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Physicochemical, Microbiological and Sensory Characteristics of Goat Milk (*Capra aegagrus hircus*) Yogurt with Mungbean (*Vigna radiata*) Extract Enrichment

Karakteristik Fisikokimia, Mikrobiologi dan Sensori Yogurt Susu Kambing (Capra aegagrus hircus) Diperkaya Sari Kacang Hijau (Vigna radiata)

Hardi Firmansyah[1]*, Risti Rosmiati[1], Iza Ayu Saufani[1], Zulfa Nur Hanifa[1]

[1]Nutrition Study Program, Faculty of Engineering, Universitas Negeri Medan, Medan, Indonesia

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Correspondent:
Hardi Firmansyah
hardigizi@unimed.ac.id

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ABSTRACT

Background: Goat milk offers more superior health benefits than cow milk, while mung beans possess high nutrient contents and promote probiotic growth. Enhancing goat milk yogurt with mung bean extract through fermentation can improve product quality and consumer acceptance by mitigating the off-flavors.

Objectives: To determine the physicochemical, microbiological, and sensory characteristics of goat milk yogurt with mung bean extract enrichment.

Methods: A Completely Randomized Design (CRD) was employed with four different formulation ratios of goat milk and mung bean extract at 100%:0%, 85%:15%, 70%:30%, and 55%:45%. Physicochemical properties, such as pH, acidity, ash, total solids, protein, fat, and total sugar were analyzed. The total amount of lactic acid bacteria (LAB) was counted as microbiological analysis component. Sensory evaluations were conducted using hedonic and hedonic quality tests. All parameters were analyzed using a one-way ANOVA, and the best formulation ratio was determined using the De Garmo method.

Results: pH of the product was 3.96 to 4.12, as acidity increased along with a higher mung bean extract. Ash, protein, fat, and total solids content varied moderately across samples, influencing the nutritional profiles of the yogurt. The amount of LAB peaked at 8.95 Log CFU/ml in the 85%:15% formulation ratio. Sensory evaluations showed the highest score of texture and overall assessments in the 85%:15% formulation ratio by achieving optimal tanginess, sweetness, and texture balance.

Conclusions: Enriching goat milk yogurt with mung bean extract can significantly influence the physicochemical, microbiological, and sensory characteristics. The formulation of 85% goat milk and 15% mung bean extract provides the more enhanced nutritional value, probiotic potential, and consumer acceptance.

INTRODUCTION

Goat milk (*Capra aegagrus hircus*) has garnered substantial scientific attention due to its superior nutritional properties in comparison to cow milk. Goat milk is advantageous for individuals with lactose intolerance and allergies to cow milk proteins. Studies have demonstrated that goat milk contains elevated levels of essential vitamins, minerals, and bioactive compounds, contributing to its health benefits. Its distinctive composition, which includes short and medium-chain fatty acids, enhances digestive efficiency and mitigates allergic reactions[1–3]. Moreover, studies indicate that goat milk is easier to digest, attributed to its smaller fat globules and lower concentrations of allergenic proteins, such as αS1-casein, which are more abundant in cow milk[4,5].

Fermentation into yogurt enhances the nutritional and functional properties of goat milk by proliferating beneficial probiotics for gut health, like lactic acid bacteria. Probiotic strains, *Lactobacillus acidophilus*, have shown promising survival rates in goat milk yogurt, thereby increasing its functional benefits[6,7]. To support the overall health, the fermentation process to produce goat milk yogurt also improves nutrient bioavailability and augments anti-inflammatory and anti-allergic properties[1,8].

Despite its nutritional advantages, goat milk yogurt is often associated with strong and pungent flavor that limits the consumer acceptance. These characteristics, often referred to "*goaty*" flavors, pose a significant barrier to its widespread adoption compared to the milder flavor of cow milk yogurt[9]. Improving the goat milk yogurt flavor is urgently needed to increase the consumer acceptance. As the dairy alternatives demand grows, overcoming this sensory barrier is crucial. Despite its health benefits, the strong flavor of goat milk yogurt

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limits its market value compared to cow milk yogurt, making flavor enhancement essential. Previous studies have explored various methods to enhance the sensory appeal of goat milk yogurt, including adding flavor enhancers or plant-based ingredients, but the solutions remain inadequate[10,11]. One potential solution to this sensory challenge is incorporating goat milk yogurt with mung bean extract. Mung beans are known for their high nutritional value and neutral flavor, which could help mask the strong taste of goat milk yogurt, while enriching the product with additional health benefits. Moreover, mung beans contain high bioactive compounds that promote probiotic growth during fermentation, enhancing the microbiological profiles and overall sensory characteristics[12].

