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Evaluation of Fermented Goat Milk Quality *Lactobacillus plantarum* SNT13 Enhanced with *Clitoria ternatea* Flower Extract and Stingless Bee Honey (*Heterotrigona itama*)

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ABSTRACT: Stingless bee honey and *Clitoria ternatea* flowers are functional foods known for their numerous health benefits. Incorporating these functional ingredients into fermented milk can influence the properties of the final product. This study aimed to evaluate the effects of supplementing stingless bee honey (SBH) from *Heterotrigona itama* and *Clitoria ternatea* flower extract (CTFE) on the physicochemical and functional characteristics of fermented goat milk. SBH and CTFE were added in varying concentrations during the fermentation process. The proximate composition, total titratable acidity (TTA), pH, color (L^*, a^*, b^*), total lactic acid bacteria (LAB), antioxidant capacity, and total phenolic content were analyzed. Supplementation with SBH and CTFE led significant changes in proximate composition across treatments, with notable increases in carbohydrate content and total LAB. However, SBH and CTFE had no effect on the TTA or pH of the fermented goat milk. Brightness and yellowness increased with SBH, while CTFE reduced L^* and a^* values. Moreover, antioxidant capacity and total phenolic content increased with higher concentrations of SBH and CTFE. In conclusion, SBH and CTFE supplementation can modify the physical properties of fermented goat milk while enhancing its quality by boosting total LAB, antioxidant capacity, and total phenolic content.

Keywords: antioxidant, functional food, *Lactobacillales*, probiotics

INTRODUCTION

Global goat milk production is currently expanding, with the fastest growth occurring in Asia (Miller and Lu, 2019). Goat milk is valued not only for its excellent nutritional content but also for its lower allergenicity and higher concentration of short-chain fatty acids compared to cow milk, which makes goat milk fat easier to digest (Goswami et al., 2017; Gallier et al., 2020). Furthermore, goat milk contains higher levels of the amino acids tryptophan and cysteine than cow milk, and its proteins have been reported to possess immunomodulatory and anti-inflammatory effects that promote health (ALKaisy et al., 2023).

The processing of goat milk has become an intriguing area of research for product diversification, including yogurt, cheese, and kefir, with the goal of increasing product value. Fermented goat milk has been reported to exhibit functional properties such as antimicrobial and ACE-inhibitory activities (Moreno-Montoro et al., 2017). Due to the action of fermenting bacteria, fermented goat milk contains a higher concentration of fatty acids, peptides, and amino acids than its unfermented counter part (Chen et al., 2020). *Lactobacillus plantarum* (*L. plantarum*) SNT13, isolated from Indonesian stingless bee honey (SBH), has been used for milk fermentation (Melia et al., 2022). Fermented goat milk using *Lactobacillus* strains has superior antioxidant activity compared to other probiotic strains and can maintain this antioxidant activity during storage (Chen et al., 2015; Liu et al., 2023). The development of fermented goat milk products often involves incorporating functional ingredients to enhance texture quality (Mayasari et al., 2024) and antioxidant activity (Melia et al., 2022). However, no fermented goat milk product has been developed using a combination of SBH and CTFE, both of which provide notable health benefits as functional foods.

SBH and *Clitoria ternatea* flowers are regarded as functional foods due to their numerous health benefits. SBH, produced by bees from the Apidae family (Meliponinae)

