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Effects of palm sugar concentration on fermentation characteristics and probiotic properties of soy milk-based beverages

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ABSTRACT

The increasing demand for functional beverages derived from plant-based ingredients has encouraged the development of probiotic soy milk products with improved sensory and nutritional qualities. Thus, this study aimed to evaluate the effect of palm sugar concentration on the characteristics of probiotic soy milk beverages. The method use in this study was a completely randomized design (CRD) with four treatments and three replications was applied. The treatments consisted of palm sugar additions at 0% (P1), 4% (P2), 8% (P3), and 12% (P4). The observed parameters included sensory quality, total soluble solids (TSS), and protein content. Data were analyzed using analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) at a 5% significance level. The results demonstrated that palm sugar concentration significantly influenced the sensory characteristics and total soluble solids (TSS) of probiotic soy milk beverages, whereas no significant effect was observed on protein content. The highest aroma preference score was recorded in the 8% palm sugar treatment (4.00), while the highest taste preference score was observed in the 12% treatment (3.60). Total soluble solids increased from 0.83° Brix in the control treatment to 6.56° Brix with 12% palm sugar addition, whereas protein content remained relatively stable, ranging from 3.05% to 3.10%. These findings indicate that palm sugar supplementation enhanced the sensory acceptability and TSS of probiotic soy milk beverages without significantly altering protein content. The conclusion is, based on sensory evaluation, the formulation containing 8% palm sugar was identified as the optimal treatment.

Keywords: fermentation; palm sugar; probiotic soy milk; sensory properties; total soluble solids

INTRODUCTION

Soy milk is a processed product derived from the extraction of soybean seeds and possesses characteristics similar to cow's milk. Soy milk is widely recognized as a plant-based beverage with a high protein content and an amino acid composition that is nearly comparable to that of cow's milk. In addition, soy milk contains lower levels of saturated fatty acids and is cholesterol-free due to its plant-based origin. Therefore, soy milk has considerable potential as a nutritious alternative to cow's milk (Jeske et al., 2018; Singhal et al., 2017).

Although soy milk possesses substantial nutritional value, its consumption level in Indonesia remains relatively low. One of the primary factors contributing to the limited consumer acceptance is the presence of an undesirable beany flavor. This characteristic aroma in soy milk is attributed to the formation of volatile compounds, such as hexanal, hexanol, and 1-octen-3-ol, which are generated through the oxidation of unsaturated fatty acids, particularly linoleic and linolenic acids, mediated by the activity of the lipoxygenase (LOX) enzyme. The activity of this enzyme increases during dehulling, soaking, and grinding processes, where the soybeans come into direct contact with atmospheric oxygen. These lipid oxidation-derived volatile compounds are recognized as the major contributors to the beany aroma, which adversely affects consumer acceptance of soy milk products, especially in terms of aroma and taste attributes (Tao et al., 2022; L. Yang et al., 2023). Therefore, appropriate processing methods, such as heat treatment and fermentation, are required to reduce lipoxygenase activity and improve the sensory characteristics of soy milk, thereby enhancing its overall consumer acceptability.

One of the approaches to improve the quality and consumer acceptability of soy milk is by processing it into a probiotic beverage through fermentation. Probiotic beverages have gained increasing consumer interest due to their potential health benefits, particularly in maintaining the balance of intestinal microflora and supporting digestive health (Jeske et al., 2018; Reid et al., 2019; Suh, 2022). Nevertheless, probiotic beverages based on soy milk still exhibit limitations in terms of taste and aroma, primarily because the natural sugar content of soy milk is relatively low, resulting in a bland flavor profile (Faisal et al., 2025; Wang, 2025). Therefore, the incorporation of natural sweeteners is necessary not only to enhance palatability but also to support the fermentation process. One promising ingredient is palm sugar.