Mung beans (*Vigna radiata*) have been extensively studied for their nutritional and health-promoting properties. Besides rich in protein, vitamins, and phytochemicals, mung beans also exhibit potent antioxidant and anti-inflammatory properties, ideal as a functional ingredient in food formulations[13,14]. Their inclusion in dairy products has been shown to improve the nutritional profile, texture, and overall quality of the milk products[15]. In yogurt production, mung bean extract demonstrated the high proliferation of beneficial probiotic bacteria, particularly lactic acid strains essential for fermentation[16,17]. This symbiotic relationship between plant-based prebiotics and probiotics is crucial to enhance the functional properties of fermented dairy products[18]. Studies also showed that mung bean extract could improve the sensory attributes of yogurt by neutralizing undesirable flavors and enhancing the texture to appeal more consumers[9,11]. Incorporating mung bean extract into goat milk yogurt could also improve the yogurt's physicochemical properties. For example, mung bean extract enhanced the viscosity and creaminess of yogurt, contributing to a more desirable texture[12,15]. Additionally, the prebiotic properties of yogurt could stimulate the growth of probiotics, thus enhancing the yogurt's microbiological and nutritional profile.

Despite these promising findings, a significant gap occurs regarding the application of mung bean extract in goat milk yogurt. Meanwhile their prebiotic effect on probiotic growth is well-documented in other dairy products, yet little is known about how these benefits can be applied for goat milk yogurt formulations. Most studies have focused on cow milk yogurt, leaving goat milk yogurt unexplored[10]. Moreover, the sensory implications of incorporating mung bean extract to goat milk yogurt have not been thoroughly investigated. As strong flavor profile occurs in goat milk, understanding how mung bean extract affects the taste, aroma, and texture of goat milk yogurt is critical to improve the consumer acceptance[19]. Moreover, the physicochemical interactions between mung bean extract and goat milk proteins are limited.

This study evaluated the physicochemical, microbiological, and sensory characteristics of goat milk yogurt with mung bean extract enrichment. The study determined the amount of mung bean extract that could affect key parameters, such as pH, acidity, ash, protein, fat, total sugar, and non-fat solids. Furthermore, this study assessed the yogurt's microbiological profile, focusing on the growth of beneficial lactic acid bacteria and its sensory characteristics, including taste, texture, and overall consumer acceptability. This study integrates mung bean extract into goat milk yogurt. Hypothetically, enriching goat milk yogurt with mung bean extract will lead to significant improvements in physicochemical properties, microbiological profile enhancement, and sensory appeal improvement. By addressing the gaps related to the sensory and physicochemical challenges of goat milk yogurt, this study contributes to the field of food science and the development of functional dairy products.

METHODS

Experimental Design

A Completely Randomized Design (CRD) was employed with four different treatment formulation ratios of goat milk and mung bean extract, namely 100:0, 85:15, 70:30, 55:45, and two replications. After mixing and the pasteurization process, 7.5% of the product volume was added with lactic acid bacteria (BAL) to increase safety, provide texture, and introduce beneficial compounds like organic acids and vitamins. The yogurt samples were incubated for 4 hours and fermented for 24 hours at room temperature in a sealed container to allow proper microbial activity. After the fermentation process, the yogurt was refrigerated to terminate the fermentation and maintain the product quality.

Materials

All materials in this study were obtained from traditional markets in North Sumatra, Indonesia, to ensure the use of locally available ingredients. These materials included goat milk (*Capra aegagrus hircus*), mung bean (*Vigna radiata*), yogurt starter, and sugar. Goat milk was obtained from local dairy farms and used as the primary base for yogurt production. The milk used was a highly qualified fresh milk that has been pasteurized to ensure safety and consistency in the production process. The yogurt starter culture used in this study was *Biokul®* plain yogurt (*PT. Diamond Cold Storage, Indonesia*), which contains *Lactobacillus acidophilus* and *Bifidobacterium* species. These strains were selected for their proven ability to aid the fermentation process, ensuring the presence of beneficial lactic acid bacteria (LAB). The *Biokul®* yogurt was chosen based on its accessibility and availability in yogurt fermentation[20,21]. All materials used in the physical, chemical, and microbiological analyses were selected and processed based on the SNI 2981:2009 standards for yogurt[22].

Sample Preparation

Mung bean extract was prepared a day before the yogurt production. After soaking the mung beans in water for 9 hours at a 1:2 ratio, the beans were grounded with water in a 1:3 ratio, filtered using a sterilized cloth, and stored in an airtight container to avoid contamination. For yogurt production, milk was pasteurized in the glass containers for 15 minutes. In the formulation mixing process between goat milk and mung

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bean extract, 10% sugar was added to each mixture. This activity was based on previous studies[23], that explored the optimal balance between maintaining the nutritional benefits of goat milk and enhancing the product's sensory properties with mung bean extract. These proportions were chosen to explore the impact of various mung bean extracts on the physicochemical and sensory characteristics of goat milk yogurt. After the mixing process, homogenization was performed to break down fat clumps and improve the product's texture and low-fat content. Pasteurization process was employed at 70°C for 15 minutes. Pasteurization was performed to ensure minimal loss of nutritional value, while maintaining the freshness and proper taste of the product.