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(Herwina et al., 2021), has been shown to possess superior antioxidant activity and higher total phenolic content compared to honey from *Apis mellifera*. It also exhibits α-glucosidase enzyme inhibition, indicating its potential as an antidiabetic food (Shamsudin et al., 2019; Setiawan et al., 2024). While previous studies have primarily focused on adding *Apis* honey to yogurt (Machado et al., 2017; Ismail et al., 2018; Mohan et al., 2020). *C. ternatea* flower, often used as a natural food colorant, is rich in bioactive compounds and demonstrates high levels of total phenol content and antioxidant activity (Siti Azima et al., 2017; Vidana Gamage et al., 2021; Goh et al., 2022). Additionally, CTFE possesses antiproliferative properties (Neda et al., 2013). Despite its promising attributes, CTFE has been used in fermented milk processing. However, our recent study successfully incorporated CTFE into kefir (Melia et al., 2023). Several factors limit the use of CTFE in processed food products. One key challenge is the stability of its bioactive components, such as anthocyanins, which provide its bright blue color but are unstable at varying pH levels, as well as under exposure to light and temperature (Oguis et al., 2019). This instability can impact the consistency and appearance of the final product. In addition, the taste profile of *C. ternatea* is unfamiliar to many consumers, and its limited availability, as it grows inly in specific regions, poses additional challenges for wider development and acceptance.

In a previous study, Suharman et al. (2022) investigated the potential of incorporating 10% of CTFE into yogurt production using sucrose. Similarly, Prastowo et al. (2023) examined the effect of adding 1% – 10% CTFE on yogurt during storage. In addition, Ammar et al. (2014) proposed the inclusion of 6% honey in yogurt production, while Bakr et al. (2017) suggested incorporating 5% – 15% black cumin bee honey into yogurt.

However, the effects of supplementing goat milk fermented with *L. plantarum* SNT13 using SBH and CTFE remain unknown. The aim of evaluating the quality of this fermented goat milk is to contribute to the development of a novel product. By assessing the physicochemical characteristics, antioxidant activity, and total phenolic content, researchers hope to create a high value functional food product that leverages the health benefits of goat milk, SBH, and CTFE.

MATERIALS AND METHODS

Materials

Fresh goat milk was sourced from local farmers in Padang City, West Sumatra, Indonesia. *L. plantarum* SNT13 was obtained from the Laboratory of Animal Product Technology at the Faculty of Animal Science, Universitas Andalas. The SBH was procured from a stingless bee farm located at the Faculty of Animal Science, Universitas Andalas, and harvested in March 2023. Fresh *C. ternatea* flowers were purchased from the local market in Padang, West Sumatra, Indonesia.

Preparation of *Clitoria ternatea* flower extract (CTFE)

The *C. ternatea* flowers used in this study were fresh and predominantly bluish-purple in color. A total of 2,000 g of flowers were dried in an oven at 60°C for 24 h. The dried flowers were then ground and passed through a 30-mesh sieve. The resulting powder was macerated three times using 70% ethanol. The macerated liquid was filtered using Whatman filter paper and concentrated at 50°C for 60 min with a rotary evaporator. The final extract was stored in glass bottles at 4°C until it was used for the production of fermented goat milk (Melia et al., 2023).

Preparation of fermented goat milk

Fresh goat milk was pasteurized at 85°C for 15 min and then cooled to approximately 40°C. The pasteurized milk was supplemented with SBH and CTFE according to the experimental treatments. The mixture was inoculated with *L. plantarum* SNT13 at a concentration of 2% (v/v) and incubated at 37°C for 24 h. The resulting fermented goat milk was stored at 4°C until further analysis.

Experimental design

The study followed a completely randomized design with two factors: SBH concentrations of 0%, 4%, 8%, and 12%, and CTFE concentrations of 0%, 5%, 10%, and 15%. SBH and CTFE were added prior to fermentation. Each treatment sample was evaluated for proximate composition, total titratable acidity (TTA), pH, viscosity, color (L^*, a^*, b^*), total lactic acid bacteria, antioxidant activity, and total phenolic content.

Physicochemical properties

Proximate composition analysis was performed to measure moisture, ash, protein, and fat contents using AOAC methods (2005), with carbohydrate content determined by difference. TTA and pH were assessed according to the procedures outlined by Melia et al. (2023). For TTA analysis, 10 mL of the sample was mixed with phenolphthalein indicator and titrated with 0.1 N NaOH until a pink color appeared. pH was measured using a pH meter (Hanna), which was calibrated with pH 4 and 7 buffers. A 10 mL sample was placed in a beaker, and the pH was recorded once the measurement stabilized. The color of the fermented milk was evaluated for L^* (brightness), a^* (redness), and b^* (yellowness) values using a Hunterlab colorimeter (ColorFlex), which was calibrated with a white board provided by the instru-

ment (Naibaho et al., 2022).

