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Effect of mangosteen peel powder substitution on the antioxidant activity and sensory properties of green tea

Pengaruh Substitusi Serbuk Kulit Manggis terhadap Aktivitas Antioksidan dan Sifat Organoleptik Teh Hijau

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ABSTRACT

Background: *Mangosteen peel powder tea is a natural beverage with a unique taste and aroma, containing xanthones and rich in antioxidants that can help regulate blood glucose levels in type II diabetes mellitus.*
Objective: *This study aimed to determine the effect of mangosteen peel powder substitution on the organoleptic properties and antioxidant activity of green tea.*
Methods: *The research design was an experimental study using a Completely Randomized Design (CRD) non-factorial, consisting of three treatments: A (mangosteen peel:green tea 50%:50%), B (60%:40%), and C (70%:30%), each with three replications. The tested parameters included acceptability (color, taste, and aroma) through a hedonic test by 30 trained panelists at the Food Laboratory, Nutrition Department, Poltekkes Kemenkes Aceh, and antioxidant activity using the DPPH (2,2-diphenyl-1-picryhydrazil) method at the Instrument and Chemistry Research Laboratory, Faculty of Mathematics and Natural Sciences, Syiah Kuala University. Data were analyzed using ANOVA and continued with Duncan's test at a 95% confidence level.*
Results: *The results showed that the highest scores for color and taste were obtained in treatment A, while aroma was highest in treatment C, categorized as "slightly liked." The highest antioxidant activity was also found in treatment C with an IC_{50} value of 4.42 µg/ml, classified as potent.*
Conclusion: *It was concluded that mangosteen peel substitution had no significant effect on color and taste but significantly affected aroma and antioxidant activity of green tea. Further In vivo studies are needed to evaluate its antidiabetic effectiveness.*

Keywords: *antioxidant activity, diabetes mellitus, green tea, mangosteen peel powder*

ABSTRAK

Latar Belakang: Teh serbuk kulit manggis merupakan salah satu minuman alami yang memiliki rasa dan aromanya yang unik, juga mengandung senyawa xanthone dan kaya akan antioksidan yang mampu mengendalikan kadar gula darah pada penderita diabetes melitus tipe II.
Tujuan: Penelitian ini bertujuan untuk mengetahui pengaruh substitusi serbuk kulit manggis terhadap sifat organoleptik dan aktivitas antioksidan teh hijau.
Metode: Desain eksperimen dengan Rancangan Acak Lengkap (RAL) non-faktorial, terdiri atas tiga perlakuan, yaitu A (kulit manggis:teh hijau 50%:50%), B (60%:40%), dan C (70%:30%), masing-masing dengan tiga ulangan. Parameter uji meliputi daya terima (warna, rasa, dan aroma) melalui uji hedonik oleh 30 panelis terlatih di Laboratorium Pangan Jurusan Gizi Poltekkes Kemenkes Aceh, serta uji aktivitas antioksidan menggunakan metode DPPH (*2,2-difenil-1-picryhydrazil*) di Laboratorium Instrumen dan Penelitian Kimia FMIPA Universitas Syiah Kuala. Data dianalisis menggunakan ANOVA dan dilanjutkan dengan uji Duncan pada taraf kepercayaan 95%.

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Hasil: Hasil penelitian menunjukkan bahwa skor tertinggi untuk warna dan rasa terdapat pada perlakuan A, sedangkan aroma tertinggi terdapat pada perlakuan C, dengan kategori penilaian agak suka. Aktivitas antioksidan tertinggi diperoleh pada perlakuan C dengan nilai IC_{50} sebesar 4,42 µg/ml yang tergolong sangat potensial.
Kesimpulan: Berdasarkan hasil analisis, substitusi serbuk kulit manggis tidak berpengaruh nyata terhadap warna dan rasa, namun berpengaruh nyata terhadap aroma serta aktivitas antioksidan teh hijau. Studi in vivo diperlukan untuk menilai efektivitas antidiabetes teh hijau dengan substitusi serbuk kulit manggis.