Parameters

The key physicochemical parameters measured pH, acidity, fat content, protein content, total non-fat solids, and ash content. All chemical analyses were conducted according to SNI 2981:2009 standards for yogurt[22], ensuring compliance with national regulations. These analyses were conducted in the Food Analysis Laboratory, Nutrition Study Program, Universitas Negeri Medan with accurate and reliable data. The microbiological analysis was conducted to determine the total amount of lactic acid bacteria (LAB) in the yogurt, using standard microbiological techniques.

For organoleptic test, a hedonic test was conducted using 30 untrained panelists. These panelists were selected based on specific inclusion and exclusion criteria to maintain sensory perception consistency. The inclusion criteria required by panelists are nutrition students who have completed a coursework related to sensory test and were familiar with organoleptic evaluation methods. All panelists were selected based on their interests of yogurt and their lack of allergies to milk proteins or dairy-based products. These criteria were critical because the sensory evaluations were uninfluenced by external factors such as allergies. The panelists evaluated several sensory attributes, such as flavor, aroma, color, thickness, and homogeneity using a five-point Likert scale. A hedonic quality test was also conducted on the same attributes to assess the overall sensory quality of the yogurt.

Statistical Analysis

The physicochemical and sensory data were statistically analyzed using an Analysis of Variance (ANOVA) to determine significant differences between the four yogurt formulation ratios of goat milk and mung bean extract (100:0, 85:15, 70:30, 55:45) across the various parameters. The ANOVA was applied to evaluate the differences in key parameters, such as pH, texture (hedonic quality), and the count of lactic acid bacteria (LAB). These parameters were chosen because they showed statistically significant differences among the formulations, as indicated by a p-value<0.05. After significant differences were identified through ANOVA, De Garmo method was applied to optimize the selection of the most suitable yogurt formula. De Garmo method involves comparing effective values (EV) and weighted values (WV) across the significant parameters. The EV represents the relative performance of each formulation, calculated by comparing the difference between the observed value and the worst-performing formulation to the range between the best and worst formulations. The WV was obtained by multiplying the EV by the assigned weight for each parameter, reflecting its importance in the final product's quality. The formula with the highest total weighted score was considered as the optimal formulation. This study was part of the project entitled "The Effects of Goat Milk Yogurt Enriched with Mung Bean Extract on the Lipid Profile of Male Rats (*Rattus norvegicus*)", which has received ethical approval from the Animal Research Ethics Committee (AREC) of Universitas Sumatera Utara with approval number: 0640/KEPH-FMIPA/2024 on July 25, 2024.

RESULTS AND DISCUSSIONS

The physicochemical and microbiological analyses of goat milk yogurt enriched with mung bean extract revealed important trends, as presented in Table 1. These results are particularly relevant to determine the effects of mung bean extract on yogurt's acidity, pH, fat content, protein levels, ash content, sugar content, non-fat solids, and microbiological profile, primarily in terms of lactic acid bacteria (LAB).

Table 1. Physicochemical and microbiological characteristics of goat milk yogurt with mung bean extract enrichment

Characteristics	Formula[1]			
	F0	F1	F2	F3
Physicochemical characteristics				
pH	4.32 ± 0.04^{a}	4.12 ± 0.02^{b}	4.08 ± 0.06^{b}	4.0 ± 0.06^{b}
Acidity	0.80 ± 0.23^{a}	0.94 ± 0.11^{a}	0.94 ± 0.18^{a}	0.97 ± 0.23^{a}
Ash (%)	0.68 ± 0.18^{a}	0.66 ± 0.04^{a}	0.68 ± 0.14^{a}	0.62 ± 0.06^{a}
Protein (%)	3.46 ± 0.62^{a}	3.20 ± 0.37^{a}	3.08 ± 0.11^{a}	3.07 ± 0.42^{a}
Fat (%)	3.52 ± 0.71^{a}	2.98 ± 0.15^{a}	2.76 ± 0.40^{a}	1.98 ± 0.01^{a}
Total Sugar (%)	12.83 ± 0.97^{a}	11.79 ± 0.87^{a}	10.81 ± 0.72^{a}	9.7 ± 0.68^{a}
Non-Fat Solids (%)	6.28 ± 0.17^{a}	7.38 ± 0.36^{a}	7.95 ± 0.21^{a}	9.0 ± 0.25^{a}
Microbiology parameter				
Lactic Acid Bacteria (Log CFU/ml)	8.4 ± 1.1^{a}	8.95 ± 1.46^{b}	8.83 ± 0.3^{c}	8.79 ± 1.35^{c}

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[1] Formulations ratios of goat milk and mung bean extract (F0=100:0, F1=85:15, F2=70:30, F3=55:45); Numbers with the same letters in the same row indicate no significant difference at α = 5%

As the concentration of mung bean extract increased, the pH of the yogurt decreased while acidity level increased. Specifically, the control sample (F0) obtained the highest pH (4.32), while the highest extract concentration (F3) obtained the lowest pH (4.00). Similarly, the acidity increased from 0.80% in F0 to 0.97% in F3. This clear correlation between higher mung bean extract and lower pH with higher acidity was attributed to the fermentation activities of LAB, which convert sugars into lactic acid, lowering pH and enhancing acidity level[24–26]. Mung bean extract contains nutrients, that could stimulate the LAB proliferation and activity, resulting in increased lactic acid production[27]. A previous study has shown that plant-based fortifications like mung bean could enhance the microbial activity and expedite fermentation processes, as seen in other dairy and plant-based fermentation studies[28]. The pH drop was occurred due to high lactic acid production, as established principles of fermentation[24].

