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Physicochemical properties and sensory acceptance of honey-enriched chickpea (*Cicer arietinum* L.) yoghurt

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Abstract. The rising demand for functional plant-based foods has driven the use of legumes as a viable alternative to traditional dairy-based yoghurt. Chickpea (*Cicer arietinum* L.) offers high protein, fibre, and bioactive compounds, while honey may improve fermentation, texture, and antioxidant properties. This study aimed to evaluate the effect of honey addition (0%,

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2%, 4%, and 6%) on the physicochemical characteristics, antioxidant activity, and sensory acceptance of chickpea-based yoghurt. Chickpea milk supplemented with skimmed milk was fermented using lactic acid bacteria and analysed for pH, titratable acidity, total soluble solids (TSS), syneresis, antioxidant activity, and consumer acceptance. Honey addition significantly improved the physicochemical and sensory properties of chickpea yoghurt by enhancing fermentation performance (higher titratable acidity, total soluble solids, and antioxidant activity), lowering pH and syneresis values. Sensory evaluation demonstrated increased taste and overall acceptance with increasing honey concentration, whereas aroma and texture were not significantly affected. Overall, 6% honey provided the best balance of stability, functionality, and consumer preference, indicating its potential as an optimal formulation for plant-based yoghurt development. These findings highlighted the role of honey as a natural functional ingredient that enhanced both technological quality and consumer acceptability in legume-based fermented products. The findings of this study can be utilised by plant-based food manufacturers and small-scale producers to develop functional yoghurt alternatives with improved nutritional and sensory profiles, addressing the growing market demand for fermented products

Keywords: plant-based fermentation; lactic acid bacteria; prebiotic sweetener; antioxidant activity; sensory evaluation

Introduction

The increasing global demand for functional foods reflects a shift in consumer awareness toward products that promote health beyond basic nutrition. At the same time, plant-based dietary patterns are gaining momentum due to lactose intolerance prevalence, sustainability concerns, and the environmental impact associated with conventional dairy production. Fermented foods play an important role within this development because fermentation enhances digestibility, improves nutrient bioavailability, and introduces beneficial microbial activity. Yoghurt, traditionally produced from milk, is widely recognised as a carrier of probiotic bacteria and bioactive compounds. However, replacing dairy substrates with plant-based materials introduces technological challenges, particularly in achieving stable gel formation, acceptable texture, and balanced sensory characteristics. These limitations highlight the need for systematic formulation strategies to improve the quality of plant-based fermented products.

The fundamental mechanism of yoghurt formation relies on lactic acid bacteria metabolism. R. Rahmawati *et al.* (2022) explained that lactic acid production during fermentation decreases pH and induces protein coagulation, resulting in gel structure development and characteristic flavour. R. Masriatini *et al*. (2023) indicated in their work that *Lactobacillus bulgaricus* and *Streptococcus thermophilus* can survive acidic gastrointestinal conditions and potentially contribute to intestinal microbial balance. In plant-based substrates, the absence of lactose becomes a limiting factor during fermentation. S. Pannerchelvan *et al*. (2024) demonstrated that plant milks lack sufficient fermentable sugars to support optimal bacterial growth, often leading to weak gel structures and lower acidification rates. These findings emphasise that carbohydrate availability plays a crucial role in determining fermentation efficiency in non-dairy systems.

Chickpea is a plant-based raw material containing protein, dietary fibre, and phenolic compounds. N. Kumar *et al.* (2025) observed that chickpea proteins can form a protein matrix during fermentation, although the resulting structure is generally less compact than that of dairy yoghurt. The same study also reported that fermentation of chickpea-based substrates may produce a beany flavour associated with lower consumer acceptance. In addition, Y. Sari *et al.* (2024) indicated that the addition of complementary ingredients is required to improve flavour and structural stability in legume-based yoghurt systems. These findings show that chickpea-based yoghurt requires formulation adjustment to obtain appropriate physicochemical and sensory characteristics. Honey has also received attention as a multifunctional ingredient in fermented foods. T. Baltić *et al.* (2025) reported that the glucose and fructose present in honey serve as readily fermentable substrates that stimulate lactic acid bacteria growth. M. Rahardjo *et al.* (2022) further demonstrated that phenolic and flavonoid compounds in honey contribute antioxidant activity and may influence microbial stability during fermentation. While previous research has mainly focused on honey supplementation in dairy yoghurt systems, its interaction with plant proteins during fermentation has received limited scientific attention. In particular, the role of honey concentration in influencing gel formation, acidity development, viscosity, and sensory perception in chickpea-based yoghurt remains insufficiently clarified.

