

PHYSICOCHEMICAL AND SENSORY PROPERTIES OF STEVIA-SUPPLEMENTED GOAT MILK YOGURT

M. Faisal^{1,2,3,✉}, Azwar¹, A. Bakar¹, D. A. Annisa¹, and M. Rahmah¹

¹Department of Chemical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

²Environmental Engineering Program, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia

³Halal Research Center, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia

✉Corresponding author: mfaisal@usk.ac.id

ABSTRACT

This study evaluated the physicochemical and sensory characteristics of goat milk yogurt supplemented with stevia (*Stevia rebaudiana Bertoni*) as a natural alternative to sugar and a potential source of calcium. Yogurt was prepared from 500 mL of goat milk, supplemented with 6% (v/v) skim milk, fermented with *Lactobacillus bulgaricus* and *Streptococcus thermophilus* at 45 °C, and subsequently supplemented with stevia at four formulation levels: 0, 0.05, 0.15, and 0.25 g. The products were analyzed for pH, lactic acid, fat, protein, moisture, ash, and calcium content, and evaluated organoleptically by 30 panellists using a 5-point hedonic scale. All formulations complied with the Indonesian National Standard (SNI) for yoghurt. Stevia addition significantly increased calcium content, with the 0.25 g treatment showing the highest value (49.29 mg). Sensory evaluation indicated that the 0.05 g sample obtained the highest mean aroma score (4.03), the 0.15 g sample achieved the highest taste score (4.70), and the 0.25 g sample had the highest texture score (4.63). Overall, stevia supplementation altered the calcium content and sensory properties of goat milk yogurt, with the 0.15 g formulation recommended as optimal due to superior taste acceptability. The development of a stevia-supplemented goat milk yoghurt as a potentially healthier food alternative is relevant to Sustainable Development Goal 3 (SDG-3): Good Health and Well-being, particularly in supporting research and innovation toward nutritious and health-oriented food products.

Keywords: Goat Milk Yoghurt, Physicochemical, *Stevia Rebaudiana Bertoni*, Calcium, Sensory.

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INTRODUCTION

Milk is an essential human food due to its high nutritional content, including fat, protein, vitamins, and minerals. Although cow's milk is the most widely consumed, goat milk offers several superior nutritional qualities. It is more easily digestible, contains antioxidants and vitamins, and has a lower allergenic potential.¹ Moreover, goat milk is increasingly valued in modern diets for its richness in amino acids, bioactive peptides, and minerals.^{2,3} The development and improvement of nutritious dairy-based foods are also relevant to Sustainable Development Goal 3 (SDG-3): Good Health and Well-being, which emphasises the importance of promoting health and well-being. In this context, research on nutrient-rich and potentially healthier food products can contribute to the broader effort to support healthy dietary choices. One functional food product that has received considerable attention from food scientists is probiotic fermented milk, particularly yoghurt. Yoghurt is produced from pasteurised milk fermented with *Streptococcus thermophilus* and *Lactobacillus delbrueckii subsp. bulgaricus*^{4,5} until a characteristic acidity, aroma, and flavour are achieved, with or without the addition of other ingredients. Beyond serving as a nutritious beverage, yoghurt has been reported to contribute to the prevention of various diseases.⁶ Nevertheless, commercially available yoghurt typically contains relatively low levels of calcium, suggesting that its nutritional quality may not yet be optimal. In yoghurt production, the addition of sweeteners is essential to enhance consumer acceptability. Commonly used sweeteners include sucrose, sucralose, allulose, xylitol, and aspartame.⁷ However, each of these has limitations. Sucrose is high in calories, while synthetic sweeteners have been associated with potential health risks, including possible carcinogenic effects, which restrict their widespread use.⁸ As a result, natural sweeteners such as stevia, extracted from *S. rebaudiana* leaves, have emerged as healthier alternatives. Stevia exhibits a remarkably

high sweetening power, estimated to be about 300 times sweeter than a 0.4% sucrose solution.⁹ It is non-caloric, low in carbohydrates, and its sweetness is derived from steviol glycosides present in the leaves.^{10,11} Stevia also contains a high concentration of calcium, making it a promising sweetener for yogurt intended for diabetic individuals.^{12,13} In addition, stevia has a long history of use in traditional medicine for conditions such as diabetes, hypertension, tumours, and dental caries.^{14,15} Therefore, this study was conducted to evaluate the physicochemical and sensory properties of goat milk yoghurt supplemented with stevia as a natural sweetener and a potential calcium source.