The ash content in the yogurt remained stable across all formulations, ranging from 0.62% in F0 to 0.68% in F3. This condition indicates that the addition of mung bean extract had no significant effect on the mineral contents of the yogurt. This stability in mineral composition aligns with the naturally consistent mineral profiles of both goat milk and mung beans. These results were similar to the previous studies, which reported minimal changes in ash content during the fermentation of goat milk[29,30]. The stable ash content suggests that mung bean extract has no effect on the mineral balance of goat milk yogurt. Instead, the incorporation of mung bean may enhance the overall nutritional value without altering the essential mineral composition, as a critical condition for maintaining the health benefits of yogurt[31]. Furthermore, the consistent mineral profile in goat milk supports the product's nutritional quality, contributing to pursue the consumer appeal, especially for functional dairy products.

The protein content exhibited a slight decrease along with the increased concentration of mung bean extract. Specifically, the control yogurt (F0) showed a protein content of 3.46%, while the sample with the highest mung bean concentration (F3) had a protein content of 3.07%. This reduction was associated with the dilution effect, as mung bean extract contains a lower protein level than goat milk[31]. Despite the slight decrease in yogurt, the protein contents were still within acceptable ranges for yogurt formulations, which retains the nutritional value and texture of the yogurt[32]. This trend is consistent with previous findings that plant-based fortification can lead to reduced protein levels, yet the yogurt still benefits from the bioactive compounds in mung beans, which include antioxidants and phytochemicals that contribute to human health[33]. Thus, while the protein content may slightly decrease, the antioxidant properties of mung bean extract could enhance the yogurt's health profiles[18].

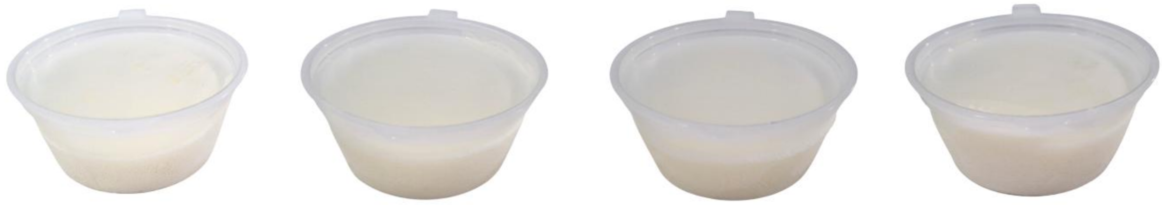
A significant reduction in fat content was occurred as mung bean extract was added by dropping from 3.52% in F0 to 1.98% in F3. This reduction is consistent with findings in previous studies, as the introduction of plant-based ingredients, which contained less fat content than dairy product, could lower fat levels in yogurt[34]. The incorporation of mung bean extract diluted the fat content, while providing additional health benefits, such as reduced cholesterol and hypolipidemic properties[35]. This reduction is particularly appealing to health-conscious consumers, who seek for low-fat or functional foods. While the fat content decreases, the overall quality and nutritional profile of the yogurt are enhanced by the addition of mung bean extract, which compensates the lower fat content by improving the antioxidant capacity and bioactive compounds[36].

The total sugar content decreased along with higher concentrations of mung bean extract, from 12.83% in F0 to 9.70% in F3. This decrease reflects the fermentation process, where LAB metabolize sugars to produce lactic acid, thus reducing the sugar content in the final product[10]. Decreased sugar content was contributed to the increasing acidity level in the yogurt[3]. In contrast, non-fat solids increased from 6.28% in F0 to 9.00% in F3, which indicates that mung bean extract contributes to the solid content of the yogurt. The high fiber and non-digestible carbohydrate content of mung beans may likely boost the non-fat solids, improving the texture of the yogurt[37,38]. The increased non-fat solids also contribute to a more desirable sensory experience, improving the yogurt's overall acceptability to consumers.

The amount of LAB showed a significant increase at 8.95 log CFU/mL in F1, then slightly decreased to 8.79 log CFU/mL in F3. This suggests that mung bean extract serves as a prebiotic, promoting the proliferation of beneficial LAB[9]. The prebiotic effects of mung beans, documented in various studies, highlight their ability to foster LAB growth, essential for the probiotic health benefits of yogurt[39]. LAB is responsible for producing lactic acid during fermentation, contributing to the yogurt's health and sensory benefits, such as digestion improvement, harmful bacteria suppression, and nutrients bioavailability enhancement[40]. A steady amount of LAB supports the yogurt's functional properties as a probiotic-rich product that can enhance gut health.