Kata kunci: aktivitas antioksidan, diabetes melitus, serbuk kulit manggis, teh hijau

INTRODUCTION

Alternative tea beverages are natural drinks that have become very popular in society due to their unique taste and aroma, as well as their beneficial health properties.[1] Tea cultivation and management in Indonesia include both company-owned plantations and smallholder tea farms. The management systems in these two types of plantations differ, with smallholder tea farms generally managed independently by the farmers. Each importing country has its own quality standards and preferences for different tea varieties. In addition, price factors play a significant role in determining a country's tea import volume. Meanwhile, the amount of tea exported is also greatly influenced by domestic consumption. Although Indonesia is known as a tea-exporting country, it simultaneously imports tea from abroad. Differences in tea varieties, types, and flavors are among the main reasons driving these imports.[2] It is estimated that the marketing trend for flavored teas will grow by 5.5% during the period from 2022 to 2029. Furthermore, the market for fruit- and candy-flavored teas is expected to offer even greater profitability.[3]

Green tea leaves are obtained without undergoing fermentation or enzymatic oxidation, by activating the polyphenol oxidase enzymes present in the fresh tea leaf buds.[4] Green tea leaves were chosen as the product to be developed because they exhibit antioxidant effects in various ways. First, the antioxidants in tea neutralize free radicals by directly acting on reactive oxygen species. Second, tea antioxidants enhance plasma antioxidant levels, such as glutathione. Third, tea bioactives suppress superoxide activity by chelating plasma zinc and copper, which are essential cofactors for superoxide. Fourth, tea catechins inhibit plasma protein carbonylation induced by hyperglycemia.[5] Green tea contains approximately 4,000 bioactive compounds, one-third of which are polyphenols. Polyphenols are secondary metabolites in plants, generally responsible for defense against ultraviolet radiation and pathogen attacks. Over the past decade, significant correlations have been observed between the presence of polyphenols in plants and their potential health benefits as antioxidants. Consuming polyphenol-rich plants can help protect the body against cancer, cardiovascular diseases, diabetes mellitus, osteoporosis, and neurodegenerative disorders.[6] Green tea has the highest antioxidant capacity, measured at 642.488 AAEAC/g of sample (dry weight) or 95 GAEAC/g of sample (dry weight). The total phenolic content in green tea also showed the highest level, at 88.317 GAE/g of sample (dry weight).[7]

Mangosteen is known as a herbal plant believed to help lower blood glucose levels in patients with diabetes mellitus. This effect is attributed to its antioxidant content, which helps reduce insulin resistance and thus aids in normalizing blood sugar levels. Additionally, mangosteen can help alleviate fatigue caused by imbalances in blood glucose.[8] Antioxidants are compounds that inhibit or delay

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the oxidation of molecules by interfering with the initiation or propagation of chain oxidation reactions, thereby potentially suppressing cancer cell proliferation and acting as anticancer agents.[9] Chemically, antioxidants are compounds that donate one or more electrons to free radicals, thereby inhibiting their reactions and preventing the formation of new free radicals. Biologically, antioxidants are compounds that can neutralize oxidants, including enzymes and metal-binding proteins.[10]

The antioxidants in mangosteen peel are notably high due to the presence of xanthones, a class of compounds not found in other fruits. Xanthones, often referred to as a 'privileged structure,' are known for their strong antioxidant activity, surpassing that of vitamins C and E, earning them the title of 'king of antioxidants.' One such antioxidant property in mangosteen peel is attributed to the compound α-mangostin.[11] Mangosteen has been used to treat various ailments, including tumors, diabetes, bacterial inflammation, hypertension, and arthritis. This application indicates that fruit extracts may also have potential benefits in the medical and pharmaceutical fields. According to Sholihah et al (2017) antioxidant activity tested using the DPPH method showed that mangosteen peel exhibits strong antioxidant activity, with an IC_{50} value of 8.667 ppm.[12] According to another the IC_{50} value of mangosteen peel was found to be 5.030 ppm.[13]

Green tea has a green to yellow color influenced by processing and variety, with deeper shades indicating stronger flavors. Its fresh, grassy aroma and balanced taste of bitterness, astringency, and umami contribute to consumer appeal.[14,15] Mangosteen peel tea shows a reddish-brown color with fruity and floral notes and a mildly sweet, slightly bitter taste from polyphenols.[16] When combined, green tea and mangosteen peel create an attractive yellowish to reddish-brown hue and a harmonious aroma and flavor profile, where green tea catechins balance the peel's astringency, enhancing overall sensory quality.[16]

The development of green tea products substituted with mangosteen peel powder is expected to result in an alternative beverage that is nutritious, palatable, and safe for consumption. Based on the review of the data above, this study aims to investigate the effect of mangosteen peel powder substitution on the organoleptic properties and antioxidant activity of green tea.

