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Anti-hyperglycemic and antioxidant activity of Bajakah herbal tea made from Bajakah rod-Tikung honey-Amblycarpa lime (jeruk Sambal)

[Aktivitas anti-hiperglikemia dan antioksidan minuman teh herbal Bajakah yang dibuat dari madu Tikung-batang Bajakah-jeruk Sambal]

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ABSTRACT

Hyperglycemia is characterized by elevated blood glucose levels, defined as instant blood glucose exceeding 200 mg/dL or fasting blood glucose surpassing 126 mg/dL. This condition has the potential to increase free radicals in the body. Using herbal ingredients or herbal drinks can also be a way to control blood glucose and free radicals. The Bajakah plant has functional anti-diabetic properties because it contains alkaloids and flavonoid compounds with anti-hyperglycemic and antioxidant effects. This study aimed to measure the antioxidant and anti-hyperglycemic potential of bajakah herbal tea with its raw materials (bajakah rod extract, honey, and Amblycarpa lime (jeruk Sambal). The formulation of Bajakah herbal tea consists of 19.32 g Amblycarpa lime (jeruk Sambal), 46.38 g Bajakah rod extract, and 57.97 g honey. Antioxidant activity was achieved using the 2,2-diphenyl-1-picrylhydrazyl or DPPH method, and anti-hyperglycemic methods were used, such as the Oral Glucose Tolerance Test (OGTT). Physical characteristics are also tested for pH, color, and total dissolved solids. Data was analyzed using one-way ANOVA. The results showed that the combination of Bajakah-based herbal drinks, Bajakah herbal tea (123.67 g or equivalent to a carbohydrate content of 50 g) and the single preparation did not have anti-hyperglycemic activity. However, bajakah herbal tea has the highest antioxidant activity compared to its raw materials.

Keywords: Bajakah rod; Tikung honey; Amblycarpa lime (jeruk Sambal); anti-hyperglycemic; antioxidant

ABSTRAK

Hiperglikemia adalah kondisi peningkatan kadar glukosa darah di atas batas normal, dengan kadar glukosa darah sewaktu >200 mg/dL atau kadar glukosa darah puasa >126 mg/dL. Kondisi tersebut berpotensi meningkatkan radikal bebas dalam tubuh. Penggunaan bahan herbal atau minuman herbal juga dapat menjadi cara untuk mengendalikan glukosa darah sekaligus radikal bebas. Genus Uncaria memiliki sifat fungsional sebagai antidiabetes karena mengandung alkaloid dan senyawa flavonoid dengan efek hipoglikemik dan antioksidan. Tujuan penelitian ini adalah mengukur potensi antioksidan dan anti-hiperglikemik teh herbal bajakah dengan bahan bakunya (ekstrak kayu bajakah, madu, dan jeruk Sambal). Formulasi teh herbal bajakah terdiri dari 19,32 g jeruk Sambal, 46,38 g ekstrak batang bajakah, dan 57,97 g madu. Aktivitas antioksidan dilakukan dengan menggunakan metode 2,2- diphenyl-1-picrylhydrazyl or DPPH and anti-hiperglikemik menggunakan Oral Glucose Tolerance Test (OGTT), serta dilakukan juga uji pH, warna, dan total padatan terlarut. Analisis data dilakukan menggunakan ANOVA one way. Hasil penelitian menunjukkan bahwa perlakukan kombinasi minuman herbal berbasis bajakah, yaitu teh herbal bajakah (123, 67 g atau setara dengan kadar karbohidrat 50 g) dan sediaan tunggalnya tidak memiliki aktifitas anti-hiperglikemia. Akan tetapi, teh herbal bajakah memiliki aktivitas antioksidan tertinggi dibandingkan bahan baku-nya.

Kata kunci: Anti-hiperglikemik, bajakah, madu Tikung, jeruk sambal;, teh herbal

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Introduction

Hyperglycemia is a medical condition in the form of an increase in blood glucose levels from normal limits, with instant blood glucose levels >200 mg/dL or fasting blood glucose levels >126 mg/dL (Masdar et al., 2021). Hyperglycemic conditions have the potential to increase free radical levels, so they require intake of free radical scavengers or antioxidants (Lestari et al., 2024). Therefore, in the condition of hyperglycemia, consuming foods with anti-hyperglycemic properties and antioxidant activity is essential. Anti-hyperglycemic and antioxidant abilities can be obtained from herbal tea having many phytochemical ingredients and secondary metabolites. Herbal tea is a drink consisting of a mixture of dried natural plant ingredients such as leaves, flowers, fruit, stems, seeds, wood, or spices which have beneficial properties (Shaik et al., 2023).