Fermentation was selected as the preferred processing method in this study as it able to enhance the consumer acceptance of soymilk because it is more effective at improving sensory characteristics than heating, refrigeration, or ultrasonic treatment. Fermentation by lactic acid bacteria has been shown to reduce the undesirable beany flavour while improving aroma, texture, and overall taste, thereby increasing consumer acceptability (Novgorodska, 2024; Retnowati & Purwestri, 2024). Although thermal processing can mitigate beany flavour through the inactivation of lipoxygenase enzymes, excessive heating may lead to the degradation of bioactive compounds and a reduction in nutritional quality (Claudia Freire Esteves et al., 2022; M. K. Tripathi, 2015). Refrigeration primarily serves to maintain product stability and extend shelf life, with limited influence on sensory enhancement (M. K. Tripathi, 2015). Ultrasonic treatment has been reported to improve emulsion stability and reduce compounds associated with beany flavour; however, its impact on consumer acceptance remains less pronounced than that of fermentation (Kong et al., 2023; Sotelo-Lara et al., 2024). Therefore, fermentation was chosen because it simultaneously enhances the sensory attributes, nutritional value, and functional properties of soymilk.

Palm sugar was selected as an additive in this study because it serves not only as a sweetener but also contains a more diverse range of bioactive compounds and minerals than refined sugar. Palm sugar is known to contain phenolic compounds and flavonoids that contribute to higher antioxidant activity, thereby potentially enhancing the functional value of fermented products (Huynh Thi Le et al., 2020; Srikaeo et al., 2018). In addition, palm sugar is a source of several essential minerals, including iron, zinc, and copper, which are largely absent in refined sugar due to extensive refining processes (Huynh Thi Le et al., 2020; Maryani et al., 2021). The carbohydrate content of palm sugar can also serve as a carbon source for lactic acid bacteria during fermentation, potentially supporting bacterial growth and metabolic activity. Furthermore, palm sugar has a relatively lower glycemic index than refined sugar, making it a more suitable ingredient for the development of functional food products (Puspareni et al., 2022; Syukri et al., 2025). The use of palm sugar is also relevant to the development of locally sourced fermented beverages, as it provides distinctive flavor and aroma characteristics while adding value to the final product. Therefore, palm sugar was selected in this study to evaluate the effects of its concentration on the chemical characteristics and quality of fermented soy milk. The addition of palm sugar during the fermentation process may also influence the chemical characteristics of the product, including protein content and total soluble solids (Dwiloka et al., 2024). During fermentation, the metabolic activity of probiotic bacteria can induce structural modifications of proteins through hydrolysis, thereby affecting the level of soluble protein in the final product (Suharto & Kurnia, 2022).

Although the addition of palm sugar provides benefits to the sensory and chemical quality of the product, the concentration used must be carefully considered. Excessive sugar concentrations may inhibit the growth of probiotic bacteria due to increased osmotic pressure, whereas insufficient sugar concentrations may fail to provide adequate nutrients to support an optimal fermentation process (Paendong et al., 2021; Y. Zhang et al., 2024). Despite previous studies have demonstrated the benefits of soybean milk fermentation and the use of palm sugar as a natural sweetener in soy-based beverages, limited information is available regarding the effects of different palm sugar concentrations on the quality characteristics of probiotic fermented soy milk produced using Lactobacillus plantarum. In particular, the combined effects of palm sugar concentration on sensory attributes, protein content, and total soluble solids (TSS) have not been systematically evaluated. This knowledge gap warrants further investigation to better understand the role of palm sugar concentration in determining the quality characteristics of probiotic fermented soy milk. Therefore, this study aimed to evaluate the effects of varying palm sugar concentrations on the sensory and physicochemical properties of probiotic fermented soy milk and to identify the formulation with the most desirable quality characteristics.

METHODOLOGY

Materials and Equipment

The primary materials employed in this study were soybeans, palm sugar, and a probiotic starter culture of Lactobacillus plantarum used for soybean milk fermentation. Several analytical-grade reagents were also used, including concentrated sulfuric acid (H_2SO_4, 98%); potassium sulfate (K_2SO_4); copper sulfate ($CuSO_4$); titanium dioxide (TiO_2); sodium hydroxide (NaOH, 40%); boric acid (H_3BO_3, 4%); hydrochloric acid (HCl, 0.1 N) or sulfuric acid (H_2SO_4, 0.1 N); bromocresol green (BCG, 0.1%); methyl red (MR, 0.1%); and distilled water. Additional supporting materials consisted of antifoam or paraffin, lint-free tissues, mineral water, sample labeling papers, hedonic assessment forms, tissues, and small plastic cups.

