Physicochemical and sensory properties of lemon – honey beverages with different honey varieties

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Abstract. Global consumption of sugar-sweetened beverages (SSBs) is increasing and has been linked to various non-communicable diseases, underscoring the need for healthier, functional beverage alternatives. This study aimed to develop and evaluate a functional beverage formulated with lemon and honey, both known for high antioxidant potential. Three honey varieties Calliandra (M1), Acacia (M2), and Itama (M3) were incorporated into fixed-ratio formulations with lemon juice (50 mL) and honey (40 mL) per serving. Comprehensive physicochemical analyses (pH, viscosity, color, and total soluble solids), and sensory evaluations using hedonic testing. Data were analyzed using Microsoft Excel and IBM SPSS, and one-way ANOVA employed to determine statistically significant differences among the formulations. The findings revealed that honey type had a significant effect on pH ($p = 0.043$), color lightness (L*) ($p < 0.001$), and total soluble solids (°Brix) ($p < 0.001$), whereas viscosity did not differ significantly ($p = 0.073$). Notably, the M1 formulation (with Calliandra honey) exhibited superior physicochemical characteristics and received significantly higher hedonic scores across all sensory attributes ($p < 0.05$) than M2 and M3. Calliandra honey significantly enhances the quality and acceptability of lemon honey beverages, supporting their potential as functional, healthier alternatives to SSBs in reducing diet-related non-communicable diseases.

1 Introduction

Sugar-sweetened beverages (SSBs) are increasingly recognized as major contributors to non-communicable diseases including metabolic syndrome, type 2 diabetes, dental caries, gout, and cardiovascular problems [1]. A global survey involving 187 countries found that adults in middle-income nations consume more SSBs than those in high- or low-income nations [2]. In Indonesia, the per capita intake of carbonated and non-carbonated soft drinks, energy drinks, and sports beverages has increased by 25% from 31 to 39 liters per year between 2013 and 2021. Riskesdas [3] indicated that 66% of children aged 5-19 and 64% of adults over 20 years old regularly consume SSBs, suggesting their widespread adoption,

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especially among youth.

This pattern is particularly alarming for adolescents. Falbe *et al.* [4] found that adolescents who frequently consume SSBs report increased cravings, headaches, and declines in motivation, concentration, emotional well-being, and contentment. Excessive SSB intake during childhood has also been linked to dysglycemia, obesity, hypertension, and long-term cardiovascular diseases [5]. SSB intake raises both blood glucose and insulin levels and, dueto their moderate-to-high glycemic index, they contribute to an elevated dietary glycemic load, glucose intolerance, and insulin resistance.

Limiting SSB intake is essential for maintaining a healthy weight and dietary habits. Moderate consumption of pure fruit juice and low-fat or non-fat milk is considered a better alternative to meet nutritional needs [6]. Moreover, diets rich in fruits, vegetables, and whole grains are associated with a reduced risk of metabolic syndrome-related diseases, including type 2 diabetes, cardiovascular disease, cancer, and neurodegenerative disorders. Flavonoids in fruits and vegetables also enhance antioxidant capacity and help lower blood pressure [7]. Lemon is one such fruits rich in antioxidants. Its distinctive flavor and acidity make it a valuable food and industrial product. It contains bioactive compounds such as ferulic acid, flavonoids (e.g., hesperidin, naringin, and neohesperidin), vitamin C, and carotenoids, all of which contribute to its health-promoting effects [8]. Honey also has cardiovascular benefits. It enhances the bioavailability of nitric oxide (NO), a vital vasodilator that supports vascular health. Studies have shown honey provides antioxidants, anti-inflammatory, antibacterial, antidiabetic, and organ-protective effects [9].

Considering the antioxidant potential of lemon and honey and the growing health concerns surrounding SSBs, this study aimed to develop a functional beverage using lemon and honey as a healthier alternative. The sourness of lemons can be balanced by the natural sweetness of honey, resulting in a refreshed and beneficial drink. However, the long-term health impact of substituting SSBs with such beverages remains unclear. Therefore, this study sought to formulate and evaluate lemon honey beverages with different honey types and analyze their physicochemical properties and sensory attributes to identify the most acceptable formulation for functional beverage innovation.