EXPERIMENTAL

Preparation of Starter Culture

Starter cultures of *L. bulgaricus* (12.5 mL) and *S. thermophilus* (12.5 mL) were prepared, corresponding to 10% of 250 mL full cream milk. The milk was heated at 85–90 °C for 15 minutes to eliminate undesirable microorganisms while being stirred to prevent coagulation. The milk was then cooled to 45 °C before inoculation with lactic acid bacteria. After homogenization, the mixture was transferred into a closed container and incubated at room temperature (30 °C) for 24 hours.

Sample Preparation

Goat milk (500 mL) was mixed with 31.19 g skim milk (6% w/v) and homogenised. The mixture was pasteurised at 85–90 °C for 15 minutes with constant stirring to prevent clotting, then cooled to 45 °C prior to fermentation.

Yoghurt Production and Quality Analysis

Pasteurized goat milk (500 mL) was inoculated with 12.5 mL *L. bulgaricus* and 12.5 mL *S. thermophilus* starter cultures (5% v/v), followed by homogenization. Fermentation was performed at 45 °C for 3, 6, and 9 hours using a yoghurt maker (Vitaclay-10131427). The resulting yoghurt was then supplemented with stevia as a natural sweetener. Stevia was added and thoroughly mixed until homogeneous. Four treatments were applied to 125 mL portions (derived from 500 mL total): P1 (control, without stevia), P2 (0.05 g stevia), P3 (0.15 g stevia), and P4 (0.25 g stevia). The yoghurt samples were analyzed for proximate composition (fat, protein, moisture, ash, lactic acid, and calcium) and evaluated organoleptically following standard methods.

Sensory Evaluation

The Sensory evaluation was conducted to assess aroma, flavour, and texture (viscosity), each on a 5-point hedonic scale. The panel consisted of 30 untrained individuals aged 19–21 years. The scores obtained from the evaluation were analysed to determine the mean hedonic score using the following formula:

$$\text{Mean hedonic score } x = \frac{\sum xi}{n}$$

Where: x = mean hedonic score, xi = hedonic score by each panelist, n = total number of panelists

RESULTS AND DISCUSSION

Yogurt Quality Assessment

Yogurt suitable for consumption must exhibit physical and sensory properties that comply with established standards. Table-1 presents the characterization results of the yogurt based on the Indonesian National Standard (SNI).¹⁶ Table-1 shows that sample T6 can be categorised as the most optimal, as it fulfilled the required yogurt characteristics more effectively than the other treatments. Therefore, it can be used as a reference for the fermentation time of goat milk yogurt.

Physical Quality Test Results

Observations indicated that sample T3 remained a non-viscous liquid and thus did not meet the SNI standard for yogurt, likely due to suboptimal lactic acid bacteria activity. In contrast, samples T6 and T9 had thickened into a viscous liquid characteristic of yogurt. In the aroma test, samples T3, T6, and T9 all possessed the typical yogurt aroma, and the goat odour of the goat milk was reduced or almost absent. Yogurt has a characteristic acidic aroma resulting from the fermentation process, during which lactose in the milk is converted into lactic acid by lactic acid bacteria.¹⁷ This aroma is caused by volatile compounds

formed during fermentation, which produce the characteristic sour scent and help mask the goaty odour of goat milk. The aroma parameter is closely related to the taste parameter.¹⁸ In the taste test, all three samples had the characteristic acidic taste of yoghurt. The results of texture observation showed that all three yoghurts had a homogeneous texture. The characteristic flavour of yoghurt is derived from chemical compounds such as lactic acid, acetaldehyde, acetic acid, diacetyl or 2,3-pentanedione, and other volatile substances.¹⁹

Table-1: Yogurt characterization Based on SNI

No.	Parameter	Unit	SNI Standard	Treatment		
				T3 (3 hours)	T6 (6 hours)	T9 (9 hours)
1	Appearance					
	Visual & consistency	-	Thick to semi-solid liquid	Thin liquid	Thick liquid	Thick liquid
	Aroma	-	Normal/characteristic*)	Normal/characteristic*)	Normal/characteristic*)	Normal/characteristic*)
	Taste	-	Tart/Characteristic	Tart/Characteristic	Tart/Characteristic	Tart/Characteristic
	Concentration	-	Homogeneous	Homogeneous	Homogeneous	Homogeneous
2	Lactic Acid	%(w/w)	0.5–2.0	0.45	1.12%	1.71
3	pH	-	3.8–4.5	4.9	3.9	3.3
4	Moisture content	%(w/w)	85	91.38	84.97	77.02
5	Ash content	%(w/w)	Max 1.0	0.78	0.80	0.81
6	Protein	%(w/w)	Min 2.7	8.24	5.45	4.21
7	Fat content	%	Min 3.0	6.64	4.98	6.23