Types of herbal ingredients that can lower blood glucose include those containing alkaloid and flavonoid compounds (Tran et al., 2020), one of which is the Bajakah (Uncaria) stem (Azzahra et al., 2022). Alkaloid and flavonoid compounds have been known as antioxidants (Zandavar & Afshari Babazad, 2023). Antioxidants can inhibit oxidation by binding to reactive free radicals, leading to more stable free radicals. Some effective antioxidants include vitamins C, and E, beta-carotene, selenium, and flavonoids. Bajakah rods contain flavonoid compounds, namely catechins (Munggari et al., 2022).

The Uncaria genus has been researched to have functional anti-diabetic properties because it contains alkaloids (Qin et al., 2021), and contains flavonoid compounds which have anti-hyperglycemic and antioxidant effects (Hasna et al., 2021). *Uncaria tomentosa* extract can prevent diabetes (Dooley et al., 2022). Catechins from the *Elaeagnus umbellate* plant can inhibit carbohydrate digestive enzymes, namely α-amylase and α-glucosidase so that fasting blood glucose levels in diabetic mice decrease (Nazir et al., 2021). *Uncaria tomentosa* also contains the compound quercetin (Anggriani et al., 2024). Quercetin can inhibit the process of glucose absorption through the transfer of GLUT2 and SLGT1 with non-competitive inhibition (Lestari et al., 2024). Gambir has high anti-diabetic potential because it is known to contain catechin and quercetin (Fajarwati et al., 2024).

Amblycarpa lime (jeruk Sambal) has a sour taste because it contains high citric acid (Narwati et al., 2020). In addition, honey also has a sour taste which is thought to be because it contains citric acid. citric acid can significantly reduce blood glucose levels and insulin resistance index, and improve insulin sensitivity (Yadikar et al., 2022). Citric acid can increase insulin permeability so that glucose levels in the blood decrease (Lestari et al., 2024). Other studies have also shown that citric acid addition increases the antioxidant capacity (Salas-Perez et al., 2018). Green tea is rich in catechins and synergizes in increasing antioxidant capacity when combined with Amblycarpa lime (Uduwana et al., 2023). Catechin stability is also influenced by pH, at low pH conditions catechins are more stable and show more stable antioxidant activity (Mita et al., 2024). A study conducted by Wongso in 2023 found that the best formulation for the Bajakah herbal tea drink involved using 10.5% Bajakah rod powder with Tikung honey and Amblycarpa lime addition. The addition of honey and Amblycarpa lime extract is only used as a bitter taste remover, but the functional properties of the Bajakah herbal tea are not yet known. Based on previous research, the main compounds of the 3 raw materials of Bajakah herbal tea (Tikung honey-Bajakah rod-Amblycarpa lime) show synergistic effects, such as quercetin, catechin, and citric acid as antioxidants and anti-hyperglycemics (Uduwana et al., 2023; Mita et al., 2024; Fajarwati et al., 2024). These three compounds are contained in the raw materials of this Bajakah herbal tea. Among the methods that can be used to see the functional properties as anti-hyperglycemic is the oral glucose tolerance test (OGTT) (Ifada et al., 2019) and the DPPH (2,2-diphenyl-1-picrylhydrazyl) test for antioxidant activity. This research evaluated the antioxidant and anti-hyperglycemic properties of bajakah herbal tea and its raw ingredients, which include bajakah rod extract, honey, and Amblycarpa lime (jeruk Sambal). In addition, the chemical characteristics (TPT and pH tests) were carried out.

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Materials and Methods

Materials

The ingredients used in making Bajaka herbal tea are Bajakah rod (*Uncaria lanosa var. glabrata*) obtained from Kapuas Hulu Regency, West Kalimantan, Tikung honey from Kapuas Hulu, and Amblycarpa lime (jeruk Sambal) obtained from the Flamboyan market on Jalan Gajah Mada, Pontianak. Chemicals for proximate content analysis include n-hexane (MERCK 104367), 40% NaOH (MERCK 106498), 0.1 N HCl (MERCK 100317), 0.1 N NaOH (MERCK 109141), HBO_3 (MERCK 100165), and bromcherosol green red (MERCK 108121). Chemicals for antioxidant analysis are the 1,1-diphenyl-2picrylhydrazyl solution (MERCK 300267-50MGCN), 95% ethanol (MERCK 100958), and distilled water.