The concentration of honey may significantly affect both microbial metabolism and physicochemical stability. Excessive sugar addition can increase osmotic pressure, potentially altering bacterial activity and fermentation kinetics. Conversely, inadequate carbohydrate supplementation may limit acid production and weaken protein aggregation. In legume-based systems where protein network formation is inherently weaker than in dairy matrices, the balance between carbohydrate availability and protein interactions becomes especially critical. In addition, determining the appropriate sweetener level is important from a technological perspective because small variations in sugar concentration can modify water binding capacity, gel firmness, and whey separation in plant protein systems. Therefore, evaluating concentration-dependent effects is necessary to ensure that improvements in fermentation performance are accompanied by stable physical properties and acceptable sensory perception. Despite growing interest in plant-based yoghurt innovation, few studies have systematically examined how varying levels of honey influence fermentation performance and product quality in chickpea-based substrates.

This study addressed that gap by investigating the influence of graded honey concentrations on the fermentation behaviour, physicochemical characteristics, and sensory acceptance of chickpea-based yoghurt to determine an optimal formulation that balances microbial activity, structural stability, and consumer preference.

Materials and Methods

The experimental work was conducted in 2025 at the Food Engineering and Agricultural Products Laboratory, Food Chemistry and Nutrition Laboratory, Faculty Animal Husbandry and Agriculture, Diponegoro University, and Cendekia Nanotech Hutama Laboratory, Semarang. Physicochemical analysis including the analysis of pH, total titratable acidity, syneresis, and total soluble solids were performed at the Food Engineering and Agricultural Products Laboratory, Food Chemistry and Nutrition Laboratory, Faculty Animal Husbandry and Agriculture, Diponegoro University and the antioxidant activity were performed at the Cendekia Nanotech Hutama Laboratory, Semarang. The materials used in this study were high-quality peeled chickpeas, skimmed milk, yoghurt starter, pure honey, baking soda, water, distilled water, pH 4 and 7 buffer solutions, 0.1 N NaOH, and 1% Phenolphthalein (PP) indicator. The equipment used in this study included digital scales, filter cloth, blender, Erlenmeyer flasks, measuring cups, beaker glass, thermometer, spatula, glass jar, pot, refractometer, Ohaus centrifuge, Brookfield viscometer, pH meter (Ohaus, USA), burette stands, and plastic cups.

Chickpea (*Cicer arietinum* L.) were sorted and washed with fresh water, then soaked in water at a ratio of 1:5 with 0.25% added baking soda. Chickpea were soaked for 24 hours to reduce the "beany" taste and aroma, and also to soften the texture of chickpea. After soaked, chickpeas were rinsed, then blended with added water (1:5, w/v), and filtered through filter cloth to obtain the chickpea milk. The filtrate then pasteurised before being processed into yoghurt. Chickpea milk was added with 5% (w/v) skimmed milk and honey according to the treatment level, where the treatments are P0 (0% honey), P1 (2% honey), P2 (4% honey), and P3 (6% honey), then homogenised and heated at 72°C for 10 minutes. The mixture is cooled down to 40°C and is inoculated with yoghurt starter culture, then incubated at 37°C for 10 hours.

The pH value was determined using a calibrated digital pH meter (Ohaus, USA). Titratable acidity was measured by titrating 10 mL of yoghurt sample with 0.1 N NaOH using phenolphthalein as an indicator until a persistent pink equivalent was reached. Results were expressed as percentage of lactic acid and calculated using the following formula (1):

$$\text{total Asam} = \frac{V1 \times N \times B}{V2 \times 1.000 \times 100} \times 100\%, \qquad (1)$$

where V1 – volume NaOH (mL); V2 – volume sample (mL); N – normality NaOH (0.1 N); B – molecular weight of lactic acid (90).

