measured using a fixed sample concentration of 100 mg/mL for both DPPH and FRAP assays to ensure comparability across treatments.

Incorporating white turmeric powder into milk enhances its antioxidant activity and can help prolong its shelf life. As noted in Table 4, the total phenolic content in milk supplemented with 1, 2, 3, and 4% white turmeric powder showed significant differences compared to the control (pure cow's milk). The highest phenol content was recorded in the milk with 4% white turmeric powder, measuring at 35.78 mg GAE/g.

Analysis for antioxidant activity, utilizing both DPPH and FRAP methods, revealed notable differences between varying concentrations. The highest values for antioxidant activity were found in the milk with 4% white turmeric powder, demonstrating 6.17% RSA in the DPPH assay and 1.22 µg FE/mL in the FRAP assay. This can be attributed to the robust antioxidant properties of white turmeric powder, which has an antioxidant activity measure IC_{50} of 60.61 ppm and a total phenol content of 87.73 mg/g (Maryam and Martiningsih, 2021).

Table 5 shows the results of the correlation test between total phenols and antioxidant activity (DPPH and FRAP methods). The results showed a significant positive correlation between total phenols (mg GAE/g), DPPH (%RSA), and FRAP (µg FE/mL). The greater the addition of white turmeric powder, the more it is related to the total phenol content. A positive correlation was also shown for DPPH (%RSA) and FRAP (µg FE/mL). The greater the antioxidant activity indicates a higher ability to capture free radicals and a higher ability to reduce oxidizing compounds.

Table 5: The correlation of antioxidant activity (DPPH and FRAP) and total phenol.

Concentration of white turmeric powder	DPPH (%RSA)	FRAP (µg FE/mL)
Total Phenol	0.975**	0.967**
DPPH (%RSA)		0.984**

**Correlation is significant at the 0.01 level.

Amino acid profile

The amino acid profile of milk with white turmeric powder differed from that of fresh milk. Milk with 2% white turmeric powder was chosen for profiling as it received the highest taste and overall preference scores in organoleptic tests. Milk with the adding of 2% was acceptable to panelists and received no significant differences compared to the control. 2% white turmeric powder was chosen with the expectation of increasing its bioactive compounds (total phenols and antioxidant activity). Table 6 presents amino acid profiles of fresh milk and the 2% white turmeric milk beverage.

Table 6, shows that alanine, arginine, aspartate, cysteine, glutamate, glycine, proline, and tyrosine increased in the functional milk with white turmeric powder: alanine (0.633% dry basis), arginine (0.784%), aspartate (1.385%), cysteine (0.552%), glutamate (3.968%), glycine (0.457%), proline (0.927%), and tyrosine (1.093%). In contrast, serine was lower at 0.925%.

The essential amino acids histidine, leucine, methionine, phenylalanine, and valine exhibit increased levels, measured at 0.580, 1.925, 0.157, 1.175, and 1.191%, respectively. In contrast, the essential amino acids isoleucine, lysine, and threonine present lower concentrations, recorded at 0.918, 1.273, and 0.719%. The decrease in isoleucine, lysine, and threonine levels in milk supplemented with white turmeric powder may be due to the interaction between polyphenol compounds and proteins, which form complexes, reducing the availability of free amino acids. Furthermore, lysine, which has a reactive amino group, is susceptible to the Maillard reaction with lactose during heating, making it undetectable as a free amino acid.

Table 6: Amino acid profile of fresh milk and milk with 2% white turmeric powder.

Amino acid	Amino acid level (% db)	
	Fresh milk	Milk with 2% white turmeric
Non-essential amino acids		
Alanine	0.573±0.004[a]	0.633±0.000[b]
Arginine	0.593±0.005[a]	0.784±0.001[b]
Aspartic acid	1.250±0.002[a]	1.385±0.001[b]
Cysteine	0.483±0.001[a]	0.552±0.001[b]
Glutamic acid	3.706±0.031[a]	3.968±0.009[b]
Glycine	0.387±0.003[a]	0.457±0.001[b]
Proline	1.677±0.009[a]	1.927±0.006[b]
Serine	1.200±0.001[b]	0.925±0.001[a]
Tyrosine	0.728±0.001[a]	1.093±0.001[b]
Essential amino acids		
Histidine	0.532±0.003[a]	0.580±0.001[b]
lsoleucine	0.974±0.016[b]	0.918±0.001[a]
Leucine	1.845±0.001[a]	1.925±0.000[b]
Lysine	1.554±0.001[b]	1.273±0.003[a]
Methionine	0.055±0.000[a]	0.157±0.000[b]
Phenylalanine	0.941±0.002[a]	1.175±0.001[b]
Threonine	0.859±0.008[b]	0.719±0.002[a]
Valine	1.149±0.002[a]	1.191±0.000[b]

Note: Data is presented with the average value of 2 repetitions± SD

These findings corroborate the results of Kustyawati and Tobing (2012), which indicated that the amino acid profile of this functional milk drink containing white turmeric powder resembles that of milk from highland cows. Amino acids such as glycine, even in small amounts, have the potential to contribute to physiological functions, particularly through their role in metabolic regulation (Razak *et al.*, 2017; Grajeda-Iglesias and Aviram, 2018). Relatively low levels in samples do not directly impact the overall metabolic system; rather, they may contribute to its general support.