Total lactic acid bacteria (LAB)

The analysis was conducted using serial dilutions of the samples, starting with the addition of 1 mL of the sample to 9 mL of sterile water. A 1 mL aliquot from each dilution was then plated onto de Man, Rogosa, and Sharp agar medium and incubated at 37°C for 48 h (Othman et al., 2012).

Antioxidant capacity

The antioxidant capacity was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, following the method described by Melia et al. (2024). A volume of 500 μL of the sample was combined with 375 μL of ethanol (99%) and 125 μL of DPPH solution (0.02% in ethanol). The mixture was stirred and incubated in the dark at room temperature (25°C) for 30 min. Absorbance was measured at 520 nm using a ultraviolet (UV)/visible spectrophotometer (Shimadzu) to determine the radical-scavenging activity. Antioxidant capacity was calculated by subtracting the absorbance of the sample from the absorbance of the control, and then dividing by the absorbance of the control. Methanol served as the control for absorbance measurements without the sample. The antioxidant capacity was expressed as a percentage of inhibition.

Total phenolic content

The diluted material (300 μL) was mixed with 1.5 mL of Folin-Ciocalteu reagent and 1.2 mL of 7.5% w/v Na_2CO_3. The mixture was homogenized and allowed to stand in the dark at room temperature for 30 min. Absorbance was then measured at 765 nm using a UV/visible spectrophotometer (Shimadzu). Total phenolic content was quantified in milligrams per milliliter of extract (mg/mL) (El-Sayed et al., 2023).

Statistical analysis

Data analysis was performed using SPSS software (version 26, IBM Corp.) with multivariate analysis. Significant differences were assessed using Duncan's multiple range test at a 5% significance level.

RESULTS AND DISCUSSION

Physicochemical properties

***Proximate composition*:** The proximate composition of fermented goat milk with the addition of a combination of SBH and CTFE at various concentrations showed significant differences ($P<0.05$) across all parameters (moisture, ash, protein, fat, and carbohydrate content) (Table 1). Generally, the addition of SBH (without CTFE) at varying concentrations led to decreased mean values for moisture, ash, protein, and fat contents, while carbohydrate content increased. Conversely, the addition of CTFE (without SBH) at different concentrations resulted in decreased ash, protein, and fat contents, although moisture content increased and carbohydrate content remains unchanged. These findings suggest that the observed differences due to SBH addition are related to the characteristics of the honey used, while has a high total solid content but only minor amounts of protein and fat, thereby reducing the proportions of moisture, protein, and fat. In contrast, the changes observed with CTFE addition are attributed to its high moisture content, while increases moisture while decreasing ash, protein, and fat content with higher CTFE concentrations.

The interaction between the treatments results in a combination of effects that yield varying outcomes. At concentrations of 4%, 8%, and 12%, a significant increase in moisture content was observed only with the addition of CTFE at concentrations of 10% and 15%. Regarding ash content, increasing SBH concentration raises the ash content, but this content is evident at a 5% CTFE concentration. At higher CTFE concentrations of 10% and 15%, however, CTFE addition significantly reduced the ash content. A notable decrease in fat content, reaching 67%, was observed, with the highest fat content being 8.09 g/100 g (0% SBH and 0% CTFE) and the lowest at 2.66 g/100 g (0% SBH and 15% CTFE). Additionally, the interaction between treatments becomes evident with the addition of 10% and 15% CTFE, where an increase in protein and fat content was noted with higher SBH concentrations. This suggest that combining SBH and CTFE helps prevent a decrease in protein and fat content.