Tools

The tools used in making herbal tea drinks are stoves, analytical scales, measuring cups, beakers, Erlenmeyer cups, stainless steel cups, aluminum foil, spoons, filter paper, knives, grinders, dropper pipettes, funnels, and 80 mesh sieves. Tools for checking the glycemic index are a glucometer (EASY TOUCH), lancet pen (EASY TOUCH), lancet needle (ONEMED BLOOD LANCET), paper strip (EASY TOUCH), tensimeter (OMRON HEM 8712) and alcohol swabs (ONE SWABS). Equipment for physicochemical analysis is cotton, fat flask, Soxhlet tube, desiccator oven, Kjeldahl flask, Spectrometer (SHIMADU UV-mini-1240), vortex, hand Refractometer (AICHOSE 58-90 Brixo and RHB-62 30-55 Brixo), pH meter (AMTAST AMT20) and Colorimeter (AMTAST AMT507).

Research design

This experimental design used a randomized block design (4 replications) with 4 treatments (Bajakah rod extract, Tikung honey, Amblycarpa lime (jeruk Sambal) extract, and a mix of these three ingredients, called Bajakah herbal tea. All treatments were given orally to respondents including pure glucose as a control. Besides that, physicochemical tests were carried out, namely pH, TPT, and color tests. Data was analyzed using the one-way ANOVA test. When it was significantly different, the data continued with the Honestly Significant Difference (HSD) test. This research obtained ethical approval for involving human respondents from the Ethics Review Team of the Faculty of Medicine, Tanjungpura University, under permit number 1566/UN22.9/PG/2024.

Research stages

a. Preparation of Bajakah rod powder

The dry Bajakah rods were chopped, crushed, and sifted using an 80-mesh sieve. As much as 10.5 g of Bajakah rod powder was mixed with 89.5 g of drinking water (ratio 1:9), then boiled for about 3 minutes using a stove until it reached boiling point. The solution is filtered using filter paper or a filtration device. The resulting extract was placed in a beaker to determine the resulting brew.

b. Preparation of Amblycarpa lime extract

The Amblycarpa Lime was washed with water, drained until dry, and cut into two parts. The part of Amblycarpa lime fruit was squeezed and the seeds were separated using a sieve to obtain the Amblycarpa lime extract.

c. Formulation of Bajakah herbal tea

Bajakah herbal tea was made by mixing 3 ml of Bajakah rod extract with 3.75 ml of honey and 1.25 ml of Amblycarpa lime (jeruk Sambal) extract. Next, the mixture called Bajakah herbal tea was stirred until evenly mixed.

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Characteristics of Bajakah herbal tea drinks and raw materials

a. Antioxidant, pH, TSS, and color analysis

Antioxidant analysis using *2,2-diphenyl-1-picrylhydrazyl or DPPH method* (Lestari et al., 2022), TSS testing is carried out by dissolving the sample with water 1:1, which is then measured using a hand refractometer(Simatupang et al., 2024), pH testing using a pH meter, and color testing using a Colorimeter AMTAST AMT507) by measuring the L, a, and b values (Anggraini et al., 2016). Color measurement is based on the red, blue, and green components of light absorbed by an object or sample

b. Proximate analysis

Proximate analysis in this study was used to obtain the conversion of carbohydrate levels in Bajakah rod herbal tea which would later be given to volunteers. Proximate analysis was carried out based on AOAC 2007: water and ash content using the gravimetric method, protein content using the micro Kjeldahl method, and fat content using the Soxhlet method. Carbohydrate content was obtained by different methods as in previous studies (Lestari et al., 2020). The replications in the OGTT analysis were 10 respondents used. Analysis of carbohydrate content was calculated using carbohydrate by difference, namely carbohydrate content = 100 – (fat content – protein content – ash content – water content). A schematic of the proximate test work can be seen in Appendix 4.