The apparatus utilized in this research included a cooking pan, gas stove, blender, sieve, storage bottles, spectrometer, thermometer, basin, analytical balance, Kjeldahl digestion flask, digestion block, Kjeldahl distillation unit, 250 mL Erlenmeyer flask, 50 mL burette, volumetric and graduated pipettes, measuring cylinders, volumetric flasks, glass funnels, condenser, clamps and support stands, a 400°C thermometer, laboratory safety equipment, refractometer, measuring cups (100–250 mL), stirring spoons, funnels, and trays.

The fermented soy milk samples were served to 30 untrained (non-expert) panelists for sensory evaluation of aroma, taste, and overall acceptance using a hedonic assessment form. Additional equipment included evaluation sheets, stationery, chairs, and tables used during sensory evaluation sessions.

Experimental Design

The experimental design employed in this study was a completely randomized design (CRD) with a single factor, namely palm sugar concentration, consisting of four treatments: P1 (0 g/100 mL; 0% w/v palm sugar concentration), P2 (4 g/100 mL; 4% w/v palm sugar concentration), P3 (8 g/100 mL; 8% w/v palm sugar concentration), and P4 (12 g/100 mL; 12% w/v palm sugar concentration). Each treatment was replicated three times, resulting in a total of 12 experimental units. The observed parameters included organoleptic quality, total soluble solids, and protein content.

Data analysis

The collected data was statistically analyzed using Analysis of Variance (ANOVA) at a 5% significance level. When significant differences among treatments were identified, Duncan's Multiple Range Test (DMRT) at a 5% significance level was subsequently performed to determine differences between treatments. All statistical analyses were conducted using SPSS software version 25.

Research Stages

The study began with the preparation of materials and equipment. Soybeans were boiled for 15 minutes using a gas stove, soaked for 8 hours, washed with clean water, and dehulled. The soybeans were then blended with water at a ratio of 3:1 and filtered to separate the soybean pulp from the soy milk filtrate. The resulting filtrate was heated at 60°C until boiling, followed by the addition of palm sugar at concentrations of 0%, 4%, 8%, and 12% while continuously stirring until homogeneous and subsequently cooled to room temperature. The cooled soy milk was transferred into sterilized fermentation bottles and inoculated with Lactobacillus sp. Fermentation was carried out for three days. After fermentation, the probiotic soy milk beverage was stored under anaerobic conditions at 2.7°C to maintain product quality and probiotic viability. The research method applied in this study was a modification of the method proposed by (Faisal et al., 2025; Fathurohman et al., 2020; Sebastian, 2018). The final stage of the study involved the analysis of several parameters, including protein content (AOAC International, 2019), total soluble solids (TSS) (A. A. Mahmoud et al., 2023), and sensory characteristics (Fathurohman et al., 2020), particularly aroma and taste.

RESULTS AND DISCUSSION

Sensory Evaluation (Aroma)

Sensory evaluation focused on aroma, taste, and overall acceptance because these attributes are the primary determinants of consumer preference for fermented soy-based beverages and are directly influenced by fermentation and palm sugar addition. Texture and color were not evaluated because all treatments used the same soy milk formulation and fermentation conditions, with palm sugar concentration as the only variable; therefore, substantial differences in these attributes were considered unlikely.

Based on Figure 1, the results of the analysis demonstrated that the addition of palm sugar significantly affected the aroma preference level of the probiotic soy milk beverage. The Analysis of Variance (ANOVA) revealed a p-value of 0.000 (< 0.05), indicating that differences in palm sugar concentration among treatments had a significant effect on the aroma acceptability of the product. These findings were further supported by Duncan's Multiple Range Test (DMRT), which showed that the control treatment without palm sugar addition (P0) differed significantly from the treatments containing 4% (P1), 8% (P2), and 12% (P3) palm sugar. However, treatments P1, P2, and P3 were not significantly different from one another.