*) characteristic refers to the typical aroma and taste expected of properly fermented yogurt

Lactic Acid Content

Table-1 shows that the lactic acid content in T3, T6, and T9 was 0.45%, 1.12%, and 1.71%, respectively. The lactic acid content in sample T3 (0.45%) was below the SNI standard (0.5–2.0%), while the levels in samples T6 (1.12%) and T9 (1.71%) were within the required SNI range. A longer fermentation time resulted in increased lactic acid production because lactose is continuously converted into lactic acid by lactic acid bacteria during fermentation. The lactic acid level in sample T6 was more suitable to the SNI standard as its value was within the optimal range, neither too close to the lower limit (0.5%) nor the upper limit (2%). *S. thermophilus* grows more rapidly in the initial stages of fermentation, producing lactic acid that lowers the medium's pH.¹⁸ At pH 4.2–4.4, the growth of *S. thermophilus* begins to decline; however, this condition stimulates the growth of *L. bulgaricus*, which produces a larger quantity of lactic acid, further reducing the pH to 3.5–3.8. The synergy between these two bacteria causes the denaturation of milk proteins, resulting in a semi-solid texture and the characteristic acidic taste of yoghurt. Furthermore, *L. bulgaricus* breaks down fatty acids into aromatic compounds that contribute to the typical yoghurt flavour.

pH Test Results

Based on Table-1, the pH values for samples T3, T6, and T9 were 4.9, 3.9, and 3.3, respectively. These results indicate that a longer incubation time leads to a lower pH due to the continued activity of lactic acid bacteria fermenting lactose into lactic acid. This finding aligns with the study by Zhao *et al.*¹⁹, which reported a pH of approximately 4.7 after 4–6 hours of fermentation, and a study on goat milk–avocado yogurt by Wulan²⁰, which observed a pH decrease to 4.5 by the eighth hour of fermentation. In this study, sample T6 with a pH of 3.9 met the SNI standard, while T3 (pH 4.9) and T9 (pH 3.3) fell outside the standard range.

The higher pH of T3 was due to suboptimal lactic acid production, whereas the excessively low pH of T9 resulted from prolonged lactic acid production throughout the extended fermentation. Yogurt with a pH of 3.9–4.2 under cold storage conditions is at risk of rapid spoilage if contaminated with mould or yeast.²¹

Fat Test Results

A good fat content for yogurt made from pure milk is a minimum of 3%. Table-1 shows that the fat content of samples T3, T6, and T9 was 6.64%, 4.98%, and 6.23%, respectively. These indicate that all three samples met the standard. A longer fermentation time resulted in lower fat content, as the lactic acid bacteria utilized the milk fat as a nutrient source during fermentation. The increased fat content in sample T9 is attributed to over-fermentation, leading to a denser texture and coagulation. Lactic acid bacteria produce the lipase enzyme, which breaks down fat into fatty acids; these are subsequently broken down into compounds that contribute to the characteristic yogurt aroma.¹⁸

Protein Test Results

Protein is a crucial component in both milk and yogurt, determining the product's nutritional value. A higher protein content indicates better nutritional quality. Protein also plays a role in texture formation through interactions between casein and whey proteins during fermentation.²² Table=1 shows that the protein content of samples T3, T6, and T9 was 8.24%, 5.45%, and 4.21%, respectively. These show a tendency for protein content to decrease with longer fermentation time. This finding differs from previous studies that reported no significant effect of fermentation on yogurt protein content. An increase in measurable protein can occur due to proteolytic enzyme activity, which hydrolyses proteins into smaller, soluble amino acids. However, the protein content of yogurt is also highly dependent on the quality of the raw material, particularly the milk. Higher protein content in the milk results in better quality yogurt.²¹ Hafeez *et al.*²³ reported that goat milk yogurt with added carrot powder had a protein content of approximately 3.4 g/100 g.