Total soluble solids were measured using a digital hand refractometer at 25°C and expressed as Brix. Syneresis was determined using a centrifugation method. A total of 15 grams of yoghurt samples was centrifuged at 3,000 rpm for 10 minutes. The separated whey was collected and weighed, and syneresis was expressed as the percentage of whey released relative to the initial sample weight. The percentage of syneresis was calculated using the formula (2):

$$\text{syneresis (\%)} = \frac{W1 - W2}{W1} \times 100\%, \qquad (2)$$

where W1 – initial weight (g); W2 – final weight (g).

Antioxidant activity was evaluated using the DPPH radical scavenging method. Approximately 0.2 grams of the sample was dissolved in ethanol, mixed with 0.1 mM DPPH solution, and incubated in the dark for 30 min. Absorbance was measured at 515 nm using a UV-Vis spectrophotometer. Results were expressed as percentage inhibition of DPPH radicals and was calculated using the following formula (3):

$$\% \text{ inhibition} = \left(\frac{\text{control absorbance} - \text{sample absorbance}}{\text{control absorbance}} \times 100\% \right). \qquad (3)$$

Consumer acceptance was evaluated by 30 untrained panellists using a five-point hedonic scale (1 = extremely disliked until 5 = extremely liked) for colour, aroma, taste, texture, and overall acceptance. The sensory evaluation was conducted in accordance with the ethical principles of WMA (1964). Informed consent was obtained from all participants prior to the study, and they were fully briefed on the nature of the samples being evaluated. Data of physicochemical properties (pH, titratable acidity, total soluble solids (TSS), and syneresis) were analysed using one-way analysis of variance (ANOVA) at a 5% significance level followed by Duncan's Multiple Range Test (DMRT). Antioxidant activity was analysed using the descriptive method. Hedonic data were analysed using the non-parametric Kruskal-Wallis test followed by Mann-Whitney test.

Results and Discussion

To better understand the effects of honey enrichment on chickpea yoghurt, the following sections present the detailed physicochemical, functional, and sensory characteristics of the product. The study evaluated how varying honey concentrations influence key quality parameters, including acidity, soluble solids, pH, syneresis, and antioxidant capacity, as well as consumer acceptance. This approach allows for a comprehensive assessment of honey's role as a natural functional ingredient in enhancing both the technological and sensory qualities of chickpea-based fermented products.

The physicochemical properties of chickpea yoghurt enriched with different levels of honey, including pH, titratable acidity, total soluble solids, and syneresis, are presented in Table 1. Honey addition significantly affected all parameters observed ($p < 0.05$). Higher honey concentrations showed an increase in total titratable acidity and total soluble solids, and a decrease in pH and syneresis value. The antioxidant activity of chickpea yoghurt enriched with different concentrations of honey is presented in Figure 1. Antioxidant activity was evaluated using the DPPH radical scavenging assay to determine the contribution of honey supplementation to the functional properties of the fermented product. And the consumer acceptance test results of chickpea yoghurt are presented in Table 2.

Table 1. *Physicochemical test results of chickpea yoghurt with additional honey*

% Honey	Parameters			
	Titratable acidity (%)	pH	TSS (°Brix)	Syneresis (%)
0	0.20 ± 0.01^a	4.52 ± 0.01^a	8.68 ± 0.15^a	51.27 ± 0.49^a
2	0.57 ± 0.02^b	4.43 ± 0.02^b	9.24 ± 0.02^b	44.03 ± 0.02^b
4	0.66 ± 0.03^c	4.32 ± 0.02^c	12.76 ± 0.02^c	43.90 ± 0.02^c
6	0.81 ± 0.03^d	4.09 ± 0.02^d	13.84 ± 0.02^d	41.67 ± 0.02^d

Note: $^{a-d}$ – values with different lowercase superscript letters in the same column indicate significant differences ($p < 0.05$). Data are presented as mean values from 5 replicates ± standard deviation
Source: developed by the authors

Table 2. *Consumer acceptance test results*

% Honey	Colour	Aroma	Texture	Taste	Overall
0	3.73 ± 0.94^a	2.67 ± 0.96	3.03 ± 0.93	1.77 ± 0.77^a	2.33 ± 0.92^a
2	3.67 ± 0.80^b	3.03 ± 0.72	3.27 ± 1.01	2.57 ± 1.14^b	2.67 ± 0.96^b
4	3.23 ± 0.82^c	3.03 ± 0.85	2.90 ± 1.09	3.27 ± 1.05^c	3.20 ± 0.66^c
6	3.03 ± 0.89^d	3.13 ± 0.97	3.27 ± 0.83	3.97 ± 0.89^d	3.87 ± 0.68^d