2 Method

2.1 Product development

This study was conducted from March to May 2025 at IPB University, Bogor, Indonesia. Product development uses two main ingredients: lemon and honey. The lemons used were the *Citrus x limon (L.)* Osbeck species from the *Rutaceae* family sourced from local farmers in Ciampea, Bogor. The selected fruits were mature, with bright yellow skin, free from blemishes or physical damage. Three types of honey were used: *Calliandra* from Jepara, Acacia from Sumatera, and Itama honey from Kalimantan, purchased from local markets or apiaries in Bogor. The selection of Acacia, Acacia, and Itama honey was based on the distinct profiles of their phenolic and flavonoid compounds, which contributed to their antioxidant potential and associated health benefits. Acacia honey, also known as forest or pine honey, exhibited the highest ferulic acid content (173.8 mg/kg), indicating its strongest antioxidant capacity among the three. Acacia honey showed a high ferulic acid level (139.8 mg/kg) and contained the highest concentration of quercetin (1.2 mg/kg), supporting both antioxidant activity and cardiovascular protection.

Although Itama honey had a lower ferulic acid content (54.4 mg/kg), it was selected for its notable levels of other phenolic compounds, such as p-HBA (22.6 mg/kg) and p-

coumaric acid (11.5 mg/kg), along with flavonoids including quercetin (0.4 mg/kg) and apigenin (1.6 mg/kg) that contribute to anti-inflammatory effects. Collectively, these three types of honey have complementary bioactive profiles, making them promising candidates for the development of functional beverages aimed at optimizing health benefits.

Table 1. The formulations of lemon and honey

Ingredients	Type of Honey		
	M1*	M2*	M3*
Lemon	50	50	50
Honey	40	40	40
Total	90	90	90

*Note: *) M1= Calliandra, M2= Acacia , M3= Itama*

Product development focused on three formulations: M1 (Calliandra Honey), M2 (acacia honey), and M3 (itama honey), with the type of honey being the main treatment. The production process started with washing the lemons, cutting them into 5x5 cm pieces, and juicing them with a manual fruit press machine (Heavy Duty Manual Juice Extractor) to obtain fresh lemon juice, yielding approximately 11.25 L of lemon juice (50 mL per serving). The juice was then mixed with the three honey varieties in equal proportions (40 mL or 57 g per serving).

The equipment used included measuring glass, fruit filters, knives, mixing containers, and utensils. For the sensory testing, plastic cups, straws, spoons, chairs, sensory test forms, and pens were provided

2.2 Physical properties of lemon – honey beverage

Physical analysis was conducted to evaluate the color, viscosity, total dissolved solids, and acidity of the lemon – honey beverage. This analysis is crucial for ensuring product quality, consistency, and acceptability.

2.2.1 Physical properties: color

Color analysis was performed at the Nutrition Laboratory, Department of Community Nutrition, IPB University, using a colorimeter based on ISO 7724-1: *Methods for Instrumental Color Measurement.* The color was measured using the CIELAB system, where L* indicates lightness (0 = black, 100 = white), a* indicates the green-red spectrum, and b* indicates the blue-yellow spectrum [10]. Samples (3-5 mL) were prepared at a consistent temperature and volume. The instrument was calibrated by using a standard blank. Each formula was poured into a transparent cuvette, and color readings were taken in triplicate.

2.2.2 Physical properties: viscosity

Viscosity was measured using a digital rotary viscometer (Normalab Series 100) following the ASTM D445 standard. Approximately 11.6 mL of the beverage sample was loaded into the viscometer through the largest bulb until filling and then allowed to flow into a smaller-diameter bulb. The flow time was recorded and viscosity was calculated using the following formulas: viscosity (mm^2/s) = time (s) × calibration factor and viscosity (cP) = viscosity (mm^2/s) × density [11].