Studies on the optimal formulation and sensory balance of mangosteen peel-based beverages remain limited. This study innovatively utilizes mangosteen peel, an underutilized agricultural by-product, as a natural antioxidant source in functional tea. The combination of mangosteen peel and green tea produces a practical powdered beverage with balanced antioxidant activity and favorable sensory characteristics.

METHODS

Study design

This study was an experimental research using a completely randomized design (CRD) with a non-factorial approach, consisting of three treatments and three replications (3×3=9 experimental units). The study was conducted from August to November 2024 at the Food Laboratory, Department of Nutrition, Poltekkes Kemenkes Aceh, and the Instrumentation and Chemical Research Laboratory, Department of Chemistry, Universitas Syiah Kuala University. The parameters tested in this study include organoleptic evaluation using a hedonic test (color, taste, and aroma) and antioxidant activity analysis using the DPPH method.

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Data source and sampling procedure

The materials used in this study were of high quality, including green tea leaves, mangosteen fruit, and corn sugar. The green tea leaves were dried leaves produced in the Bener Meriah region. Mangosteen fruits were purchased from Banda Aceh with criteria of being fresh, purple in color, easy to peel, and weighing approximately 150–200 grams per fruit. Corn sugar used was Tropicana Slim brand.

Variables of the study

The independent variable in this study was the formulation ratio of green tea and mangosteen peel powder (50%:50%, 60%:40%, and 70%:30%). The dependent variables included organoleptic quality (color, taste, aroma) and antioxidant activity (DPPH inhibition percentage and IC_{50} value). Corn sugar was added equally in all treatments to maintain consistent sweetness and reduce bias in sensory evaluation.

Measurement and instruments

Preparation of Green Tea Leaf Powder

Separate the dried tea leaves from the stems. Grind the dried green tea leaves into a fine powder. Prepare tea bags and then fill them with the powdered tea.

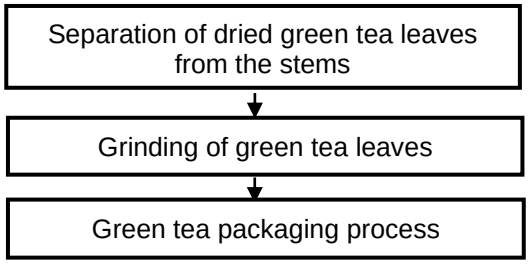

Figure 1. Flow Diagram of Green Tea Powder Preparation

Production of Mangosteen Peel Powder

Select and separate the mangosteen fruit from its peel, then slice the inner part of the peel. Dry the mangosteen peel using a food dehydrator. After drying, grind the dried peel into powder using a mortar and pestle. Finally, place the mangosteen peel powder into tea bags.

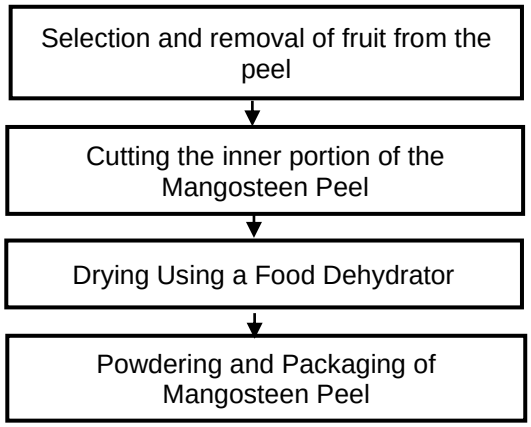

Figure 2. Flow Diagram of Mangosteen Peel Powder Preparation

Preparation of Green Tea Substituted with Mangosteen Peel Powder

The preparation of green tea substituted with mangosteen peel powder involved three treatments (Table 1): Treatment A (50% mangosteen peel powder: 50% green tea), Treatment B (60% mangosteen peel powder: 40%

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green tea), and Treatment C (70% mangosteen peel powder: 30% green tea). The selection of the 50–70% mangosteen peel ratio was based on: (1) its high bioactive content, particularly xanthones, which enhance antioxidant activity in a dose-response manner; (2) synergy with green tea catechins that contribute to antioxidant activity as well as balance in flavor and aroma; and (3) the trade-off between increased antioxidant activity and potential bitterness, making the 50–70% range appropriate for exploring the most balanced composition.