Based on the hedonic evaluation, the highest aroma preference score was obtained in treatment P2 with 8% palm sugar addition, reaching 4.00, whereas the lowest score was observed in the control treatment P0, with a value of 2.93. These results indicate that palm sugar addition improved panelists' acceptance of the aroma of the probiotic soy milk beverage.

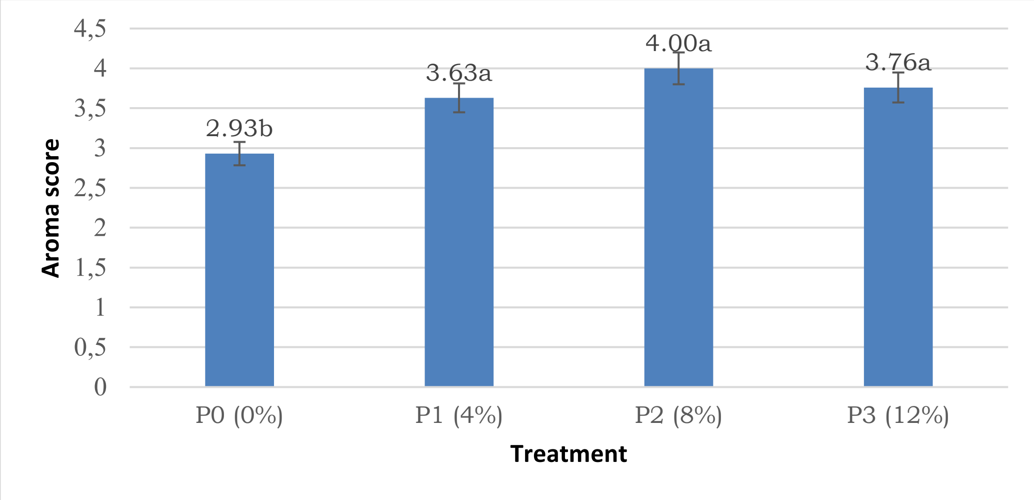

Figure 1. Effect of palm sugar concentration on the aroma hedonic quality of probiotic soy milk beverage. Different superscript letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at the 5% significance level.

The aroma of the control treatment tended to be less preferred because the characteristic beany flavour of soy milk remained more pronounced. Previous studies have reported that this undesirable aroma is associated with volatile compounds generated during soybean processing, particularly those derived from lipoxygenase-catalysed oxidation reactions, which contribute to the typical beany notes of soy-based products (Maryani et al., 2023; Yuan & Chang, 2007). In contrast, the addition of palm sugar may have improved aroma acceptance by introducing various volatile aroma compounds that contribute caramel-like, roasted, coconut-like, honey-like, and sweet notes to the product (S. F. K. Dewi et al., 2026; Katherinatama et al., 2025). Volatile aroma compounds formed during the thermal processing of palm sap, including furans, pyrazines, aldehydes, ketones, alcohols, esters, and organic acids. These compounds contribute caramel-like, roasted, sweet, and pleasant aroma notes that may help mask the characteristic beany flavour of fermented soy milk, thereby enhancing consumer acceptance of the product (Baiq Afriza Lia Fitri et al., 2025; Katherinatama et al., 2025; Osawa et al., 2013; Yokoyama et al., 2023; W. Zhang et al., 2016). The formation and composition of these volatile compounds are influenced by the heating conditions applied during palm sap processing, particularly temperature and heating duration (Bao et al., 2022; Gao et al., 2023; LIU et al., 2023).

In addition, the fermentation process carried out by Lactobacillus sp. produces metabolites in the form of organic acids and flavor compounds that contribute to the improvement of aroma characteristics in soy-based fermented beverages (Tangyu et al., 2019). The treatment containing 8% palm sugar resulted in the highest aroma preference score because this concentration was considered to provide the most balanced combination of palm sugar aroma and fermentation aroma without producing an excessively strong sweet odor. Meanwhile, the aroma preference score slightly decreased in the treatment containing 12% palm sugar compared with the 8% treatment. This condition may be attributed to the overly dominant sweet aroma, which reduced the balance of the characteristic fermented aroma and consequently lowered panelist acceptance (Kim et al., 2025; W. Zhang et al., 2019).