2.2.3 Physical properties: total dissolved solids

The total dissolved solids were measured using a refractometer based on light refraction through the solution. Brix values indicate the sugar content (g/100 mL) and reflect sweetness. Samples (10-50 mL) were measured at a constant temperature. Brix values in lemon beverages typically range from 6 to 10 depending on the added sugar levels [11].

2.2.4 Physical properties: degree of acidity (ph)

Degree of acidity (pH) was measured using a pH meter calibrated with buffer solutions at pH 4 and 7, following AOAC Method 981.12 (1990). The electrode was immersed in 10-50 mL of sample until a stable reading was obtained. This analysis is important for determining product stability and flavor preferences [11].

2.3 Sensory test of lemon – honey beverage

A hedonic test was conducted to assess the panelists' preferences for the product. A total of 49 untrained panelists, representing the target population for a subsequent intervention study at the KPKNL (Kantor Pelayanan Kekayaan Negara dan Lelang) Bogor institution, participated in the evaluation. The hedonic test is a sensory evaluation method used to measure consumer preferences for the specific sensory attributes of a food product.

The inclusion criteria for panelists were willingness and previous participation in organoleptic tests, age between 18 and 55 years, good general health, no olfactory disorders, color blindness, psychological conditions that might affect sensory perception, not pregnant or breastfeeding, and no citrus allergies. Panelists were also required to provide consent to undergo sensory evaluation according to the specified procedures at their respective locations. Additionally, they were instructed to refrain from consuming strongly flavored foods (sour, spicy, bitter, or sweet) for at least one hour before the test and to avoid smoking, chewing gum, or consuming snacks or beverages for at least 20 min before the evaluation. The test followed the ISO 6658 standards [12].

Three lemon-honey beverage formulas (M1, M2, and M3) were randomly presented without direct comparisons. The evaluation used a 10 cm linear line scale (hybrid hedonic scale). The assessed parameters included color, appearance, aroma, taste, mouthfeel, aftertaste, and overall taste. Scores ranged from 1 to 9 with the following interpretations: 1= extremely dislike, 2 = very dislike, 3 = dislike, 4 = slightly dislike, 5 = neutral, 6 = slightly like, 7 = like, 8 = very like, and 9 = extremely like. To minimize sensory fatigue, the panelists were instructed to rinse their palates with water between the samples. An average score ≥ 5 is considered an indicator of general consumer acceptance.

2.4 Data analysis

Physical and sensory test data were analyzed using Microsoft Excel and IBM SPSS Statistical Software. One-way ANOVA was performed to evaluate differences among the three formulations (M1, M2, and M3) in terms of physical parameters (pH, color, total dissolved solids, and viscosity) and sensory attributes (color, aroma, taste, mouthfeel, aftertaste, and overall acceptability). When significant differences were detected ($p < 0.05$), a post-hoc analysis using Duncan's multiple range test was applied to identify differences between groups.

3 Results and discussion

3.1 Physicochemical analysis

Table 2 presents the physicochemical properties of lemon honey beverage formulations. Significant differences were observed in pH, color (L*), and total soluble solids (TSS, in °Brix), whereas viscosity showed no statistically significant difference at the 5% level.

Table 2. Physicochemical properties of lemon honey beverage formulations

Sample	Parameter			
	pH	Viscosity (cP)	Color (L*)	Total Solids (Brix)
M0*	2.16 ± 0.15^{a}	74.66 ± 29.50^{a}	12.63 ± 0.057^{b}	6 ± 0.00^{a}
M1*	2.44 ± 0.28^{b}	132.86 ± 10.85^{b}	14.33 ± 0.97^{c}	43 ± 0.00^{a}
M2*	2.55 ± 0.015^{b}	103.70 ± 27.79^{ab}	7.69 ± 0.58^{a}	40 ± 0.00^{a}
M3*	2.49 ± 0.02^{b}	99 ± 15.58^{ab}	8.7 ± 0.83^{a}	39.3 ± 0.57^{b}
p-value	p= 0.043	p= 0.073	p<0.001	p< 0.001

*$^{a,b,ab)}$ Means within the same column followed by the same letter are not significantly different according to Duncan's test at the 5% significance level (p *) M.05).*
$^{*)}$M0: Control (without honey); M1, lemon with Calliandra honey; M2, lemon with acacia honey; M3, lemon with Itama honey.