The procedure for preparing mangosteen peel powder tea included preparing and weighing all ingredients according to the required amounts, then placing them into tea bags. Next, the mangosteen peel powder tea was brewed in 200 ml of warm water. The mangosteen peel powder tea beverage was then ready to serve (Figure 3).

These formulations were designed to identify the optimal balance between antioxidant activity and organoleptic acceptability. A higher proportion of mangosteen peel increases xanthone content and antioxidant activity but may intensify bitterness and astringency. Conversely, green tea catechins help balance flavor, aroma, and color. Varying the ratios enables determination of the most favorable formulation that combines strong antioxidant properties with acceptable sensory qualities.

Table 1. Composition of Mangosteen Peel Powder Tea Ingredients

Ingredients	Amount		
	A 50%:50%	B 60%:40%	C 70%:30%
Mangosteen peel powder	5 g	6 g	7 g
Green tea	5 g	4 g	3 g
Corn sugar	1 g	1 g	1 g

Corn sugar was added to all formulations to maintain a consistent base flavor and improve overall sensory acceptance. It serves as a natural sweetener that balances the bitterness and astringency from green tea catechins and mangosteen peel xanthones. Using the same amount in each formulation minimizes differences in sweetness perception, allowing panelists to focus on aroma, color, and characteristic taste. Its mild sweetness and neutral aroma make its effect on taste perception minimal while enhancing overall flavor harmony

Organoleptic and Antioxidant Activity Test

A hedonic test was conducted to evaluate panelists' preferences for the color, taste, and aroma of green tea substituted with mangosteen peel powder. Thirty semi-trained panelists who had completed the Food Technology (ITP) course participated in the evaluation. All panelists were healthy and available during the scheduled sessions. Each tea sample (50 mL) was served warm at 60 ± 2 °C in identical coded cups. Samples were presented in a randomized order to minimize bias, with a 2-minute interval between samples to allow panelists to rinse their mouths with warm water and neutralize residual flavors. Panelists rated each attribute using a 5-point hedonic scale (1=dislike extremely to 5=like extremely).

Antioxidant activity was analyzed using the DPPH method at the Instrumentation and Chemical Research Laboratory, Department of Chemistry,

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Syiah Kuala University. The antioxidant capacity of the mangosteen peel tea formulations was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging method. A 0.1 mM DPPH solution prepared in methanol was combined with the sample solution at a 1:1 ratio and incubated for 30 minutes at room temperature in the dark. Absorbance reduction was recorded at 517 nm using a UV–Vis spectrophotometer. The antioxidant activity was expressed as a percentage of radical inhibition, calculated as % inhibition = [(A_control – A_sample) / A_control] × 100%. A greater decrease in absorbance indicates stronger radical scavenging ability. The IC_{50} value, representing the concentration required to inhibit 50% of DPPH radicals, was obtained from the linear regression of inhibition percentage versus sample concentration.