Note: $^{a-d}$ – values with different lowercase superscript letters in the same column indicate significant differences ($p < 0.05$). Data are presented as mean values from 5 replicates ± standard deviation
Source: developed by the authors

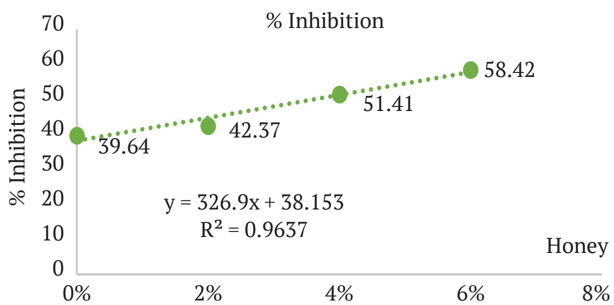

Figure 1. Antioxidant activity (% inhibition)
Source: developed by the authors

Total Titratable Acidity (TTA) values of chickpea yoghurt are presented in Table 1. Honey addition significantly affected chickpea yoghurt ($p < 0.05$). Titratable acidity showed an increasing trend with increasing honey concentration. This result suggests that honey influenced the acidification process during fermentation, which is associated with enhanced metabolic activity of lactic acid bacteria leading to increased organic acid production. P. Ningrum *et al.* (2022) demonstrated that honey supplementation provides additional energy for lactic acid bacteria and supports acid formation during yoghurt fermentation. Based on the result obtained in this study, the titratable acidity of chickpea yoghurt showed lowest value at 0% honey addition (0.20%) and the highest value at 6% honey addition (0.81%). M. Nugroho *et al*. (2023) stated that these values were higher than those observed for cow's milk yoghurt (0.63-0.73%). The higher titratable acidity observed in this study may be attributed to differences in raw materials and fermentation characteristics as chickpea yoghurt addition with honey exhibits a carbohydrate profile distinct from yoghurt produced solely from milk as a lactose source. J. Wang *et al.* (2021) confirm that the presence of fermentable carbohydrate components in chickpea may further enhance organic acid formation during fermentation. R. Rizkyanto & M. Ulfah (2025) emphasised that lactic acid production is driven by the fermentation of available sugars by lactic acid bacteria with substrate availability determining the extent of acid formation. The increased titratable acidity observed in the present study indicates that honey addition, together with the inherent carbohydrate content of chickpea, contributed to enhanced acidification during yoghurt fermentation.

The pH values of chickpea yoghurt are presented in Table 1. Honey addition significantly affected chickpea yoghurt. The pH decreased from 4.52 at 0% honey addition to 4.09 at 6% honey addition, indicating effective fermentation. The reduction in pH reflects increased lactic acid production during fermentation, as lactic acid bacteria (LAB) metabolise available sugars into lactic acid, thereby acidifying the yoghurt matrix. Research by I. Kumalasari & I. Fajriyanti (2024) confirms that sugar availability enhances LAB growth and promotes lactic acid formation, which directly contributes to pH reduction. In the work of Y. Putri *et al.* (2024), it was determined that the lower pH values are associated with improved yoghurt quality and shelf life because acidic conditions suppress spoilage microorganisms and enhance product stability relative to fresh milk. The lower pH observed at higher honey concentrations indicates that honey served as an additional fermentable carbohydrate source during fermentation. This is consistent with the findings of S. Fatimah & R. Agustini (2024) where higher honey levels increased sugar availability with fructose being efficiently metabolised by lactic acid bacteria (LAB), thereby enhancing lactic acid formation and reducing pH. Based on the result obtained in this study, the lowest pH value obtained (4.09) was lower than that reported for cow's milk yoghurt (4.20) by M. Nugroho *et al.* (2023) which may be attributed to differences in raw materials and formulation.