Water Content Test Results

As seen on Table-1, the water content of samples T3, T6, and T9 was 91.38%, 84.97%, and 77.02%, respectively. This difference in water content is related to the product's texture; the thin yogurt (T3) had high water content, while the thick yogurt (T9) showed lower water content. An increased starter concentration accelerates the formation of a thicker texture, thereby reducing water content. Compared to the SNI standard for water content in yogurt (85%), only sample T6 complied. Sample T3 had excessively high water content, and T9 had excessively low water content; thus, both failed to meet the SNI criteria.

Ash Content

Ash content reflects the mineral content in yogurt. The analysis results in Table-1 show that the ash content of samples T3, T6, and T9 was 0.78%, 0.80%, and 0.81%, respectively. All these values are below the maximum SNI limit of 1.0%, thus meeting the quality standard. A higher ash content indicates a greater mineral content in the product.²³ Differences in the ash content of yogurt are primarily influenced by the mineral content of the milk, such as potassium, phosphorus, and calcium, as well as the addition of skim milk, which can increase mineral levels.²⁴

Calcium Content after Stevia Supplementation

Based on Fig.-1, the calcium content of yogurt with the addition of 0 g, 0.05 g, 0.15 g, and 0.25 g of stevia sweetener was 41.34 mg, 46.11 mg, 47.17 mg, and 49.29 mg, respectively. These data show an increase in calcium content corresponding to the amount of stevia added. The calcium content of pure goat milk (134 mg/100 ml) decreased after processing into yogurt, reaching 49.29 mg in the treatment with 0.25 g of stevia. This decrease is suspected to be related to the fermentation process. Diantoro *et al.*²⁵ stated that a 48-hour fermentation period affects the calcium content in yogurt.

The increase in calcium content in yogurt with added stevia is linked to the high calcium content in stevia itself, which is 464.6 mg/100 g. A greater addition of stevia resulted in a higher calcium content in the yogurt.

Therefore, the use of stevia not only increases the calcium content but also enriches the nutritional value. The increased calcium content observed with stevia supplementation highlights the potential of this formulation for developing nutrient-oriented dairy products. From a broader perspective, these findings are relevant to SDG 3 (Good Health and Well-being), as they support research and innovation toward the development of nutritious and potentially healthier food alternatives.

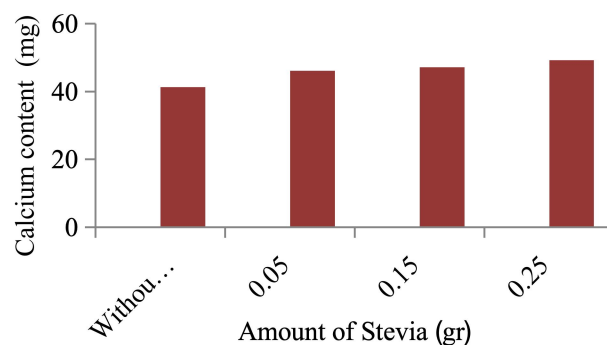


Fig.-1: Calcium Content in Yogurt with Stevia Supplementation

Sensory Evaluation

The organoleptic evaluation was conducted on all samples with a 6-hour fermentation time. The sample descriptions are as follows: Treatment A= without stevia addition; Treatment B= with 0.05 g stevia addition; Treatment C= with 0.15 g stevia addition; Treatment D = with 0.25 g stevia addition. The evaluation assessed aroma, taste, and texture, and the results are presented in Table-2.

Sensory Evaluation Results for Aroma

Consumer preference for aroma is an important sensory parameter. The results of the aroma evaluation for goat milk yogurt are presented in Table-2.

Table-2: Results of aroma evaluation

Panelist	Treatment				Panelist	Treatment			
	A	B	C	D		A	B	C	D
1	2	3	3	3	16	4	4	4	4
2	2	3	3	3	17	4	4	4	4
3	3	3	3	3	18	4	4	4	4
4	3	3	3	3	19	4	4	4	4
5	3	3	3	3	20	5	4	5	4
6	3	3	3	3	21	5	5	5	4
7	3	3	3	3	22	5	5	5	5
8	3	3	3	3	23	5	5	5	5
9	3	4	3	3	24	5	5	5	5
10	3	4	3	3	25	5	5	5	5
11	4	4	3	3	26	5	5	5	5
12	4	4	4	3	27	5	5	5	5
13	4	4	4	4	28	5	5	5	5
14	4	4	4	4	29	5	5	5	5
15	4	4	4	4	30	5	5	5	5
Average						3.9	4.03	4	3.9

Scale anchors: 1= Dislike, 2= Slightly dislike, 3= Neutral, 4= Slightly like, 5= Like