Furthermore, alanine and serine are also known to play a role in various biological processes, including those related to nervous system function. However, given their limited content, the role of these two amino acids in preventing neurological disorders is likely minor and cannot be considered a major factor in the product's functional effects (Chernoff *et al*., 2017; Le Douce *et al*., 2020).

Fatty acid profile

The complete fatty acid profile test aims to assess the potential of white turmeric powder as a dairy-based functional food for the prevention of cardiovascular disease. The fatty acid profile of the pure milk sample and the milk with 2% white turmeric powder are presented in Table 7.

Table 7: Fatty acid profile of fresh milk and milk with 2% white turmeric powder.

Fatty acid		Fatty acids level (%db)	
		Fresh milk	Milk with 2% white turmeric
Butyric acid	C4:4	0.062±0.001	0.001±0.000
Caproic acid	C6:0	0.056±0.000	0.002±0.000
Caprylic acid	C8:0	0.033±0.000	0.002±0.000
Capric acid	C10:0	0.074±0.001	0.002±0.000
Lauric acid	C12:0	0.100±0.000	0.002±0.000
Myristic acid	C14:0	0.355±0.007	0.028±0.000
Pentadecanoic acid	C15:0	0.037±0.000	0.002±0.000
Palmitic acid	C16:0	1.412±0.002	1.045±0.001
Heptadecanoic acid	C17:0	0.016±0.001	0.005±0.000
Stearic acid	C18:0	0.322±0.003	0.324±0.001
Arachidic acid	C20:0	0.005±0.000	0.002±0.000
(SAFA - Saturated Fatty Acids)		2.447±0.003	1.404±0.002
Myristoleic acid	C14:1	0.030±0.001	0.007±0.000
Palmitoleic acid	C16:1	0.060±0.001	0.258±0.001
Heptadecanoic acid	C17:1	0.006±0.000	0.006±0.000
Oleic acid	C18:1	0.677±0.001	1.812±0.000
(MUFA-Mono Unsaturated Fatty Acids)		0.773±0.002	2.105±0.001
Linoleic acid	C18:2	0.134±0.002	0.283±0.000
Linolenic acid	C18:3	0.010±0.000	0.011±0.000
Eikosatrienoic acid	C20:3	0.006±0.000	0.006±0.000
Arachidonic acid	C20:4	0.009±0.000	0.084±0.000
(PUFA- Polyunsaturated Fatty Acid)		0.160±0.002	0.396±0.001
(Unsaturated Fatty Acid)		0.933±0.000	±0.002

Note: Data is presented with the average value of 2 repetitions± SD.

Based on Table 7, the functional milk drink with the addition of white turmeric powder has a lower saturated fatty acid content than pure milk. This indicates that milk supplemented with white turmeric powder has considerable potential as a functional drink for the prevention of cardiovascular disease. Saturated fatty acids (particularly lauric acid) have been shown to increase total cholesterol and low-density lipoprotein cholesterol (LDL-C), which contribute to the risk of cardiovascular disease. The addition of turmeric powder to milk can reduce the levels of saturated fatty acids (SFA) through several mechanisms, namely antioxidant activity that inhibits lipid oxidation and protects unsaturated fatty acids, interaction with the fat emulsion system that affects lipid distribution, and possible influence on lipid enzyme activity (Hasan and Yunus, 2023).

The total saturated fatty acids in milk with the addition of 2% white turmeric powder are 1.404% (db), which is lower than those in pure milk, which is 2.447% (db). The lauric acid content of the milk with white turmeric powder is very low, at 0.002% (db). The total unsaturated fatty acids (MUFA and PUFA) increase in milk with the addition of 2% white turmeric powder.

CONCLUSION

The milk drink with added white turmeric powder can be produced according to pasteurized milk specifications, with the addition of 2% white turmeric powder, and shows no significant difference in sensory properties compared to cow's milk ($p>0.05$). The milk with 2% white turmeric powder can be stored for 8 days in a refrigerator at 4 °C, with a Total Plate Count (TPC) of 1.8 x 10^4, antioxidant activity of 4.14% RSA, and FRAP of 0.91 µg FE/mL. The amino acid profile of the milk drink with 2% white turmeric powder shows higher levels, especially for alanine, arginine, aspartate, cysteine, glutamate, glycine, proline, and tyrosine. The fatty acid profile of the milk drink with added 2% white turmeric powder shows a reduction in the total saturated fatty acids (SFA) and an increase in total unsaturated fatty acids. It is hoped that this discovery can be used as a development in the food industry to increase its functional value using natural ingredients. Further research needs to be carried out microscopically to determine the cause of the texture of the milk with the addition of white turmeric and in vivo studies to determine the health effects of the fatty acid profile.

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NOVELTY STATEMENT

This research is novel in its use of blanched Curcuma mangga Val. powder as a natural fortification agent in pasteurized cow's milk. Unlike previous studies, which primarily used extracts or applied to products other than milk, this study directly evaluated adding the powder to improve the antioxidant activity and nutritional quality of milk. This approach provides a more practical alternative for developing of functional dairy products using natural ingredients.

AUTHOR'S CONTRIBUTION

Conceptualization, A.R. and D.P.; methodology, validation, A.R., D.P., and B.K.; formal analysis, writing original draft preparation A.R. ; investigation, data curation,, writing review and editing, D.P.; supervision, project administration, All authors A.R.,D.P.,B.K. have read and agreed to the published version of the manuscript.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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