The TSS values of chickpea yoghurt are presented in Table 1. Honey addition significantly affected the TSS values of chickpea yoghurt. Higher honey concentration showed an increase in TSS values, with the highest value observed at 6% honey (13.84 °Brix) and the lowest value observed at 0% honey (8.68 °Brix). The increase in °Brix value indicates that the addition of honey contributes significantly to the accumulation of soluble solids in the yoghurt matrix. It was observed that honey fortification increased the soluble solids in fermented dairy products. The increase in TSS value along with the increase in honey addition is due to the sugar content in honey, especially glucose and fructose, which contribute significantly to the increase in the amount of soluble solids in yoghurt. According to Z. Albay *et al.* (2025), honey mostly contains sugar and has a high total soluble solids content that can increase the value of the TSS in yoghurt. Sugar plays an important role in the fermentation process of yoghurt by helping the growth of lactic acid bacteria (LAB) that break down fructose during fermentation and are calculated as TSS. Authors D. Kartika *et al*. (2025) indicated in their work that the main component of TSS is sugar which during fermentation, sugar that has not been completely fermented by LAB will be counted as total soluble solids. The nutritional components of chickpea milk can also contribute to the TSS values during processing, particularly during heating and fermentation. Research by A. Sitohang *et al.* (2024) shows that heating especially with high temperatures may facilitate carbohydrate degradation into simple sugars and partial starch gelatinisation, which enhances solid solubility in the yoghurt. Furthermore, the increase in TSS occurs along with a decrease in syneresis value, which occurs because high sugar content can bind water. This is consistent with the findings of A. Famuji *et al.* (2023) that the water-binding capacity of sugars may reduce free water release, which explains the inverse relationship between TSS and syneresis.

The percentage syneresis of chickpea yoghurt is presented in Table 1. The analysis of variance showed that the additional honey significantly affected the syneresis value of chickpea yoghurt ($p < 0.05$). Increasing the concentration of honey showed a decrease in syneresis values, with the highest values observed at 0% honey (51.27%) and the lowest values observed at 6% honey (41.67%). Previous studies by T. Singh *et al.* (2024) have also reported that the reduced syneresis of yoghurt may come from honey. A similar effect was reported by T. Brčina *et al.* (2022) that showed a positive effect of adding honey to yoghurt on viscosity and water retention and may cause the reduction of syneresis. The decrease in syneresis values along with an increase in honey concentration may be due to the ability of honey in yoghurt to bind water. A. Anwar *et al*. (2025) emphasised that fructose content in honey can improve the texture of yoghurt and prevent the syneresis because of its water-binding properties. The fructose in honey which can bind water, increases viscosity and total soluble solids. Research by A. Famuji *et al.* (2023) stated that high total soluble solids values are inversely proportional to syneresis and cause syneresis values to decrease. Gel formation during fermentation also plays an important role. Lactic acid bacteria such as *Streptococcus thermophillus* and *Lactobacillus bulgaricus* promote protein coagulation and are capable of entrapping water. L. Campos *et al*. (2024) reported that protein denaturation and aggregation during acidification strengthen this gel structure and improve water retention which contributes to lower syneresis.

The percentage antioxidant activity of chickpea yoghurt is presented in Figure 1. The linear regression analysis showed a strong relationship between honey concentration and the antioxidant activity of chickpea-based yoghurt, with a coefficient of determination (R^2) of 0.96. N. Shaharom *et al*. (2024) explained that the R^2 value close to 1 suggests that the regression model provides highly accurate predictions of the optimal value. The increase in honey concentration significantly contributes to an increase in DPPH radical inhibition and indicates a higher antioxidant capacity in yoghurt. The antioxidant activity was evaluated using the DPPH method, which is widely applied to determine the free radical scavenging capacity of food samples. DPPH inhibition activity correlates with the ability of antioxidant compounds in yoghurt to reduce the properties of free radicals and increase the percentage of inhibition as the concentration of honey increases, thus indicating an increase in antioxidant activity. Previous study by I. Gulcin & S. Alwasel (2023) stated that this method is commonly used as an indicator to measure antioxidant capacity.

In this study, the inhibition values ranged from 39.64% to 58.42%, where yoghurt with 6% honey exhibited the highest antioxidant activity, while the 0% honey showed the lowest value. These findings indicate that honey serves as the main contributor to antioxidant compounds in the yoghurt. The fermentation process may also enhance antioxidant activity. Previous studies by G. Budryn & J. Grzelczyk (2024) state that during fermentation, the metabolic activity of microorganisms may be an additional source of antioxidants and will affect the release of flavonoids. In addition, the antioxidant activity of chickpea yoghurt may be related to TSS values, because the amounts of soluble components such as sugar during the heating process will go through a Maillard reaction and produce compounds that are indicated to have an antioxidant activity. Additionally, F. Nirwana *et al*. (2025) reported that the Maillard reaction has the potential to produce the brown-coloured melanoidin as the antioxidant compounds.