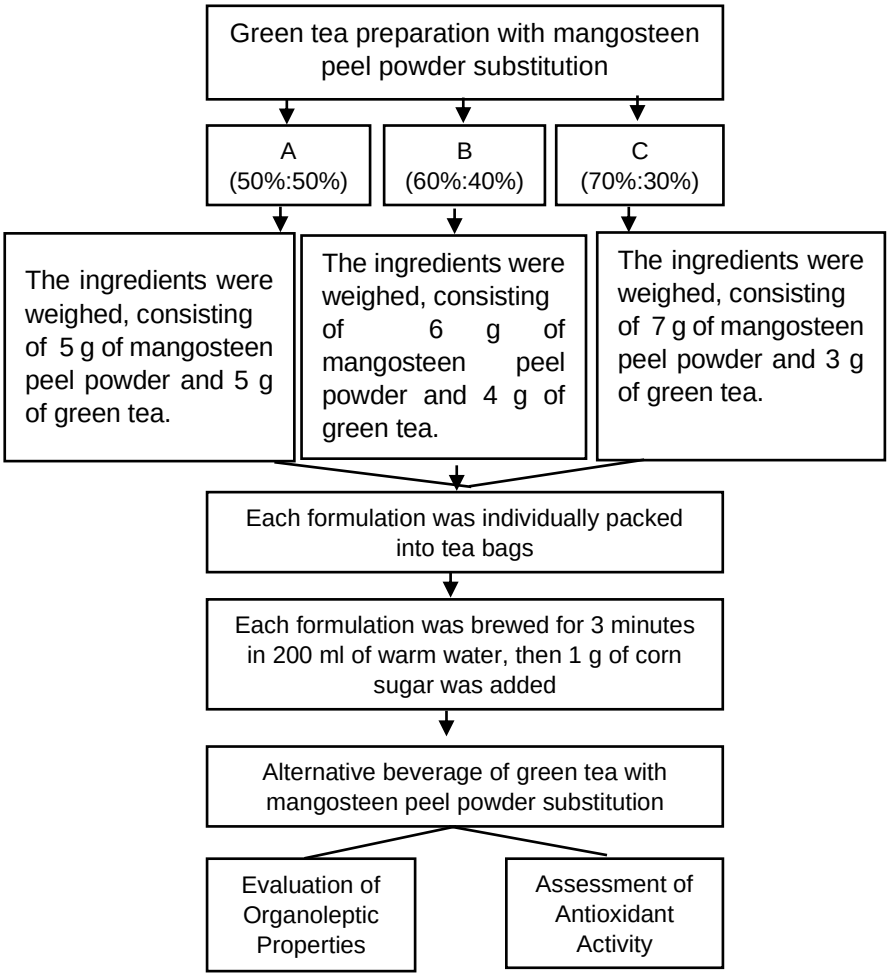

Figure 3. Process Flow Diagram for the Production of Mangosteen Peel Powder Tea

Data Collection

Organoleptic testing was performed through panelist evaluation of color, taste, and aroma. Samples were presented randomly with rinsing intervals to reduce bias. Antioxidant activity data were collected from laboratory analysis using the DPPH method, including percentage inhibition and IC_{50} values.

Ethical Consideration

This study received ethical approval from the Health Research Ethics Committee of Poltekkes Kemenkes Aceh (DP.04.03/12.7/267/2024). All respondents signed informed consent forms before participation.

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Data Analysis

Data were analyzed using Analysis of Variance (ANOVA), followed by Duncan's multiple range test if significant differences were found. Prior to analysis, normality testing was conducted. All statistical tests were performed at a 95% confidence level.

RESULTS

This study examined the effect of mangosteen peel powder substitution on the organoleptic properties and antioxidant activity of green tea as a potential beverage for type II diabetes mellitus. The treatments were: A (50:50), B (60:40), and C (70:30) ratios of mangosteen peel powder to green tea. The results were as follows:

Table 2. Descriptive Characteristics of Mangosteen Peel Powder Tea

Treatment A	Product Description
	Color : Yellowish-green Taste : Predominantly sweet Aroma : Characteristic of brewed tea Antioxidant (IC_{50}) : 8.28 µg/mL
Treatment B	**Product Description**
	Color :Slightly deep yellow Taste :Sweet with a slight bitterness Aroma :Characteristic of brewed tea with a slightly sour note Antioxidant (IC_{50}): 7.27 µg/mL
Treatment C	**Product Description**
	Color : Yellowish-brown Taste : Predominantly sweet and bitter Aroma : Characteristic of mangosteen peel powder Antioxidant (IC_{50}): 4.42 µg/mL

Organoleptic test

The organoleptic evaluation of the alternative green tea beverage substituted with mangosteen peel powder was conducted using the hedonic test method to determine the panelists' preference for color, taste, and aroma. Research findings (Table 3) showed that panelists slightly liked the tea color, with mean scores of 3.96 (A: 50:50), 3.80 (B: 60:40), and 3.81 (C: 70:30) for mangosteen peel powder to green tea ratios. The treatment effect on tea color was negligible (η^2=0.0069), indicating minimal impact of mangosteen peel substitution on panelists' color preference.