Regarding carbohydrate content, the combination of SBH and CTFE significantly increased the carbohydrate levels in fermented goat milk, more than doubling them (from 5.45 g/100 g to 11.67 g/100 g) at SBH and CTFE concentrations of 12% and 15%, respectively. This increase is likely due to honey's high carbohydrate content, primarily fructose and sucrose; thus, higher honey additions lead to greater carbohydrate content (Bogdanov et al., 2008). Adding up to 5% honey to kefir and 6% honey to yogurt has been reported to significantly reduce water activity (Sert et al., 2011; Bielska et al., 2021). In contrast, adding honey at 10%–15% to goat milk yogurt significantly decreased the protein and fat content (Machado et al., 2017).

***Total titriable acidity (TTA) and pH*:** The addition of SBH and CTFE to fermented goat milk did not significantly affect the TTA and pH values ($P<0.05$) (Fig. 1). Increasing concentrations of SBH and CTFE tended to raise the TTA values from 1.27% to 1.61% ($P=0.059$ and $P=0.485$, respectively) while pH decreased from 3.95 to 3.81 ($P=$

Table 1. Proximate composition of fermented goat milk with different levels of SBH and CTFE

Proximate composition (g/100 g)	SBH levels (%)	CTFE levels (%)				Average
		0	5	10	15	
Moisture	0	81.26±1.22	87.81±0.10	89.53±0.06	89.48±0.93	87.02±3.92[a]
	4	82.99±0.97	82.98±0.78	86.54±0.88	85.34±0.45	84.46±1.78[b]
	8	82.66±0.77	80.97±0.90	82.34±0.50	84.30±0.42	82.57±1.37[c]
	12	79.62±0.24	80.38±0.54	81.49±0.95	80.06±0.08	80.39±0.80[d]
	Average	81.63±1.54[c]	83.04±3.37[b]	84.98±3.75[a]	84.80±3.87[a]	
Ash	0	0.81±0.01	0.78±0.01	0.71±0.01	0.68±0.00	0.75±0.06[a]
	4	0.88±0.01	0.75±0.00	0.65±0.01	0.53±0.00	0.70±0.15[b]
	8	0.82±0.00	0.84±0.00	0.46±0.00	0.57±0.01	0.67±0.19[c]
	12	0.82±0.01	0.90±0.01	0.47±0.00	0.46±0.01	0.66±0.23[d]
	Average	0.83±0.03[a]	0.82±0.07[b]	0.57±0.13[c]	0.56±0.09[d]	
Protein	0	4.40±0.08	3.60±0.01	3.05±0.01	3.11±0.03	3.54±0.62[bc]
	4	3.57±0.04	3.35±0.03	3.71±0.04	3.40±0.08	3.51±0.16[c]
	8	3.62±0.01	3.84±0.01	3.40±0.00	3.50±0.01	3.59±0.19[a]
	12	3.94±0.03	3.22±0.06	3.67±0.06	3.46±0.05	3.57±0.31[ab]
	Average	3.88±0.38[a]	3.50±0.27[b]	3.46±0.30[b]	3.37±0.18[c]	
Fat	0	8.09±0.05	5.26±0.07	3.98±0.07	2.66±0.28	5.00±2.32[b]
	4	6.09±0.13	6.00±0.06	3.75±0.02	4.61±0.01	5.11±1.13[ab]
	8	5.50±0.04	5.56±0.14	5.60±0.14	4.26±0.06	5.23±0.65[a]
	12	5.48±0.01	5.06±0.06	4.06±0.06	4.35±0.04	4.74±0.65[c]
	Average	6.29±2.01[a]	5.47±3.40[b]	4.35±3.31[c]	3.97±3.21[d]	
Carbohydrate	0	5.45±1.15	2.55±0.16	2.73±0.00	4.08±0.69	3.70±1.35[d]
	4	6.48±0.87	6.93±0.69	5.34±0.90	6.12±0.37	6.22±0.67[c]
	8	7.40±0.80	8.80±0.76	8.20±0.05	7.37±0.40	7.94±0.69[b]
	12	10.14±0.29	10.44±0.42	10.30±0.83	11.67±0.40	10.64±0.70[a]
	Average	7.37±2.01	7.18±3.40	6.64±3.31	7.31±3.21	

Different letters in the row and column indicate a significant difference (P<0.05).
SBH, stingless bee honey; CTFE, *Clitoria ternatea* flower extract.