Consumer acceptance was evaluated for colour, aroma, taste, texture, and overall acceptance. Hedonic quality evaluation was carried out to assess the acceptance and preference levels of chickpea-based yoghurt with different concentrations of honey, using a scoring-based assessment. The evaluation comprised five hedonic quality parameters. Based on the results presented in Table 2, the mean hedonic scores for colour preference of chickpea yoghurt ranged from 3.03-3.73. Chickpea yoghurt with 0% honey addition received the highest score (3.73) whereas chickpea yoghurt with 6% honey addition obtained the lowest score (3.03). The hedonic values for all in terms of colour were classified as slightly liked by the panellist. The Mann-Whitney test result indicated that the 0% honey did not show a significant difference compared to the 2% honey, but differed significantly from the 4% and 6% honey. The colour of the resulting chickpea yoghurt appeared slightly yellowish-white, which was attributed to the addition of honey. According to A. Anwar *et al*. (2025), the yellow colour intensity in yoghurt increases due to the presence of natural golden yellow pigments derived from honey. Higher levels of addition tend to produce a more yellowish colour, as honey contains natural pigments such as carotenoids. I. Smetanska *et al.* (2021) stated that honey colour is influenced by various factors, including pigments such as carotenoids and flavonoids, total phenolic content, and handling methods. Another contributing factor is the occurrence of Maillard reaction during heating and fermentation processes which may contribute to the development of a slightly brownish colour in yoghurt. According to previous studies by M. Alief *et al.* (2025), Maillard reactions between fructose and glucose and amino acids during fermentation or heating leads to the formation of melanoidin compounds, which are responsible for yellowish-brown coloration in honey. Furthermore, honey colour is directly associated with its antioxidant content.

Based on the data presented in Table 2, the aroma parameter showed no significant difference among chickpea yoghurt with varying levels of honey addition, therefore the Kruskal-Wallis was not followed by a Mann-Whitney test. The data in Table 2 indicate that the mean hedonic scores for the aroma parameter ranged from 2.67-3.13 with preference scores increasing as the percentage of honey addition increased. Chickpea-based yoghurt containing 6% honey exhibited the highest hedonic score (3.13), which was classified as slightly liked by the panellists, whereas yoghurt without honey addition (0%) showed the lowest hedonic score (2.67), categorised as slightly disliked. Overall, variations in honey addition did not result in significant differences in the aroma preference of chickpea-based yoghurt. The aroma of chickpea yoghurt was characterised by contributions from honey and a slight beany odour originating from chickpea. Although increasing honey levels enhanced panellists' perception of aroma complexity, this effect was not sufficient to produce significant differences in overall aroma preference, resulting in similar acceptance levels across samples. The characteristic aroma of honey introduces sweet and floral notes that may reduce the perception of undesirable beany odours, thereby contributing to improved hedonic scores. M. Al-Khalili *et al.* (2025) stated that the importance of volatile aroma compounds as key determinants of flavour perception and consumer acceptance in food products has been well documented. Honey contains aroma components commonly described as sweet, floral, acidic and woody. H. Mulheron *et al.* (2024) reported that the aroma of honey differs from that of common sweeteners and is characterised by distinctive notes such as sweet, floral, citrus, medicinal, and woody. More than 600 volatile organic compounds have been identified in various types of honey, including aldehydes, ketones, acids, alcohols, esters, hydrocarbons, and sulphur-containing compounds. Chickpea has a distinctive aroma and may produce a beany odour due to its volatile compounds. M. Tangyu *et al.* (2021) identified unfermented chickpeas contain aldehydes such as pentanal, hexanal, and heptanal, which originate from plant lipid oxidation and contribute to the characteristic beany odour. Panellists perceived the aroma differences among chickpea yoghurt samples as subtle, making them difficult to distinguish. This similarity in aroma acceptance may be attributed to comparable fermentation rates, resulting in similar formation of volatile compounds and lactic acid across samples. This finding is in consistent with E. Anggraini *et al.* (2018), who stated that acidic aroma is generated by volatile compounds and lactic acid formed during fermentation.