The study results (Table 3) showed that panelists slightly liked the taste of tea in treatments A (3.07) and B (3.06), but slightly disliked it in treatment C (2.88). The treatment had a negligible effect on taste preference (η^2=0.0061), suggesting that changes in mangosteen peel substitution did not substantially influence panelists' taste perception.

Based on Table 3, panelists slightly liked the tea aroma, with mean scores of 3.36 (A), 3.44 (B), and 3.68 (C). ANOVA showed a significant effect of treatment on aroma (p=0.04), indicating that mangosteen peel substitution influenced the tea's aroma. The treatment had a small to moderate effect on aroma preference (η^2=0.0238), showing that mangosteen peel substitution slightly influenced panelists' aroma ratings.

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Duncan's test was then performed to identify the most distinct treatment differences. Based on Table 4, Duncan's test showed that treatments A and B differed significantly from treatment C, but not from each other.

Tabel 3. Analysis of variance (ANOVA)

Treatment	Mean	η² (Effect Size)	*p*
Color			
A (50%:50%)	3.96[a]	0.0069	
B (60%:40%)	3.80[a]		0.395
C (70%:30%)	3.81[a]		
Taste			
A (50%:50%)	3.07[a]	0.0061	0.440
B (60%:40%)	3.06[a]		
C (70%:30%)	2.88[a]		
Aroma			
A (50%:50%)	3.36[a]	0.0238	0.04*
B (60%:40%)	3.44[a]		
C (70%:30%)	3.68[b]		

*significant at 95% confident interval

Table 4. Results of Duncan's Post Hoc Test for Tea Aroma

Treatment	N	Subset for alpha = 0,05	
		1 (a)	2 (b)
A (50%:50%)	90	3.36	
B (60%:40%)	90	3.44	
C (70%:30%)	90		3.68

Antioxidant activity findings

Table 5. Results of Tea Antioxidant Activity

Treatments	Replication			IC_{50}	*p*
	1	2	3		
A (50:50)	8.59	8.30	7.97	8.28	
B (60:40)	8.60	5.44	7.77	7.27	0.038*
C (70:30)	4.49	2.57	6.20	4.42	

Table 6. Results of Duncan's Post Hoc Test for Tea Antioxidant Activity

Treatment	N	Subset for alpha = 0,05	
		1 (a)	2 (b)
C (70%:30%)	3	4.42	
B (60%:40%)	3		7.27
A (50%:50%)	3		8.28

Based on Table 5, the average IC_{50} values for antioxidant activity were 8.28 µg/mL (A: 50:50), 7.27 µg/mL (B: 60:40), and 4.42 µg/mL (C: 70:30), with the highest activity in treatment C. ANOVA showed a significant effect of treatment on antioxidant activity (p=0.038), indicating that mangosteen peel substitution influenced antioxidant capacity. Duncan's test (Table 6) revealed that treatment C differed significantly from A and B, while no significant difference was found between A and B.

DISCUSSION

The results showed that Treatment A was preferred for color due to its higher green tea content, producing a bright greenish-yellow appearance considered fresh and appealing. In contrast, Treatment C scored higher in aroma because its greater

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mangosteen peel content produced a stronger fruity and sweet scent. DPPH analysis indicated that higher mangosteen peel levels increased antioxidant activity, suggesting potential benefits for individuals with type II diabetes mellitus. This antioxidant capacity may help reduce oxidative stress related to insulin resistance and cellular damage, indicating potential support for diabetes management.

Tea is a caffeinated beverage made by infusing the leaves, buds, or stems of the Camellia sinensis plant. This beverage has a distinctive aroma and flavor that varies depending on the processing method used, resulting in a wide range of taste variations.[14] To date, tea has become the most widely consumed beverage in the world after water.[6] Generally, tea contains polyphenols, particularly catechins such as epigallocatechin gallate (EGCG), which are the main components of tea and act as strong antioxidants. In green tea, polyphenols can account for 25-35% of the dry weight of tea leaves. In addition, tea also contains flavonoids, proanthocyanidins, and tannins, which contribute to its astringent taste and health benefits.[15] Therefore, local food ingredients such as mangosteen fruit contain xanthones (particularly α-mangostin) in the peel, which exhibit strong antioxidant, anti-inflammatory, and anticancer activities.[16]

A study conducted by Ulfa et al (2019) showed that the addition of 60 g of mangosteen peel extract to a jelly drink resulted in an antioxidant activity of 96.81%.[20] A study conducted by oleh Ratna Kurniawati (2023) stated that mangosteen peel contains a high content of xanthones.[21] Another study reported that the total antioxidant activity of mangosteen peel using the DPPH method was 40.30 ± 2.32%, whereas that of mangosteen peel extract was 84.42 ± 4.44%.[19]

Organoleptic testing was conducted to assess the acceptability of color, taste, and aroma of the alternative green tea beverage substituted with mangosteen peel powder. The tests also included an evaluation of antioxidant activity.