c. Conversion of reference food calculations

Research of Bajakah herbal tea drinks uses a reference food standard, namely pure glucose which is equivalent to 50 g of carbohydrates (Lestari & Dewi, 2023). The glucose administration was adjusted to the carbohydrate content of the test food. If the carbohydrate content of the test food is 25 g, the administration of pure glucose was also adjusted to 25 g. If the carbohydrate content in the Bajakah rod herbal tea drink was known, the total test food requirements were calculated using the following formula:

$$\text{Total Test Food} = \frac{\text{Carbohydrate Content of Reference} \times 100\ \text{mL}}{\text{Carbohydrate Content of Test Food}}$$

Taking volunteer blood samples for the Oral Glucose Tolerance Test (OGTT)

In the OGTT tests, 10 volunteers were used in this study: 2 men and 8 adult women, students from the Faculty of Agriculture, Food Technology Science Study Program. Subjects involved must meet the inclusion and exclusion criteria. Inclusion criteria are having normal blood pressure of 120/80 mmHg, having fasting blood glucose levels between 70-110 mg/dL, having normal body mass index (BMI) (18.5 kg/m2 – 24.9 kg/m2), aged 18-25 years old adult men and women, have agreed and signed informed consent. Exclusion criteria are not consuming drugs or smoking, not suffering from or having a history of diabetes mellitus, and not experiencing digestive disorders or allergies to the ingredients tested. Other requirements are that they are not on a special diet for medical reasons, have chronic illnesses such as liver and kidney disease, are not pregnant or breastfeeding, and have no history of allergies to standard and tested foods.

The food ingredients given to respondents were reference food (pure glucose) and test food (Bajakah extract, honey, Amblycarpa lime (jeruk Sambal) extract, and mix of these). Respondents fasted for 10-12 hours, the next step was checking the volunteer's blood pressure, then taking GDP (Fasting Blood Sugar) blood samples using a lancet pen and a disposable lancet needle that was inserted into the volunteer's finger (Setia et al., 2021). The blood drop was placed on the glucometer strip sensor. After 11 seconds, the blood glucose level will be read and counted as the 0^{th} second. Respondents were given 75 g of standard glucose solution for a maximum of 5 minutes. Blood glucose levels were measured again at 30 to 120 minutes. The intervention interval was 4 days, on the 4th day and so on the respondent remained fasted before taking blood samples and administering the test solution. GDP was taken at the 0th second, then

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the respondent was given the test solution first according to the experimental design and spent for 5 minutes, followed by a standard glucose solution of 75 g dissolved in approximately 250 mL of water and spent a maximum of 5 minutes. Blood glucose levels were measured again after 30 minutes until the 120th minute.

Results and Discussion

Characteristics of Bajakah herbal tea drinks and raw materials

Bajakah herbal drink and their raw materials possess distinct characteristics, including aroma, taste, texture, and color. Some chemical properties of Bajakah herbal tea and its raw materials are presented in Table 1.

Table 1. pH, TSS, and color analysis values

Sample	pH	TSS (Brix°)	Color		
			L*	a*	b*
Amblycarpa Lime (jeruk Sambal) Extract	2.91± 0.01	7.93 ± 0.11	24.83 ± 0.55	4.80 ± 0.30	6.63 ± 0.80
Tikung Honey	4.59 ± 0.10	66.33 ± 0.28	18.87 ± 0.28	1.46 ± 0.11	13.5 ± 0.60
Bajakah Rod Extract	6,.06 ± 0.01	1.23 ± 0.05	21.60 ± 4.35	6.30 ± 0.20	13.03 ± 0.11
Bajakah Herbal Tea	3.58 ± 0.01	37.13 ± 0.05	18.87 ± 0.80	5.86 ± 0.20	8.06 ± 0.75

Table 1 shows that the Bajakah rod herbal tea drink and its single preparations such as Bajakah rod extract, Amblycarpa lime (jeruk Sambal) extract, and Tikung honey have a pH value with a value range of 2.91-6.06. The pH indicator in the solution ranges from 1-7, the solution is acidic if the pH value is <7 and the base >7, it is considered neutral with a pH value of 7 (Karangan et al., 2019). The single preparation or the Bajakah herbal tea drink is acidic because the pH value is <7. Bajakah rods with a pH value of 6.06 combined with Amblycarpa Lime (jeruk Sambal) extract and honey experienced a decrease in pH to 3.58.