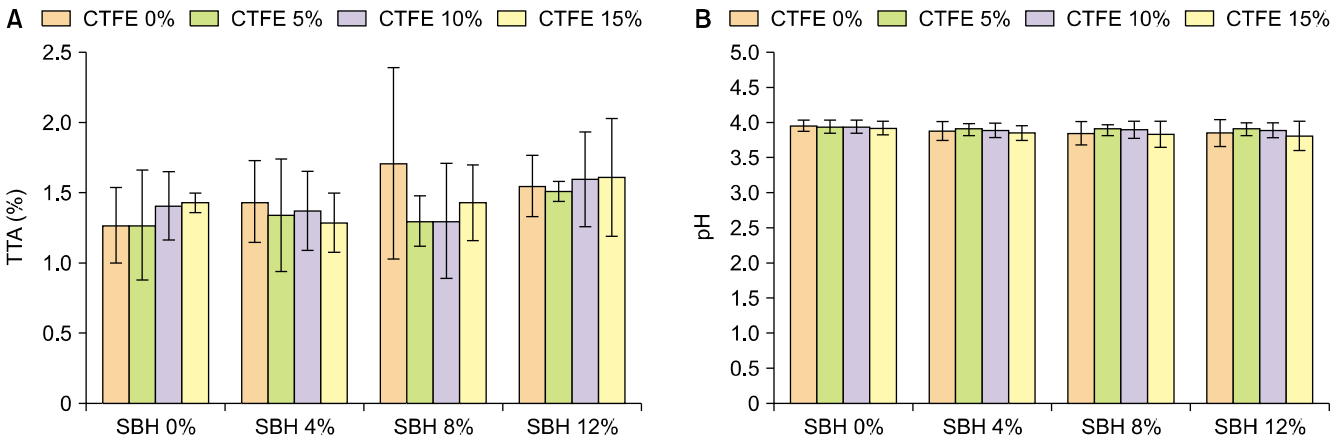

Fig. 1. TTA (A) and pH (B) of fermented goat milk with different levels of SBH and CTFE. TTA, total titratable acidity; SBH, stingless bee honey; CTFE, *Clitoria ternatea* flower extract.

0.059 and P=0.243, respectively), though these changes were not statistically significant. The increase in average TTA values was most notable with the addition of 12% honey, which raised the average TTA from 1.35% to 1.56%.

An increase in TTA and a decrease in pH could be attributed to the presence of organic acids naturally found in honey and CTFE (Neda et al., 2013; Shamsudin et al., 2019). However, in this study, these organic acids did not cause significant changes in TTA or pH. This lack of significant change may be because the pH of *Heterotrigona itama* honey used in this study was 3.94, which is similar to the pH of untreated yogurt, while the CTFE had a pH of 5.6. Consequently, higher concentrations of CTFE did not decrease lower the pH of fermented goat milk. Mayasari et al. (2024) reported that fermented goat milk from *Levilactobacillus brevis* DSM02 had TTA and pH values of 1.37% and 4.08, respectively. In contrast, the com-

bination of 12% SBH and 15% CTFE in this study resulted in higher TTA values and lower pH values of 1.61% and 3.81, respectively.

***Total lactic acid bacteria (LAB)*:** The addition of SBH and CTFE at various concentrations resulted in significant differences ($P<0.05$) in the total LAB count in fermented goat milk (Fig. 2). Increasing the concentrations of each treatment led to an higher LAB count, although no significant interaction between the two treatments ($P=0.090$) was observed. The highest LAB count, 314×10^8 CFU/mL, was achieved with the addition of 12% SBH and 15% CTFE, while the lowest LAB count, 43×10^8 CFU/mL, was observed in yogurt without SBH and CTFE. The increase in LAB count with CTFE addition may be attributed to the higher sugar content provided by honey during fermentation, which supports LAB growth. Adding SBH to goat milk yogurt can offer functional benefits for the growth of *L. acidophilus* La-05 (Machado et al., 2017).