Color

Organoleptic evaluation of color in beverages is a sensory assessment that uses the sense of sight to judge the visual appeal of a product. Color is the first parameter observed by consumers before tasting the beverage, thus significantly influencing their perception of quality and overall liking of the product.[20] The color of a product is one aspect that affects the quality of food products and plays a role in attracting the attention of panelists. The ideal and standard color of tea typically ranges from yellowish-green to reddish-brown.[21]

The color of mangosteen peel powder tea was relatively similar across all treatments, with all formulations producing a yellowish-green hue. However, increasing the proportion of mangosteen peel powder resulted in a shift toward a more yellowish-brown color.Based on Table 3, Treatment A (50% mangosteen peel powder: 50% green tea) received the highest color acceptability score, categorized as “like slightly.” This is due to the influence of mangosteen peel concentration, where higher levels deepen the tea color. These findings are consistent with Pratiwi et al. (2024), who reported that consumers tend to prefer a yellowish-brown tea color, as it is perceived as more appealing than overly bright tea infusions.[25]

Taste

Taste determination involves the taste receptors on the tongue and can be categorized into four main types: salty, sour, sweet, and bitter. In general, food ingredients do not possess a single taste but rather a combination of flavors that create an overall taste impression. This taste is influenced by several factors, including chemical compounds and their interactions with other flavor components. Differences in panelists’ evaluations of taste reflect the level of acceptance of the flavor resulting from the combination of ingredients in the product.[21]

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The taste of green tea substituted with mangosteen peel powder was relatively similar across all treatments, with differences mainly in sweetness and bitterness intensity. Treatment A (50% mangosteen peel powder: 50% green tea) had a predominantly sweet taste, while Treatment B (60%:40%) showed a sweet taste with slight bitterness. Treatment C (70%:30%) produced a more pronounced sweet–bitter taste from the mangosteen peel, indicating that higher substitution increases bitterness. Based on Table 3, Treatment A obtained the highest taste acceptability, categorized as "like slightly," because it had a balanced flavor and was not overly bitter. In contrast, Treatment C received the lowest acceptability due to its stronger bitterness from the higher mangosteen peel content. The bitterness of mangosteen peel tea is attributed to compounds such as tannins and xanthones. Xanthones, despite their antioxidant properties, contribute to a bitter taste, while tannins add bitterness and astringency. This is consistent with Rahmawati et al. (2024), who reported that mangosteen peel tea has a bitter and astringent flavor influenced by these compounds.[26]

Aroma

Aroma in a food product plays an important role in determining its palatability. Moreover, aroma is considered crucial as it can serve as an indicator for consumers to accept or reject a product. Changes in aroma can occur due to the composition of components within the food itself or through interactions with external components.[21] The aroma of green tea substituted with mangosteen peel powder differed across treatments. Treatment A (50%:50%) had a typical brewed tea aroma, Treatment B (60%:40%) showed a brewed tea aroma with a slight sour note, while Treatment C (70%:30%) was dominated by the characteristic aroma of mangosteen peel with a mildly acidic scent. Increasing mangosteen peel content enhanced the distinctive aroma of the tea.