The analysis revealed highly significant differences (p< 0.001) in both color (L*) and total soluble solids (°Brix) among ththeeverage formulations. The highest L* value was observed in sample M1 (14.33 ± 0.97), indicating a significantly lighter color than the other samples. In contrast, M2 and M3 had the lowest L* values, indicating a darker color, possibly because of Maillard browning and pigment content in Itama honeys. The bright tone in M1 could reflect the natural clarity of *Calliandra* honey and fewer browning reactions. While darker colors may imply higher antioxidant potential due to melanoidin formation [11], panelists showed a clear preference for lighter-colored beverages. M1 also received the highest hedonic scores for visual appearance, reinforcing the role of color in consumer acceptance.

In terms of total soluble solids (TSS), M1 again showed the highest °Brix (43 ± 0.00), followed by M2 (40 ± 0.00), M3 (39.3 ± 0.57), and the control M0 (6 ± 0.00) with the lowest. The significant differences (p < 0.000) suggest that honey type has a substantial impact on °Brix, even when used in the same volumes. This may be due to the different intrinsic sugar compositions and concentrations of honey used. Higher °Brix values enhance flavor intensity and contribute to a fuller mouthfeel which is important attributes in consumer satisfaction. The richness of Calliandra honey in simple sugars may explain its stronger sweetness and overall higher acceptance of M1.

For pH, a statistically significant difference was observed (p=0.043). M0, formulated with lemon only, had the lowest pH (2.16 ± 0.15), confirming lemon's natural acidity. M1 – M3 showed significantly higher pH values, although they were not significantly different from each other. This indicates a buffering effect of honey, which contains phosphate, carbonate, and mineral salts that stabilize acidity [13]. This buffering effect not only reduces

acidity – related discomfort, such as GERD, but also improves flavor balance and sensory acceptance, particularly in M1, which received the highest hedonic score. This effect may also contribute to M1's superior sensory ratings.

Although the differences in viscosity were not statistically significant ($p = 0.073$), trends were observed. M1 showed the highest viscosity (132.86 ± 10.85^{b}), followed by M2, M3, and M0. This can be attributed to the sugar profile of *Calliandra* honey, which is rich in glucose and fructose. A thicker texture improves the mouth-feel and sensory smoothness. Moreover, honey contributes not only to sweetness but also to emulsion stability and beverage body, adding to the overall consumer experience

These findings emphasize the importance of honey type selection for determining the final quality of lemon honey beverages. It is not only the quantity, but also the intrinsic properties of honey, such as sugar profile, mineral content, and processing history, that influence physicochemical characteristics.

3.2 Sensory analysis

Sensory or organoleptic testing is essential for determining product acceptance by consumers as it reflects preferences and market potential. In this study, hedonic evaluation was performed on three lemon-honey beverage formulations (M1, M2, and M3) based on seven key attributes: color, aroma, taste, viscosity, mouthfeel, aftertaste, and overall acceptance.

Table 3. Hedonic scores of lemon honey beverage formulations on sensory attributes

Parameter	Sample			*p-value*
	M1	M2	M3	
Color	7.74 ± 1.24^{b}	5.48 ± 1.65^{a}	5.29 ± 1.34^{a}	<0.001
Aroma	7.34 ± 1.37^{b}	5.27 ± 1.71^{a}	4.91 ± 1.67^{a}	<0.001
Taste	7.42 ± 1.37^{c}	5.34 ± 1.78^{b}	4.59 ± 1.86^{a}	<0.001
Viscosity	7.14 ± 1.12^{c}	5.95 ± 1.60^{b}	5.29 ± 1.38^{a}	<0.001
Mouthfeel	7.29 ± 1.42^{b}	5.06 ± 1.77^{a}	4.55 ± 1.79^{a}	<0.001
Aftertaste	6.76 ± 1.68^{b}	5.29 ± 1.64^{a}	4.91 ± 2.04^{a}	<0.001
Overall	7.40 ± 1.29^{c}	5.42 ± 1.71^{b}	4.63 ± 1.78^{a}	<0.001