Similar results were observed by Ammar et al. (2015), who found that increasing honey concentrations (2%–6%) led to higher bifidobacterial counts. In contrast, other studies have reported that higher honey concentrations could decrease LAB counts in yogurt. For example, Bakr et al. (2017) noted that while 5% honey increased viable count of *Streptococcus thermophilus*, concentrations of 10% and 15% honey led to a decrease in the viable count of *L. delbrueckii* subsp. *bulgaricus*. This suggests that both the concentration and type of honey can either stimulate or inhibit LAB growth (Ismail et al., 2018). The addition of CTFE to fermented milk has been reported to increase the amounts of glucose and sucrose in yogurt, providing additional sugars that support the growth of starter bacteria during fermentation (Prastowo et al., 2023).

The addition of CTFE, which contains bioactive components such as flavonoids, polyphenols, and anthocyanins, with potential prebiotic effects, enhanced LAB growth despite a reduction in overall carbohydrate content. Zhang et al. (2016) found that consuming purple sweet potato, rich in anthocyanins, may positively impact gut microbiota and improve host health. The bioavailability and beneficial effects of polyphenols appear to depend on their biotransformation in the gut. Additionally, polyphenols seem to modulate microflora through bidirectional interactions. These findings support the hypothesis that both polyphenol components and microbial metabolites should be considered when assessing the impact of polyphenols on host health.

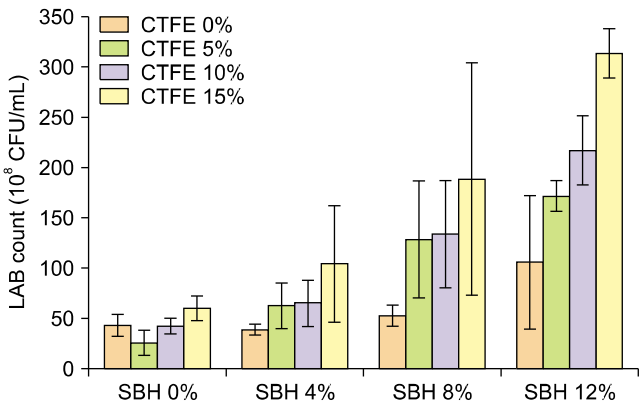

Fig. 2. LAB Count of fermented goat milk with different levels of SBH and CTFE. LAB, lactic acid bacteria; SBH, stingless bee honey; CTFE, *Clitoria ternatea* flower extract.

From the results of this study, we can conclude that fermented goat milk using *L. plantarum* SN13T bacteria, combined with SBH and CTFE, has the potential to increase the total number of LAB to 314×10^8 CFU/mL. In comparison, research by Abdel Moneim et al. (2011), indicates that goat milk yogurt made from *L. bulgaricus* and *S. thermophilus* strains has a total LAB count of 8×10^5 CFU/mL, while traditional goat milk yogurt has a count of 5.4×10^8 CFU/mL.

***Color*:** The impact of SBH and CTFE on the L^*, a^*, and b^* values of fermented goat milk is shown in Table 2. Generally, the addition of honey increased the brightness (L^*) and yellowness (b^*), while CTFE significantly reduced these attributes. However, neither SBH nor CTFE had any effect on the redness (a^*) of the samples. The changes in the L^* and b^* values were dependent on the concentrations of SBH and CTFE used. Higher concentrations of SBH typically raised L^* and b^* values, especially in samples containing 5%, 10%, and 15% CTFE, whereas higher concentrations of CTFE led to a decrease in L^* and b^* values.