The physicochemical and microbiological characteristics of goat milk yogurt enriched with mung bean extract highlight the functional benefits. The decreased pH level and increased amount of LAB demonstrate the fermentation dynamics enhanced, while the stability of ash content ensures that the yogurt's mineral profile remains intact. Though a slight decrease occurred in protein and fat contents, the overall nutritional and sensory properties are improved with mung bean extract enrichment, proposing the yogurt as an attractive functional food option. These findings underscore the potential of mung bean extract to enhance the health benefits and market appeal of goat milk yogurt.

The hedonic test for goat milk yogurt with mung bean extract enrichment provides valuable insights into consumer preferences, particularly in terms of color, aroma, flavor, texture, and overall acceptability. In Table 2, the sensory attributes of the yogurt formulations (F0 to F3) revealed that mung bean extract affected consumer acceptability across various dimensions.



F1 (100%:0%) F2 (85%:15%) F3 (70%:30%) F4 (55%:45%)

Figure 1. Goat milk yogurt with mung bean extract enrichment in various formulations

The color score significantly declined as the concentration of mung bean extract increased. The control sample (F0) received the highest score of 4.21, while F3 yogurt scored 3.41. This condition emerged due to the natural pigments in mung bean extract, which altered the appearance of the yogurt, shifting the typical bright white of goat milk yogurt to a slightly darker color[31]. As color plays a significant role in consumer perception, the relatively high scores suggest that the visual change had no drastic effect on overall consumer acceptance. While fortified products could alter the color condition, previous studies have noted that moderate shifts in color may not always lead to rejection, if the other sensory qualities remain favorable[41].

Table 2. Sensory characteristics of goat milk yogurt with mung bean extract enrichment

Characteristics	Formula[1]			
	F0	F1	F2	F3
Hedonic Test				
Color	4.21 ± 0.17ᵃ	3.96 ± 0.36ᵃ	3.88 ± 0.21ᵃ	3.41 ± 0.25ᵃ
Aroma	3.72 ± 0.22ᵃ	3.6 ± 0.23ᵃ	3.46 ± 0.09ᵃ	3.46 ± 0.02ᵃ
Flavor	3.44 ± 0.08ᵃ	3.42 ± 0.49ᵃ	3.36 ± 0.01ᵃ	3.32 ± 0.01ᵃ
Texture	3.7 ± 0.19ᵃ	3.89 ± 0.37ᵃ	3.56 ± 0.33ᵃ	3.58 ± 0.3ᵃ
Overall	3.82 ± 0.01ᵃ	3.63 ± 0.23ᵃ	3.46 ± 0.23ᵃ	3.33 ± 0.33ᵃ
Hedonic Quality				
Color	2.04 ± 0.97ᵃ	1.64 ± 0.87ᵃ	1.88 ± 0.72ᵃ	1.76 ± 0.68ᵃ
Beany Aroma[2]	3.11 ± 0.17ᵃ	3.04 ± 0.36ᵃ	2.91 ± 0.21ᵃ	2.88 ± 0.25ᵃ
Milk Aroma	2.84 ± 0.08ᵃ	3.1 ± 0.49ᵃ	3.06 ± 0.01ᵃ	3.18 ± 0.01ᵃ
Fermentation Aroma	3.14 ± 0.01ᵃ	3.16 ± 0.23ᵃ	2.98 ± 0.23ᵃ	2.88 ± 0.33ᵃ
Sourness	3.16 ± 0.3ᵃ	3.19 ± 0.74ᵃ	3.21 ± 0.54ᵃ	3.10 ± 0.90ᵃ
Sweetness	3.21 ± 0.54ᵃ	3.23 ± 0.2ᵃ	2.96 ± 0.16ᵃ	3.04 ± 0.47ᵃ
Texture	2.17 ± 0.37ᵃ	3.78 ± 0.22ᵇ	3.77 ± 0.42ᵇ	3.8 ± 0.33ᵇ

[1] Formulations ratios of goat milk and mung bean extract (F0=100:0, F1=85:15, F2=70:30, F3=55:45); [2] A distinctive smell emerges due to mung beans presence; Numbers with the same letters in the same row indicate no significant difference at α = 5%

The aroma was relatively stable across all formulations at 3.72 in F0 to 3.46 in F3. This stability indicates that the addition of mung bean extract had no negative effect the yogurt's smell. Aroma often becomes the main concern in using the goat milk products, as presenting a strong "goaty" aroma that some consumers find it unappealing. The stable aroma suggest that mung bean extract could help maintain or neutralize the "goaty" aroma of the yogurt[9]. Similar results have been observed in other dairy products fortified with plant-based extracts, yet the addition of plant-based ingredients had no influence in aroma changes[42].

The flavor was also relatively consistent, with only a slight decrease from 3.44 in F0 to 3.32 in F3. This indicates that the addition of mung bean extract had minimal impact on the yogurt's flavor profile. Previous studies have shown that plant-based fortifications, particularly those using legumes like mung beans, often lead to minimal changes in flavor, allowing the base flavor of the dairy product to remain intact[31]. While the extract introduces new compounds, the small variations in flavor scores suggest that it does not detract from the overall taste experience. In fact, moderate additions of plant extracts can sometimes enhance the flavor profile, like in other yogurt formulations[42].