The mean scores for aroma in treatments A, B, C, and D were 3.9 (Slightly like), 4.03 (Slightly like), 4.0 (Slightly like), and 3.9 (Slightly like), respectively. Treatment B was slightly more preferred, with approximately 37% of panelists giving a score of 5, while the remainder gave scores of 4 and 3. The evaluation results indicate that the different levels of stevia addition did not significantly affect the aroma, as stevia primarily functions as a sweetener without contributing a significant aromatic effect. Some panellists said that yogurt with added stevia sweetener had a herbal-like aroma. Powdered stevia sweetener no longer possesses a distinct aroma; thus, it did not significantly impact the yogurt's aroma in this test. In contrast, stevia sweetener in leaf form has a characteristic aroma that can significantly affect the product's scent. The acidic aroma in yogurt is produced by *L. bulgaricus*, which is responsible for aroma formation, while *S. thermophilus* contributes to flavor development. Together, these bacteria reduce milk lactose to lactic acid and various aromatic and flavor components.²⁷

Sensory Evaluation Results for Taste

The results of the taste evaluation for goat milk yogurt are presented in Table-3. From Table-3, the mean taste scores for treatments A, B, C, and D were 1.76 (Slightly dislike), 3.63 (Slightly like), 4.7 (Like), and 3.9 (Slightly like), respectively. Treatment C was the most preferred, with approximately 70% of panelists giving the highest score of 5, and the remainder giving scores of 4 and 3. The results demonstrate that increasing the amount of stevia sweetener enhanced the sweetness of the yogurt across all treatments. Treatment C was the most preferred because its sweetness did not introduce a bitter aftertaste. In contrast, Treatment D, while sweeter than C, produced a bitter taste, making the yogurt less pleasant. Treatment A was the least preferred due to the absence of stevia and consequent lack of sweetness. Replacing sucrose with stevia significantly affected the taste; however, the bitter taste associated with stevia is due to its stevioside components. The acidic taste of the yogurt originates from *S. thermophilus*, which converts lactose into lactic acid during the milk fermentation process.²⁸

Table-3 Results of Sensory Evaluation for Taste

Panelists	Treatment				Panelists	Treatment			
	A	B	C	D		A	B	C	D
1	1	3	4	2	16	2	4	5	4
2	1	3	4	2	17	2	4	5	4
3	1	3	4	3	18	2	4	5	4
4	1	3	4	3	19	2	4	5	5
5	1	3	4	3	20	2	4	5	5
6	1	3	4	3	21	2	4	5	5
7	1	3	4	3	22	2	4	5	5
8	1	3	4	3	23	2	4	5	5
9	1	3	4	4	24	2	4	5	5
10	1	3	5	4	25	2	4	5	5
11	2	3	5	4	26	2	4	5	5
12	2	3	5	4	27	2	4	5	5
13	2	3	5	4	28	2	5	5	5
14	2	3	5	4	29	2	5	5	5
15	2	4	5	4	30	5	5	5	5
Average						1.76	3.63	4.7	4.06

Scale anchors: 1= Dislike, 2= Slightly dislike, 3= Neutral, 4= Slightly like, 5= Like

CONCLUSION

Fermentation time significantly influenced the quality of goat milk yogurt. While an optimal duration is necessary, extending fermentation could reduce quality, as reflected in changes to physicochemical parameters. The optimal fermentation time identified in this study was 6 hours. Stevia addition increased the calcium content of the yogurt, with the highest value (49.29 mg) observed at the 0.25 g formulation. However, organoleptic evaluation indicated that yogurt with 0.15 g stevia was the most preferred by panellists, particularly in terms of taste. A key finding is that higher levels of stevia addition enhanced calcium content but also introduced a bitter aftertaste. These results provide a valuable reference for the food industry in developing goat milk yogurt products with improved nutritional value and consumer acceptability using natural sweeteners. The findings are relevant to SDG-3 (Good Health and Well-being), as they support research and innovation toward the development of nutritious and potentially healthier food alternatives.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-3: Good Health and Well-being*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

Muhammad Faisal  <https://orcid.org/0000-0001-5199-3477>

Azwar  <https://orcid.org/0009-0003-7301-3160>

Abubakar  <https://orcid.org/0009-0001-9016-3094>

Dinda Alfath Annisa  <https://orcid.org/0009-0002-1139-7368>

Mawaddah Rahmah  <https://orcid.org/0009-0006-6308-2789>

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