The increase in brightness and yellowness observed with SBH addition may be attributed to the natural color of the honey components used. This honey was found to have the highest levels of brightness and yellowness compared to SBH from *Geniotrigona thoracica*, *Tetrigona melanoleuca*, and *Tetrigona binghami* (Melia et al., 2024). Conversely, the decrease in brightness and yellowness due to CTFE addition is linked to the high anthocyanin content in *C. ternatea* flowers, which impart a blue color. *C. ternatea* flowers range from bright blue to deep blue and are used as a natural food colorant (Siti Azima et al., 2017). This deep blue color results in reduced brightness and yellowness in the fermented goat milk. Higher concentrations of CTFE give the product a darker color, which may negatively impact consumer preference (Juliyarsi et al., 2023).

***Antioxidant capacity and total phenolic content*:** The antioxidant capacity and total phenolic content of fermented goat milk are shown in Fig. 3. Overall, the addition of SBH and CTFE significantly affected ($P<0.05$) both antioxidant capacity and total phenolic content. Higher concentrations of SBH and CTFE led to increased antioxidant capacity and total phenolic content, attributed to

Table 2. L^*, a^*, and b^* value of fermented goat milk with different levels of SBH and CTFE

	SBH levels (%)	CTFE levels (%)				Average
		0	5	10	15	
L^*	0	81.40±5.21	74.50±3.44	74.90±3.12	69.70±6.47	75.13±4.80^{b}
	4	83.50±8.10	75.70±5.83	77.80±1.56	79.40±3.40	79.10±3.30^{ab}
	8	78.10±12.38	74.30±5.05	79.80±3.44	78.60±3.97	77.70±2.38^{ab}
	12	83.00±8.35	77.90±12.16	82.30±6.48	80.80±4.06	81.00±2.26^{a}
	Average	81.50±2.44^{a}	75.60±1.65^{b}	78.70±3.13^{ab}	77.13±5.03^{b}	
a^*	0	−1.40±1.06	−0.60±0.20	−0.10±0.23	−0.60±1.38	−0.68±0.54
	4	−0.80±0.56	−1.30±0.61	−1.00±0.40	−1.40±1.59	−1.13±0.28
	8	−0.50±0.31	−1.10±0.55	−1.50±1.93	−1.10±1.18	−1.05±0.41
	12	−1.00±0.82	−1.60±0.20	−1.00±0.73	−0.70±0.42	−1.08±0.38
	Average	−0.93±0.38	−1.15±0.42	−0.90±0.58	−0.95±0.37	
b^*	0	5.30±0.67	5.10±4.74	−0.40±1.21	−2.90±0.75	1.78±4.09^{c}
	4	6.80±0.76	5.40±0.76	3.00±2.49	0.60±2.17	3.95±2.73^{b}
	8	7.80±3.48	6.80±3.20	4.20±3.07	2.40±3.11	5.30±2.46^{ab}
	12	9.70±1.42	5.70±2.23	4.70±2.73	4.40±4.64	6.13±2.45^{a}
	Average	7.40±1.85^{a}	5.75±0.74^{a}	2.88±2.30^{b}	1.13±3.10^{c}	

Different letters in the row and column indicate a significant difference (P<0.05).
L^*, brightness; a^*, redness; b^*, yellowness; SBH, stingless bee honey; CTFE, *Clitoria ternatea* flower extract.