Based on Table 3, Treatment C obtained the highest aroma acceptability score due to the stronger and more distinctive scent produced by volatile compounds in mangosteen peel, which contribute a tropical, fruity, and slightly acidic aroma. In contrast, Treatment A had the lowest aroma rating because the mangosteen peel contribution was less pronounced.These aroma characteristics are influenced by volatile compounds present in both green tea and mangosteen peel powder. This is consistent with Pirna et al. (2023), who reported that mangosteen contains volatile compounds that produce a fresh fruity aroma capable of influencing and masking other underlying aromas.[27]

Antioxidant Activity

Table 5 shows that the highest antioxidant activity was observed in green tea substituted with mangosteen peel powder in Treatment C (70% mangosteen peel powder: 30% green tea), with an average IC_{50} of 4.42 µg/mL. This is because increasing the amount of mangosteen peel powder leads to higher antioxidant content in the tea product. This finding aligns with the study by Ihsanulhaq (2020) which reported that the more mangosteen peel powder added to a product, the higher the antioxidant activity in the product.[28]

A compound is considered a very strong antioxidant if its IC_{50} value is less than 50 µg/mL, strong if the IC_{50} value is 50–100 µg/mL, moderate if the IC_{50} value is 100–150 µg/mL, and weak if the IC_{50} value is 151–200 µg/mL.[26] Based on these categories, Treatments A (50% mangosteen peel powder:50% green tea), B (60% mangosteen peel powder: 40% green tea), and C (70% mangosteen peel powder:30% green tea) all had IC_{50} values below 50 µg/mL, classifying them as very strong antioxidants. Among these, Treatment C exhibited the highest antioxidant activity. This indicates that the lower the IC_{50} value obtained from the analysis, the higher the antioxidant activity present in a product.

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The antioxidant activity in mangosteen peel is attributed to the presence of xanthone compounds, particularly alpha-mangostin and gamma-mangostin, which are types of polyphenolic compounds. These compounds exhibit very strong antioxidant activity.[27] The presence of these compounds plays an important role in lowering blood glucose levels. This aligns with the study conducted by Yahya & Perdana (2022) which reported that mangosteen peel contains xanthones with antidiabetic therapeutic effects.[31] According to Ihsanulhaq (2020) the higher the percentage of mangosteen peel powder added to a product, the greater its antioxidant activity.[28] According to N. Pratiwi (2021) chemical response tests, including antioxidant activity, xanthones, tannins, and pH, on combinations of mangosteen peel powder with tea leaf powder showed that the antioxidant value reached the highest level, making it the most prominent component in the product.[32] According to Martiningsih et al (2016) products containing antioxidant compounds demonstrate that the higher the concentration, the more compounds are available to donate electrons or hydrogen atoms to DPPH free radicals.[33] This reaction causes the DPPH color to fade; thus, lower absorbance indicates higher antioxidant activity. Mangosteen peel contains potent free radical scavengers that help prevent and manage degenerative diseases, including type II diabetes mellitus. By reducing oxidative stress, its antioxidants may protect against complications such as neuropathy, nephropathy, and retinopathy, while enhancing the body's endogenous antioxidant defense.[31] Therefore, mangosteen peel powder tea can be used as an alternative beverage to help lower blood glucose levels in individuals with type II diabetes mellitus.

Mangosteen peel is rich in highly active xanthones and green tea contains water-soluble polyphenols with strong measurable antioxidant effects, and when combined they create a synergistic interaction that stabilizes these bioactive compounds, enhances total antioxidant capacity, and achieves optimal activity at specific formulation ratios.[35]

The strength of this study lies in the use of mangosteen peel as a natural antioxidant source to develop an innovative functional beverage. Its limitation is the seasonal availability of mangosteen peel, affecting production consistency. This study provides a basis for developing herbal beverages from local ingredients and supports further research on formulation, storage stability, and alternative ingredient substitutions to ensure year-round production. Although the product demonstrated high antioxidant activity in vitro, this does not necessarily translate into physiological effects such as blood glucose reduction. Further in vivo studies are required to confirm its antihyperglycemic and systemic antioxidant potential

CONCLUSION

The study revealed that Treatment A achieved the highest scores for color and taste, while Treatment C exhibited the highest aroma score and the strongest antioxidant activity (IC_{50}= 4.42 µg/mL). Substitution of mangosteen peel powder at ratios of 50%:50%, 60%:40%, and 70%:30% had no significant effect on color and taste but significantly influenced aroma and antioxidant activity. Substitution up to 70% increases antioxidant activity but reduces taste acceptability, indicating the need for a balanced formulation in product development. Further in vivo studies are required to evaluate the antihyperglycemic effects and systemic antioxidant activity of mangosteen peel powder tea in a type 2 diabetic rat model.

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