Overall, the findings of this study demonstrate that palm sugar addition plays an important role in improving the sensory quality, particularly aroma, of probiotic soy milk beverages. In addition to functioning as a natural sweetener, palm sugar also enhances the aroma characteristics of the product through the formation of caramel-like aromas that effectively mask the undesirable beany flavor of soy milk.

Sensory Evaluation (Flavor)

Based on Figure 2, the results of the analysis demonstrated that the addition of palm sugar significantly affected the taste preference level of the probiotic soy milk beverage. The Analysis of Variance (ANOVA) revealed a p-value of 0.003 (< 0.05), indicating that differences in palm sugar concentration among treatments had a significant effect on the taste acceptability of the product. These findings were further supported by Duncan's Multiple Range Test (DMRT), which showed that the control treatment without palm sugar addition (P0) was not significantly different from the treatment containing 4% palm sugar (P1) but differed significantly from the treatments containing 8% (P2) and 12% (P3) palm sugar.

Based on the hedonic evaluation, the highest taste preference score was observed in treatment P3 with 12% palm sugar addition, reaching 3.60, whereas the lowest score was obtained in the control treatment P0, with a value of 3.06. These results indicate that increasing palm sugar concentration tended to improve panelists' acceptance of the taste of the probiotic soy milk beverage. The improvement in taste preference may be associated with the addition of palm sugar, which increased the Total Soluble Solids (TSS) content of the product and contributed to a sweeter taste perception. Palm sugar possesses a distinctive sweet taste accompanied by mild caramel-like flavor notes that can enhance the overall sensory quality of food products (Agustiani et al., 2025; Siswanto et al., 2016). Previous studies have reported that palm sugar supplementation improved taste acceptability in various food products, including pineapple yogurt and traditional confectionery products, due to its favorable sensory characteristics (Inayah et al., 2023; Novayanti, 2016). Moreover, the higher TSS values observed in palm sugar-supplemented treatments indicate a greater concentration of soluble solids, which has been associated with increased sweetness perception and consumer preference (Agustiani et al., 2025; Rindengan et al., 2020). Although some sugars may have been utilized during fermentation, the elevated TSS values suggest that palm sugar addition contributed to the greater taste preference observed in the present study.

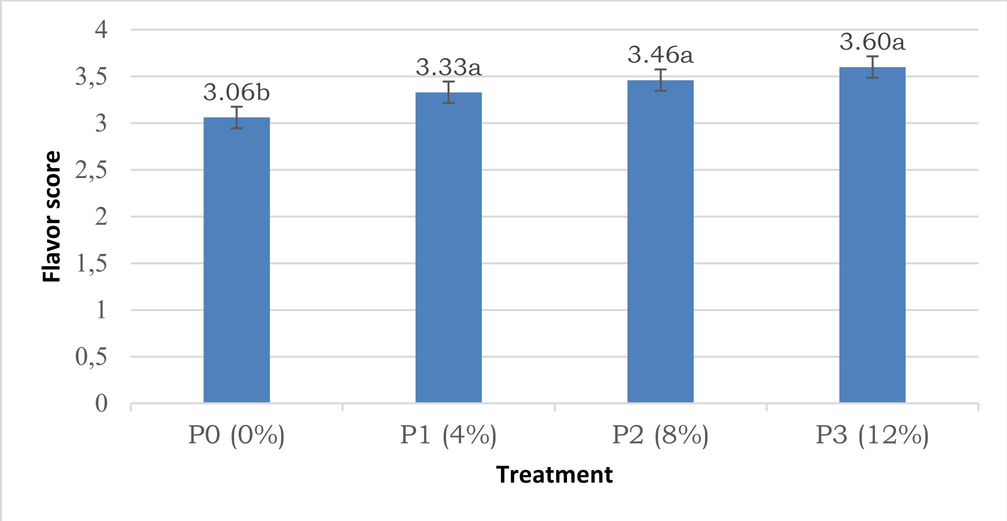

Figure 2. Effect of palm sugar concentration on the flavor hedonic score of probiotic soy milk beverage. Different superscript letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at the 5% significance level.