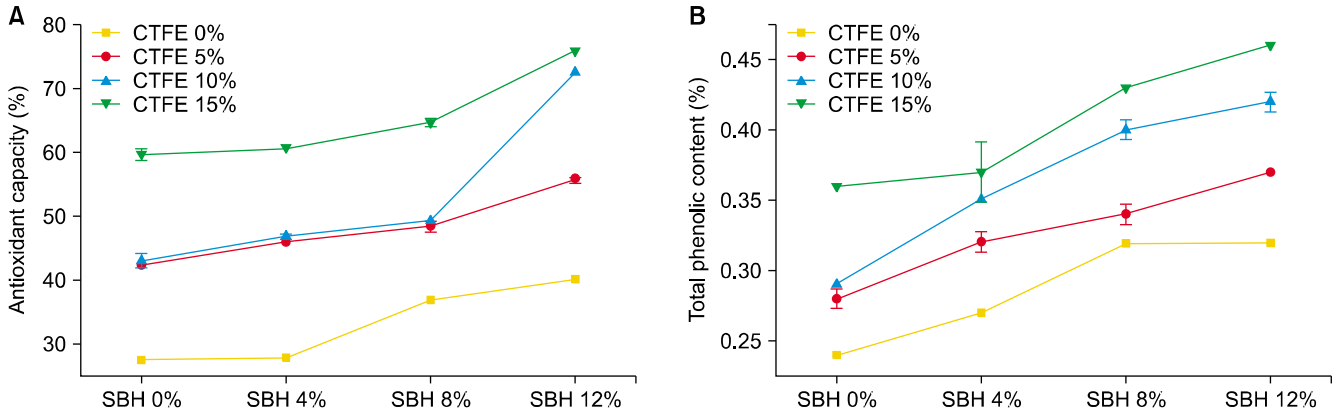

Fig. 3. Antioxidant capacity (A) and total phenolic content (B) of fermented goat milk with varying levels of SBH and CTFE. SBH, stingless bee honey; CTFE, *Clitoria ternatea* flower extract.

the antioxidant and phenolic components present in both SBH and CTFE. The antioxidant capacity is derived from the phenolic and flavonoid components in SBH and CTFE. Our previous study reported that *H. itama* honey exhibits DPPH inhibition activity (IC_{50}) and a total phenolic content of 21.6 mg/mL and 52.61 mg GAE/g, respectively (Melia et al., 2024). The phenolic and flavonoid components in SBH include major components such as gallic acid, salicylic acid, *p*-coumaric acid, kaempferol, naringin, luteolin, catechin, apigenin, and taxifolin (Al-Hatamleh et al., 2020).

Additionally, CTFE is known to contain various phenolic components, including epigallocatechin, quercetin, kaempferol, and myricetin, with anthocyanins being the most abundant phenolic component in CTFE. These anthocyanins, often referred to as ternatin, are a form of polyacylated anthocyanins (Escher et al., 2020; Vidana Gamage et al., 2021). In this study, fermented goat milk without SBH and CTFE also demonstrated antioxidant capacity, with a total phenol content of 27.52% and 0.24 mg GAE/g, respectively. This indicates that antioxidant compounds are derived from the fermentation of goat milk by *L. plantarum* SNT13. El-Fattah et al. (2018) reported that milk fermentation can produce peptides with antioxidant properties. Furthermore, Liu et al. (2024) found that goat milk fermentation generates metabolites such as 3-dehydroshikimic acid, 2-heptanone, and quercetin, which also possess antioxidant activity.

The use of SBH and CTFE in fermented goat milk represents a form of product diversification, aiming to develop new products enriched with functional ingredients. Incorporating SBH and CTFE into the fermentation process alters the physicochemical and microbiological characteristics of goat milk compared to fermentation without these additives. SBH and CTFE significantly influenced the proximate composition, color, total LAB, anti-

oxidant capacity, and total phenolic content but did not affect the TTA and pH of the samples. Notably, the carbohydrate content and total LAB count increased substantially, especially at higher concentrations of SBH and CTFE. Honey addition enhanced the L^* and b^* values, while CTFE significantly reduced the L^* and a^* values. Furthermore, the antioxidant capacity and total phenolic content rose with higher concentrations of SBH and CTFE. The antioxidant and antimicrobial properties of SBH and CTFE may provide health benefits, potentially leading to products designed for specific health concerns such as digestive health or immune support. However, the stability of fermented goat milk remains uncertain; further research is needed to assess storage stability, particularly regarding the retention of antioxidant activity and other functional properties over time, to ensure the product's continued efficacy.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Concept and design: SM. Analysis and interpretation: SM, RDS, SNA, R. Data collection: SM, IJ. Writing the article: SM, RDS. Critical revision of the article: SNA, IJ. Final approval of the article: all authors. Statistical analysis: RDS. Obtained funding: SM. Overall responsibility: SM.

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