The texture scores revealed a more complex trend. The control yogurt (F0) received a score of 3.70, while the yogurt with the lowest mung bean extract

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concentration (F1) scored the highest texture score at 3.89. This suggests that a small amount of mung bean extract can improve the yogurt's texture, as the polysaccharides in the extract enhanced the creaminess[31]. However, as the concentration increased, texture scores slightly declined at 3.56 in F2 and 3.58 in F3. This condition may indicate that excessive levels of mung bean extract could result in a denser or less smooth texture, potentially due to the fibrous nature of the extract, which could negatively impact on the mouthfeel[9]. The findings align with a study on yogurt fortification, which highlighted a balanced approach when adding plant-based ingredients. Small amounts can enhance texture, while higher concentrations may lead to undesired changes, like high viscosity or grittiness levels[43].

The overall acceptability scores reflect all individual sensory attributes effect. The control yogurt (F0) received the highest overall score of 3.82, while the highest concentration of mung bean extract treatment (F3) scored the lowest overall score at 3.33. This condition suggests that mung bean extract can enhance certain qualities of the yogurt, such as texture. A higher concentration of mung bean extract may lead to diminished consumer satisfaction due to changes in color, texture, and flavor. Previous studies have shown that overall acceptability was closely linked to the balance of sensory attributes. Excessive fortification can lower the consumer ratings, even if individual attributes are acceptable[44]. The hedonic test results highlight the potential of mung bean extract as a functional ingredient in goat milk yogurt. The addition of moderate extract concentrations can enhance texture and maintain acceptable flavor and aroma profiles, while excessive concentrations may lead to slight declines in sensory attributes, like color and texture. The findings align with existing study on dairy fortification, which emphasizes the importance of plant-based enrichment strategy to ensure consumer acceptability.

The color hedonic quality test for color in goat milk yogurt with mung bean extract enrichment reveals a clear trend, as declining scores occurred in contrast with the concentration of mung bean extract. The control formulation (F0) of 2.04, while the F3 received the lowest score of 1.64. This suggests that the incorporation of mung bean extract, with its natural pigments, altered the yogurt's visual to less attractive to consumers. The typical bright white appearance of yogurt is often associated with freshness and quality, while a slightly greenish hue in mung bean-enriched yogurt may negatively influence the consumer perceptions[45,46].

Color is a key factor that influences the dairy products acceptance. According to Yilmaz-Ersan and Topçuoğlu, deviations from expected color patterns can significantly affect consumer preferences, as color is closely linked to perceptions of freshness and overall quality[45]. Similarly, Kim et al. highlight that food color as the visual appearance plays a crucial role in shaping consumer acceptance[46]. Thus, slight changes introduced by the mung bean extract, could lead to reduced appeal. Zhu et al. supported that color is a major determinant of yogurt's marketability and consumer satisfaction[47]. The relatively low color scores in all formulations suggest that the natural color of goat milk yogurt may not meet consumer expectations for brightness, even before fortification. Costa et al. and Dias et al. both emphasize that color and texture are vital for consumer acceptance in dairy products, which highlights the challenge of maintaining visual appeal in yogurt formulations, particularly when using additives that can alter the color[32,48].

The aroma hedonic quality test goat milk yogurt enriched with mung bean extract provides significant insights into consumer perceptions. The general aroma scores for both the control sample (F0) and the highest concentration of mung bean extract (F3) were relatively stable at 3.11 and 2.88, respectively. This indicates that the incorporation of mung bean extract did not substantially alter the overall aroma profile of the yogurt. This condition is important as a strong "goaty" aroma of goat milk products often limits consumer acceptance[9]. The neutral impact of mung bean extract suggests that it can be used to enrich goat milk yogurt without compromising the sensory attributes related to aroma.

In milk-specific aroma, the hedonic scores showed a slight improvement with the addition of mung bean extract from 2.84 in F0 to 3.18 in F3. This condition may be linked to the fermentation process, which could interact with volatile compounds and produce more appealing aromatic notes. Studies have shown that mung bean can contribute positively to the sensory profile of fermented dairy products through the production of aromatic compounds[42]. This suggests that the fermentation of goat milk yogurt with mung bean extract can boost the natural milk aroma, which can be more favorable to consumers, particularly those who may be sensitive to the strong aroma of goat milk[49]. These findings are consistent with broader studies, that indicate the sensory attributes of goat milk yogurt can be enhanced through the incorporation of functional ingredients and fermentation techniques. For example, probiotic strains have been shown to mitigate undesirable "goaty" flavors and improving overall sensory quality[49]. Similarly, plant extracts and specialized fermentation processes can enhance the flavor and aroma of yogurt to produce more appealing product to a wider audience[50]. The addition of mung bean extract in goat milk yogurt has a neutral effect on the general aroma, while positively affect the milk-specific aroma. This supports the use of mung bean extract as a functional ingredient that can improve the sensory quality of goat milk yogurt, addressing the challenges posed by its distinctive aroma, and potentially increasing consumer acceptance.