In addition to imparting sweetness, palm sugar also contributes a characteristic caramel-like flavor derived from volatile compounds such as furfural, maltol, and Maillard reaction products formed during the heating process of palm sap. These compounds provide a more complex flavor profile and help mask the beany flavor and acidic taste produced during soy milk fermentation. Therefore, palm sugar functions not only as a natural sweetener but also as a flavor-enhancing ingredient that improves the overall taste balance of probiotic soy milk beverages (Yokoyama et al., 2023).

The control treatment without palm sugar addition exhibited the lowest taste preference score because the characteristic flavor of fermented soy milk remained dominant. This flavor is associated with non-volatile compounds, such as oligosaccharides and soybean proteins, which may contribute to a beany and slightly bitter taste in soy-based products (Cao et al., 2023). In contrast, treatments containing 8% and 12% palm sugar produced a sweeter taste that balanced the acidic flavor generated during fermentation and reduced the undesirable beany flavor, resulting in greater panelist acceptance.

Overall, the findings of this study demonstrate that palm sugar addition significantly influenced the sensory quality, particularly taste, of probiotic soy milk beverages. Higher concentrations of palm sugar resulted in greater panelist preference for the product, as palm sugar provided natural sweetness and caramel-like flavor characteristics that enhanced consumer acceptance of probiotic soy milk beverages.

Protein Content Analysis

Based on Figure 3, the results of the analysis indicated that the addition of palm sugar to the probiotic soy milk beverage did not significantly affect protein content. The results of the Analysis of Variance (ANOVA) showed a p-value of 0.765 (> 0.05), indicating that differences in palm sugar concentration among treatments did not result in significant changes in protein content. These findings were further supported by Duncan's Multiple Range Test (DMRT), which demonstrated that all treatments, namely P0 (control), P1 (4% palm sugar), P2 (8% palm sugar), and P3 (12% palm sugar), shared the same letter notation. This result indicates that there were no significant differences among treatments in terms of the protein content of the probiotic soy milk beverage.

The highest protein content was observed in the treatment without palm sugar addition (P0), with a value of 3.10%, whereas the lowest protein content was recorded in the treatment containing 12% palm sugar (P3), with a value of 3.05%. However, the differences in protein content among treatments were relatively small, suggesting that the addition of palm sugar up to a concentration of 12% did not significantly influence the protein content of the product.

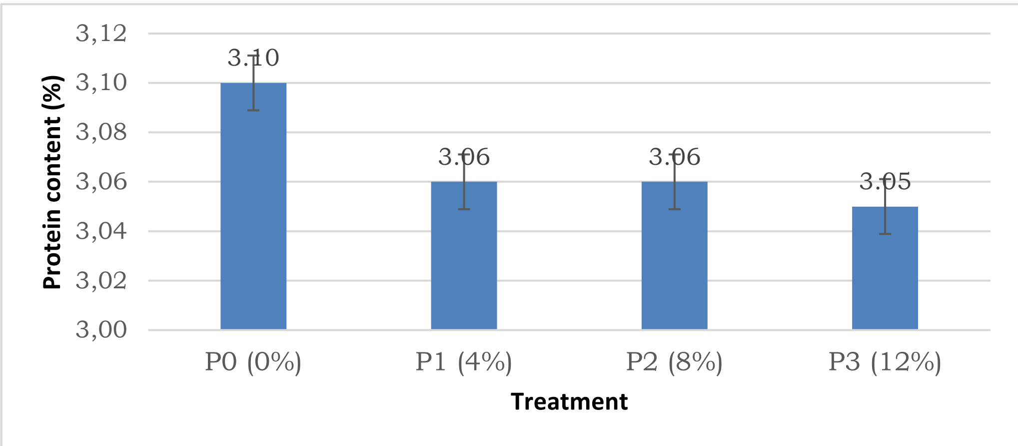

Figure 3. Effect of palm sugar concentration on the protein content of probiotic soy milk beverage. Different superscript letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at the 5% significance level.