The taste attribute in the sensory test was significantly influenced by honey addition ($p < 0.05$). Hedonic scores increased along with the honey concentration, with the highest scores observed at 6% honey (3.97) and the lowest scores observed at 0% honey (1.77). Yoghurt generally has a distinctive sour taste caused by lactic acid. E. Suharto & F. Ferawati (2024) explained that the distinctive taste of yoghurt is caused by the content of lactic acid and small compounds such as diacetyl, acetaldehyde, and acetic acid produced by the symbiotic interaction between *Streptococcus thermophilus* and *Lactobacillus*. L. Campos *et al*. (2024) stated that honey is perceived to have the best taste by consumers. Honey acts as a natural sweetener. Enhancing the sweetness to balance the sweet and sour flavour in yoghurt. Fructose, in particular, plays a dominant role in enhancing sweetness perception due to its higher sweetness intensity compared to other sugars. According to previous studies by J. Wu *et al.* (2025), fructose exhibits a sweetness level approximately 1.73 higher than sucrose and 2.34 higher than glucose, which explains the marked increase in hedonic taste scores observed with higher honey concentrations. Consequently, the incorporation of honey effectively improves taste acceptance by moderating sourness and enhancing sweetness in chickpea yoghurt.

Texture. Based on the data presented in Table 2, honey addition did not significantly affect the texture preference of chickpea yoghurt ($p > 0.05$). Hedonic scores of the texture ranging from 2.90 to 3.27. Although differences were not statistically significant, a tendency toward improved smoothness was observed in this yoghurt. Higher levels of honey addition tended to increase the softness of the yoghurt texture, which may contribute to higher hedonic acceptance by the panellists. This improvement in texture perception is likely related to the role of honey as a natural sweetener containing sugars that interact with the yoghurt matrix. A previous study by A. Rashwan *et al.* (2023) reported that the addition of honey to soy yoghurt increased sensory acceptance, including texture attributes. A. Anwar *et al.* (2025) explained that sugar content in honey can improve the texture quality of yoghurt by its water-binding properties that can produce a more stable gel matrix in yoghurt when combined with protein. According to T. Lubis & D. Ardila (2024) higher sugar content indicates the viscosity value becomes higher because it reduces the water content. An increase in honey concentration is related to the viscosity value because it produces a high total soluble solids content and makes the viscosity enhanced. This statement is in consistent with S. Susanti *et al*. (2023) that the higher the sweetener added, the higher viscosity produced.

The results presented in Table 2 indicate that the mean overall hedonic scores of the yoghurt ranged from 2.33 to 3.87. Chickpea-based yoghurt with 6% honey addition obtained the highest overall preference score (3.87), while yoghurt without honey addition (0%) showed the lowest score (2.33). Overall, panellists tended to prefer chickpea-based yoghurt with 6% honey addition, presumably due to the sweeter taste produced. M. Taufik *et al.* (2025) reported that honey has been shown to enhance consumer acceptance by masking undesirable flavours and balancing bitter, sour, and salty tastes. Similar findings were observed by M. Rahardjo *et al.* (2022), in which higher honey concentrations resulted in greater preference for plant-based soy yoghurt. Honey also contributes to masking the beany odour derived from chickpeas, resulting in a more pronounced acidic aroma typical of yoghurt combined with a slight sweet aroma. Panellists perceived the aroma differences among chickpea-based yoghurt samples as subtle, making them difficult to distinguish, which resulted in similar hedonic scores for the aroma parameter. Research by L. Xiang *et al.* (2023) explained that the beany off-flavours, generated by volatile compounds such as aldehydes and ketones derived from plant proteins, are recognised as sensory characteristics that influence overall flavour profiles and consumer perception in plant-based foods. Consequently, the improvement in overall acceptability observed at higher honey levels is likely driven by the combined effects of enhanced sweetness and moderated beany notes, rather than pronounced differences in aroma intensity.