The fermentation aroma showed minimal variation with the highest score in F1 (3.16) and the lowest score in F3 (2.88). This suggests that the level of mung bean extract had no significant effect on the yogurt smell. Fermentation aroma is typically associated with the production of lactic acid and other fermentation byproducts. Mung bean extract, while supporting LAB growth, released no overpowering odors. The minor differences across formulations indicate that the fermentation process remained consistent, without any adverse impacts on the sensory quality, like smell. As fermentation aroma is closely tied to the freshness and

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quality of yogurt, maintaining stable scores across the formulations is a positive outcome. This consistency aligns with studies that emphasize the importance of controlled fermentation in maintaining the yogurt sensory quality[7].

The scores for sourness remained relatively stable across all formulations, ranging from 3.10 (F3) to 3.21 (F2). Thus, the addition of mung bean extract had no effect on the yogurt sourness. This stability is crucial, as excessive sourness can negatively affect the consumer acceptability[4]. Consistent sourness suggests that the fermentation process has been proceeded successfully without lactic acid overproduction, despite the addition of mung bean extract, which could have provided additional substrates for microbial fermentation. In contrast, sweetness scores showed a slight decline along with the increased mung bean extract, from 3.21 in F0 to 2.96 in F2. The sweetness reduction may be attributed to the fermentation process, where the sugars in the yogurt are consumed by LAB, converting them into acids. The sweetness decrease aligns with the observed acidity improvement and decreased in total sugar content in the physicochemical analysis. Consumers may have noticed a less sweet taste as the concentration of mung bean extract increased, which could affect the balance of sweet and sour flavors.

Texture quality improved after adding the mung bean extract, as shown in F0 at 2.17 and F3 at 3.80. This condition suggests that mung bean extract positively influence the yogurt's mouthfeel, likely due to the thickening properties of mung bean. Mung bean polysaccharides can contribute to the viscosity and creaminess of the yogurt, improving overall texture[51]. Improved texture is particularly important for consumer satisfaction, as texture is one of the key factors in determining the yogurt acceptability. The texture improvement from F0 to F3 substantially indicates that mung bean extract makes yogurt more desirable for consumers. The thickening effect of mung bean extract likely compensated for the reduction in fat content observed in the physicochemical analysis, which typically affects the creaminess and mouthfeel of yogurt. This finding highlights the potential of mung bean extract as a functional ingredient that enhances the texture of fortified dairy products.

The results of hedonic quality test revealed several important trends regarding the sensory characteristics of goat milk yogurt enriched with mung bean extract. The most significant improvement was observed in the texture. Meanwhile, the addition of mung bean extract substantially enhanced the mouthfeel of the yogurt. This improvement aligned with previous studies that demonstrated the thickening properties of plant-based polysaccharides in yogurt formulations[51]. The improved texture is likely to positively impact overall consumer acceptance, as it contributes to a creamier and a more enjoyable eating experience.

The consistent scores for sourness and fermentation aroma suggest that the fermentation process remained stable across all formulations, even with the addition of mung bean extract. This means that the fortification did not disrupt the natural fermentation process or introduce any undesirable flavors or odors. The slight reduction in sweetness may reflect the increased fermentation activity due to the added mung bean extract, which provided additional substrates for the LAB. While color scores decreased slightly with increasing mung bean extract, the relatively stable scores for aroma and flavor indicate that mung bean extract had no off-flavors or overpowering smells. The increased milk-specific aroma suggests that mung bean extract may even enhance the natural aroma of goat milk yogurt, beneficial for consumer perception.

From a practical perspective, the results of the hedonic quality test suggest that mung bean extract can be successfully incorporated into goat milk yogurt to enhance texture without negatively affecting other key sensory attributes. The improvement in texture is particularly noteworthy, as it addresses one of the primary sensory challenges in low-fat or fortified yogurts. This finding is significant for the dairy industry, as it highlights the potential of mung bean extract to improve the sensory appeal of functional dairy products. The slight reduction in sweetness and color indicates that higher concentrations of mung bean extract may require adjustments to the formulation, like natural sweeteners or color enhancers, to maintain optimal sensory quality. However, the overall sensory profile of the yogurt remains favorable, without significant negative impact on aroma, flavor, or sourness.