This finding may be attributed to the fact that the primary protein source in probiotic soy milk beverages originates from soybeans themselves, while palm sugar mainly functions as a carbohydrate source and fermentation substrate for probiotic bacteria (Singhal et al., 2017). Furthermore, the fermentation process carried out by Lactobacillus spp. is more closely associated with flavour development, microbial metabolic activity, and sensory characteristics than with alterations in total protein content. The addition of palm sugar at different concentrations tended to increase carbohydrate content and total soluble solids, but it did not directly enhance the protein content of the fermented product (Tangyu et al., 2019). The slight decrease in protein content observed at higher palm sugar concentrations may be attributed to a relative dilution effect caused by the increased proportion of non-protein components in the final product.

The findings of this study are consistent with those reported by (Santos et al., 2019), who stated that the addition of carbohydrate sources during soy milk fermentation had a greater impact on the physical and sensory characteristics of the product than on its protein content. Therefore, it can be concluded that palm sugar addition up to a concentration of 12% did not significantly affect the protein content of probiotic soy milk beverages but rather played a more important role in supporting the fermentation process and improving the sensory properties of the product.

Physicochemical Analysis (Total Soluble Solids)

Based on Figure 4, the results of the analysis demonstrated that the addition of palm sugar significantly affected the total soluble solids (TSS) of the probiotic soy milk beverage. The Analysis of Variance (ANOVA) revealed a p-value of 0.000 (<0.05), indicating that different concentrations of palm sugar had a significant effect on the total soluble solids content of the product. These findings were further supported by Duncan's Multiple Range Test (DMRT), which showed that treatments P1 (4% palm sugar) and P2 (8% palm sugar) were not significantly different from each other but were significantly different from the control treatment P0 and treatment P3 (12% palm sugar). The highest total soluble solids value was observed in treatment P3 with 12% palm sugar addition, reaching 6.56°Brix, whereas the lowest value was recorded in the control treatment without palm sugar addition (P0), with a value of 0.83°Brix. The increase in total soluble solids in treatments supplemented with palm sugar was attributed to the presence of sucrose, glucose, and fructose in palm sugar, which readily dissolved in the fermentation medium and consequently increased the concentration of soluble solids in the product. Therefore, higher concentrations of palm sugar resulted in higher total soluble solids values in the probiotic soy milk beverage (Hapsari et al., 2025; Maryani et al., 2023; Rastika et al., 2025).

The differences in TSS values were closely associated with the sensory responses of the product. Although P0 exhibited the highest protein content, this treatment received lower aroma and taste preference scores than the treatments supplemented with palm sugar. These findings indicate that protein content was not the primary factor determining consumer acceptance. Instead, the higher TSS values observed in treatments containing palm sugar contributed to greater sweetness intensity, thereby enhancing flavour perception and overall product acceptability. Palm sugar contains simple sugars that can increase sweetness perception and provide sensory characteristics that are more favourable to consumers (N. K. K. S. Dewi et al., 2022; Listyaningrum et al., 2018; Novayanti, 2016). In addition to enhancing sweetness, the presence of fermentable sugars also plays an important role in the fermentation process by serving as substrates for microbial activity. Microbial metabolism during fermentation produces a variety of volatile compounds that contribute to the development of more complex aroma and flavour profiles, including alcohols, esters, and organic acids, while simultaneously increasing desirable floral and buttery aroma compounds (Guo et al., n.d.; Harlé et al., 2025; Yu et al., 2024). Fermentation has also been reported to reduce the concentration of aldehyde compounds, such as hexanal, which are responsible for the characteristic beany off-flavour of soymilk, thereby improving aroma acceptance among consumers (Harlé et al., 2025; Meng et al., 2023). Therefore, the improvement in aroma and taste scores observed in treatments containing palm sugar was associated not only with the increased concentration of soluble sugars reflected by higher TSS values but also with modifications in the aroma compound profile during fermentation. These findings suggest that TSS and sensory attributes are closely interconnected in determining consumer acceptance, whereas protein content appears to exert a more limited influence on the sensory preference of the product.