In conclusion, the addition of honey to chickpea-based yoghurt significantly improved overall consumer acceptance, particularly at the 6% concentration, by enhancing sweetness and mitigating undesirable beany notes. While aroma differences among samples were subtle, the combination of improved taste and texture contributed to higher hedonic scores and overall preference. These findings highlight the potential of honey as a natural functional ingredient in plant-based fermented products, offering both sensory appeal and technological benefits, and providing valuable insights for the development of nutritionally enhanced, consumer-friendly yoghurt alternatives.

Conclusions

The addition of honey significantly influenced the physicochemical and sensory characteristics of chickpea-based yoghurt ($p < 0.05$). Increasing honey concentration from 0% to 6% enhanced fermentation performance, as shown by the increase in titratable acidity from 0.20% to 0.81% and total soluble solids from 8.68 to 13.84 °Brix. At the same time, pH decreased from 4.52 to 4.09, confirming intensified acid production by lactic acid bacteria. Product stability also improved, indicated by the reduction of syneresis from 51.27% to 41.67%. These findings demonstrate that honey promotes gel formation and water retention in chickpea yoghurt. Sensory analysis revealed that honey addition significantly improved taste and overall acceptance ($p < 0.05$), while aroma and texture were not significantly affected ($p > 0.05$). The formulation containing 6% honey produced the most balanced sensory profile and the highest consumer preference. The improvement in yoghurt quality is associated with the functional role of honey as both a fermentable carbon source and a bioactive ingredient. The glucose and fructose present in honey are easily metabolised by lactic acid bacteria, leading to increased organic acid production and accelerated acidification. This process enhances protein coagulation and strengthens the gel matrix, thereby reducing whey separation. Furthermore, phenolic and flavonoid compounds in honey contribute to antioxidant activity and may stabilise the fermentation system through mild antimicrobial effects. However, concentrations higher than 6% may potentially generate osmotic pressure that inhibits bacterial activity, explaining the optimal performance observed at this level. From an industrial application perspective, incorporating 6% honey provides a natural sweetener that improves product stability, functional properties, and consumer acceptance without the need for artificial additives Therefore, chickpea-based yoghurt enriched with honey has strong potential for commercial development as a plant-based functional food suitable for lactose-intolerant and health-conscious consumers. Future studies should evaluate probiotic viability during storage, shelf-life stability, and the influence of different botanical origins of honey on product quality.

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Conflict of Interest

None.

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Фізико-хімічні властивості та сенсорна привабливість йогурту з нуту (*Cicer arietinum* L.), збагаченого медом

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Анотація. Зростаючий попит на рослинні функціональні продукти сприяє ширшому використанню бобових культур як альтернативи традиційній молочній сировині. Нут (*Cicer arietinum* L.) є багатим на білок, клітковину та біоактивні сполуки, тоді як мед може покращувати ферментацію, текстуру та антиоксидантні властивості. Метою цього дослідження було оцінити вплив додавання меду (0 %, 2 %, 4 % та 6 %) на фізико-хімічні характеристики, антиоксидантну активність та сенсорну привабливість йогурту на основі нуту. Молоко з нуту, збагачене знежиреним молоком, ферментували за допомогою молочнокислих бактерій і аналізували на pH, титровану кислотність, загальні розчинні речовини, синерезис, антиоксидантну активність та сприйняття споживачами. Додавання меду значно покращило фізико-хімічні та сенсорні властивості йогурту з нуту, підвищуючи ефективність ферментації (збільшення титрованої кислотності, загальних розчинних речовин та антиоксидантної активності) та знижуючи значення pH і синерезису. Сенсорна оцінка показала покращення смакових якостей та загальної привабливості з підвищенням концентрації меду, тоді як аромат і текстура істотно не змінювалися. В цілому, 6 % меду забезпечили оптимальний баланс стабільності, функціональності та сприйняття споживачами, що вказує на його потенціал як оптимальної формули для розробки рослинного йогурту. Ці результати підкреслили роль меду як природного функціонального інгредієнта, який покращує як технологічні властивості, так і прийнятність продукту серед споживачів у ферментованих продуктах на основі бобових.

Результати дослідження можуть бути використані виробниками рослинної продукції та малими підприємствами для розробки функціональних аналогів йогурту з покращеними поживними та органолептичними властивостями, що особливо актуально для ринків із високим попитом на ферментовані продукти

Ключові слова: рослинна ферментація; молочнокислі бактерії; пребіотичний підсолоджувач; антиоксидантна активність; сенсорна оцінка