Tabel 3. Comparison of effective value (EV) and weighted values (WV) for each goat's milk yogurt formula enriched with mung bean extract

Parameter	Weight	Formula							
		F0		F1		F2		F3	
		EV	WV	EV	WV	EV	WV	EV	WV
pH	0.3	0.000	0.000	0.636	0.191	0.788	0.236	1.000	0.300
Lactic Acid Bacteria	0.5	0.000	0.000	1.000	0.500	0.782	0.391	0.709	0.355
Texture Quality	0.2	0.000	0.000	0.988	0.198	0.982	0.196	1.000	0.200
Total	1		0.000		0.888		0.824		0.855

EV: Effective Value; WV: Weighted Value

Table 3 provides a comparative analysis of the effective value (EV) and weighted value (WV) for key parameters—pH, lactic acid bacteria (LAB), and hedonic texture quality—in various goat milk yogurt formulations

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enriched with mung bean extract. The De Garmo method was employed to determine the optimal formula. The F1 achieved the highest total weighted value (0.888), surpassing the other formulations (F0, F2, and F3). For LAB, F1 attained an EV of 1.000, contributing to its maximum WV of 0.500, while F0 had the lowest LAB (EV = 0.000). For pH, the F3 led with an EV of 1.000 and a WV of 0.300, as a higher pH occurred in the treatment than other formulations. Texture quality, measured via hedonic evaluation, showed that the F3 was the best in this category (EV = 1.000, WV = 0.200), while F0 exhibited the lowest performance across all measured parameters.

The De Garmo method allowed a multifaceted evaluation of the yogurt formulations, balancing functional and sensory attributes. The F1, with optimal combination of pH, LAB, and texture, emerged as the best formulation, emphasizing microbiological activity and sensory quality balance. A previous study mentioned that pH and LAB are vital for fermentation and probiotic efficacy in yogurt production[49]. The high LAB in a F1 aligned with Yacoub[50], who demonstrated that plant-based extracts addition, such as mung bean, could enhance LAB proliferation, promoting the yogurt's probiotic potential.

The lower pH in F1 and F2 indicates higher acidity due to LAB fermentation, consistent with the role of LAB in yogurt production. LAB fermentation produces lactic acid, lowering the pH, which improves yogurt texture and prolongs shelf life[42]. This trend is also supported by Michael et al., who demonstrated that plant-based additives could increase microbial activity, enabling more acid production and texture improvement, like in F1[26]. In contrast, the control sample (F0), which lacked mung bean extract, consistently underperformed, emphasizing the positive impact of mung bean extract on the functional and sensory properties of the yogurt. The lower LAB and higher pH in F0 suggest a less efficient fermentation process than the enriched formulations.

The findings underscore the value of the De Garmo method in optimizing complex food formulations. By integrating both microbiological and sensory factors, De Garmo method ensures that the chosen formula offers the best overall performance. The superior results of F1 indicate a moderate amount of mung bean extract to support LAB growth and enhance overall yogurt quality. As consumer preferences shift towards functional foods, using mung bean extract in goat milk yogurt represents a promising strategy for enhancing both health benefits and sensory appeal in yogurt[32]. The practical implications of this study are significant for the dairy industry, particularly in the development of functional yogurt products. The balanced performance of F1, reflected in high LAB and favorable texture, makes it a suitable candidate for commercial production, catering to health-conscious consumers seeking probiotic-rich dairy products. Furthermore, the ability of mung bean extract to positively influence fermentation without compromising the sensory quality highlights its potential as a valuable ingredient in future yogurt formulations. The De Garmo method effectively identified F1 as the optimal yogurt formulation, offering the best balance of pH, LAB, and texture quality. The results emphasize the importance of plant-based fortification to improve the goat milk yogurt's functional and sensory characteristics, providing a framework for future product development.

This study presents several strengths, including the enhancement of goat milk yogurt's nutritional profile through the incorporation of mung bean extract, which promotes probiotic growth, increases bioactive compounds, and improves overall sensory characteristics, especially in mitigating the strong "goaty" flavor. Furthermore, the formulation containing 15% mung bean extract achieved an optimal balance between acidity, texture, and probiotic content, positioning the yogurt as a promising functional food product. Additionally, the reduction in fat content with the addition of mung bean extract could be advantageous for consumers seeking low-fat options, aligning with the growing demand for healthier food choices. However, the inclusion of mung bean extract resulted in noticeable color changes that may affect consumer appeal. Future studies should address these limitations by exploring strategies to maintain both the sensory quality and nutritional integrity of the yogurt, possibly through optimizing formulation ratios or incorporating natural color enhancers.

CONCLUSIONS

The study demonstrated that mung bean extract enrichment can significantly influence the physicochemical and sensory properties of goat milk yogurt. The formulation ratio of 85% goat milk yogurt and 15% mung bean extract(F1) achieved the most optimum level of pH, texture, and total amount of lactic acid bacteria. This formulation also provided a smooth texture, acceptable acidity, and enhanced microbial activity, thereby suitable for consumer acceptance. Applying the De Garmo method confirmed F1 as the best formula, which offers the highest overall quality among the formulations. These findings suggest that mung bean extract can effectively improve goat milk yogurt's nutritional and functional attributes without compromising its sensory appeal.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

HF: conceptualization, investigation, methodology, supervision, writing–original draft, writing–review and editing; RR: methodology, visualization, writing–original draft, writing–review and editing; IAS: methodology; formal analysis, data curation, writing–original draft; ZNH: formal analysis, writing–original draft, writing–review and editing.

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