In treatments P1 and P2, the total soluble solids values increased compared with the control treatment; however, the increase was not significantly different. This condition may be explained by the utilization of part of the added sugar by Lactobacillus sp. as an energy source during the fermentation process. The metabolic activity of probiotic bacteria converted simple sugars into organic acids and other metabolites, thereby relatively reducing the concentration of dissolved sugars in the product (Tangyu et al., 2019). As a result, the total soluble solids value in treatment P2 (8%) was slightly lower than that observed in treatment P1 (4%).

The treatment P3 with 12% palm sugar addition exhibited a significant increase in total soluble solids. This finding indicates that the amount of sugar added exceeded the optimal capacity of probiotic bacteria to ferment the substrate during the incubation period. Consequently, a portion of the sugar remained unfermented and continued to contribute to the soluble solids content of the product. Excessive sugar concentrations may also increase osmotic pressure, thereby inhibiting the metabolic activity of lactic acid bacteria (Lactobacillus sp.) during fermentation (Santos et al., 2019). Therefore, the elevated total soluble solids value observed at the 12% palm sugar concentration suggests that not all of the added sugar was optimally utilized throughout the fermentation process.

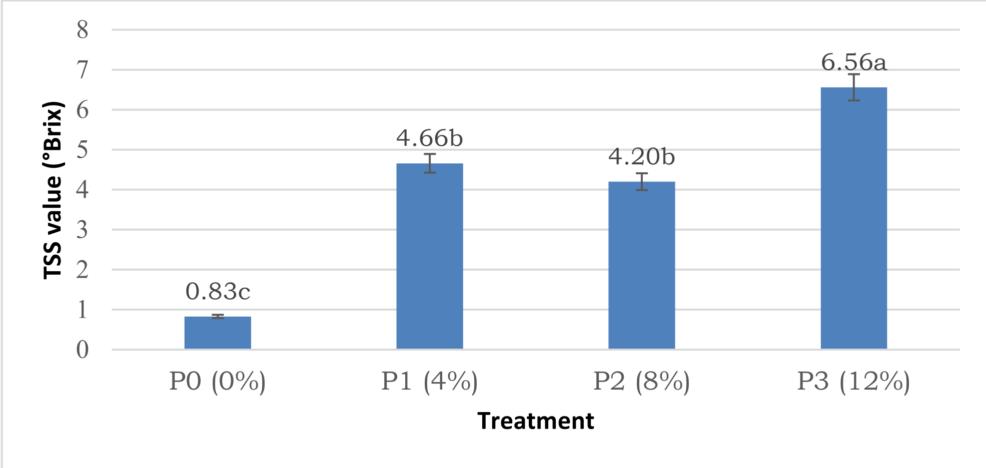

Figure 4. Effect of palm sugar concentration on the total soluble solids (TSS) of probiotic soy milk beverage. Different superscript letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Overall, the findings of this study demonstrate that palm sugar addition significantly affected the total soluble solids of probiotic soy milk beverages. In addition to serving as a natural sweetener, palm sugar also functions as a carbon source for probiotic bacteria during fermentation, thereby influencing the physicochemical characteristics of the final product.

CONCLUSION

The results showed that palm sugar concentration significantly affected the sensory characteristics (aroma and flavor) and total soluble solids value of probiotic soy milk beverages but had no significant effect on protein content. The highest aroma preference score was obtained in the 8% palm sugar addition (4.00), whereas the highest taste preference score was observed in the 12% palm sugar addition (3.60). Total soluble solids increased from 0.83° Brix in the control treatment to 6.56° Brix at 12% palm sugar addition, while protein content remained relatively stable (3.05–3.10%). Overall, the formulation containing 8% palm sugar was identified as the optimal treatment based on overall sensory acceptance.

Future studies should evaluate probiotic viability, product stability, and shelf life during storage; conduct comprehensive proximate analyses, including carbohydrate, fat, and residual sugar determinations, to better explain the relationship between nutritional composition and sensory attributes; and explore the use of high-quality local raw materials and natural flavoring agents to further enhance product quality, consumer acceptance, and market potential.

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