Notes: [a,b,ab] Means within the same column followed by the same letter are not significantly different according to Duncan's test at the 5% significance level ($p < 0.05$).
[*)]M0: Control (without honey); M1: lemon with Calliandra honey; M2: lemon with Acacia honey; M3: lemon with Itama honey.

As shown in Table 3, M1 (formulated with Calliandra honey) obtained significantly higher hedonic scores ($p < 0.05$) across all sensory attributes than M2 and M3. Its highest ratings were found in color (7.74 ± 1.24), aroma (7.34 ± 1.37), taste (7.42 ± 1.37), and overall acceptance (7.40 ± 1.29), indicating a clear preference by the panelists.

The superior acceptance of M1 can be attributed to the unique sensory profile of Calliandra honey, which is rich in volatile aromatic compounds and natural reducing sugars [14]. These components enhance the balance between sweetness and acidity, contributing to a refreshed taste and pleasant aroma. Furthermore, M1's moderate viscosity (7.14 ± 1.12) offered a smooth texture and comfortable mouthfeel. This aligns with the physicochemical results, where M1 showed the highest viscosity (132.86 cP) and a bright color ($L^* = 14.33$), contributing to better visual appeal and mouth-feel experience.

In contrast, M3 (formulated with Itama honey) received the lowest scores for all attributes, particularly in mouthfeel (4.55 ± 1.79) and aftertaste (4.91 ± 2.04). This is likely related to its lower viscosity, darker and less attractive color, as supported by the physicochemical data showing that M3 had the lowest viscosity and lowest L^* value. These characteristics likely produce a watery texture and a less harmonious flavor profile, reducing

its sensory appeal.

Panelists tended to prefer beverages with balanced sweetness and acidity, a smooth mouthfeel, and bright color. These findings emphasize the importance of achieving sensory balance in functional beverages [12].

Notably, M1 has emerged as the best formulation because of its favorable physicochemical properties, such as optimal viscosity, light color, and high total soluble solids, all of which directly contribute to superior sensory characteristics, including better taste, texture, and visual appeal. These qualities not only reflect functional excellence but also align with consumer preferences for beverages that are slightly sweet, translucent, aromatic, and have broad, pleasant flavor profiles [15]. The use of Calliandra honey, which is known for its smooth taste and mild aftertaste, further contributed to the panelists' high acceptance of M1. Moreover, the presence of bioactive compounds from both lemons and honey offers added health benefits, including antioxidant activity and a low glycemic index. Its natural formulation is free from artificial sweeteners, colors, and flavors, making M1 a strong candidate for commercial development, providing a healthier and more appealing alternative to conventional sugar-based or carbonated beverages.

Nevertheless, future research should also consider local market preferences and cultural profiles, as these may influence the success of product commercialization. Understanding specific consumer expectations can inform targeted product development and strategic positioning in the functional beverage markets.

4 Conclusion

Lemon honey beverages have been successfully formulated using different types of honey. Physicochemical analyses revealed significant differences among the formulations in terms of pH, color (L*), and total soluble solids. The formulation using Calliandra honey (M1) exhibited the most favorable physicochemical profile, including higher brightness and viscosity. Sensory analysis confirmed that M1 was also the most preferred by panelists, achieving the highest scores for taste, aroma, mouthfeel, and overall acceptability. The alignment between physicochemical attributes and sensory appeal highlights the critical role of formulation composition in determining consumer preferences. Overall, M1 demonstrated the best potential for further development as a sensory-acceptable, naturally derived functional beverage.

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