This acidic nature is influenced by the composition of Bajakah herbal tea drinks, especially the single preparation, namely Amblycarpa Lime (jeruk Sambal) extract and Tikung honey. Amblycarpa lime contains organic acids such as citric, and ascorbic acid. Honey also has organic acids, namely glutamic acid, succinic acid, acetic acid, malate, butyric acid, malic, formic, citric, glycolic, pyruvate and pyroglutamate (Wardhani et al., 2022). Organic acids have an important role in biological processes in the body, such as helping digestion, nutrient absorption, energy metabolism, and maintaining the body's pH balance, being antimicrobial and antioxidant (Al-Maqtari et al., 2022).

The total soluble solids in Bajakah rod herbal tea drinks and their single preparations have different TSS. The TSS test in the food industry is generally used to measure the total sugar in food. The total soluble solids value of the Bajakah rod tea herbal drink and its single preparations ranged from 1.23-66.33°Brix (Table 1). Honey has the highest total dissolved solids, this is because honey contains monosaccharide and disaccharide sugars, namely glucose, fructose, and sucrose (Lestari & Dewi, 2023; Wardhani et al., 2022). . Lime and Bajakah rods have low total soluble solids, indicating that their sugar content is minimal and have high water content. TSS measurements of Amblycarpa lime (jeruk Sambal)s have been carried out from three different countries (Malaysia, Philippines, and Vietnam), namely having a range of 7.56 to 8.09°Brix (Cheong et al., 2012).

When these three ingredients, such as honey, Amblycarpa lime extract, and Bajakah rod extract, are combined, they produce a total soluble solids value of 37.13°Brix (Table 1). This means there is a decrease in honey Brix when it is dissolved with Amblycarpa lime (jeruk Sambal) extract and Bajakah rods. The added water dilutes the sugar in the honey. Lime also contains water and some sugar but in smaller amounts than

honey. Therefore, the final mixture has a lower sugar concentration than pure honey, which causes a decrease in the Brix value. This is influenced by the water contained in Amblycarpa Lime (jeruk Sambal) extract and Bajakah rod extract because water can dissolve various components in ingredients such as salt, vitamins, minerals, carbohydrates, and many other micro-compounds (Baldelli et al., 2023).

This research measured the color index on samples of Amblycarpa Lime (jeruk Sambal) extract, Bajakah rod extract, Tikung honey, and herbal tea a combination of these three ingredients. The scoring system is in the form of L* a* and b*. L* is the brightness level, a* is a reddish color assessor, and b* is for the yellowish color category. L* brightness values range from 18.87 to 24.83 (Table 1). The brightest colors were Amblycarpa Lime (jeruk Sambal) extract (24.83) and Bajakah rod extract (21.60), while the lowest was Tikung honey and Bajakah rod herbal tea which had the same brightness level (18.87). The brightness level L* indicates that mixing or combining ingredients can reduce the brightness level compared to a single preparation of Amblycarpa lime (jeruk Sambal) extract and Bajakah rod extract. This is influenced by the brightness level of Tikung honey which has a dark brown color. Honey which has a darker color also indicates that it contains higher levels of phenolic and flavonoid compounds than light-colored honey (Becerril-sánchez et al., 2021). Other studies show that the color of honey is brownish (Suhandy et al., 2021).

The a* redness value ranges from 1.46-6.30 with the highest reddish color from a single herbal drink preparation, namely Bajakah rod extract, and the lowest being Tikung honey. Meanwhile, the yellowness b* value ranged from 6.63-13.5 with the highest yellowish color from a single herbal drink preparation, namely tikung honey and Bajakah rod extract, and the lowest was Amblycarpa Lime (jeruk Sambal) extract. This means that mixing a single preparation into a combined herbal tea with values a* 5.86 and b* 8.06 can reduce the color levels of a* and b* in the single preparation. The reddish and yellowish color levels are influenced by extracts of Bajakah rods, Tikung honey and *Amblycarpa lime* (jeruk Sambal). Antioxidant compounds influence this in the flavonoid group, antioxidant compounds can provide color and flavor to food if dissolved in water (Ullah et al., 2020).

The effectiveness of the antioxidants tested in this study was a combination of herbal tea, namely Bajakah rod extract, *Amblycarpa lime* (jeruk Sambal) extract, and Tikung honey, in addition to the raw materials for the herbal tea. Antioxidant activity test using the DPPH method which can evaluate antioxidant activity, especially phenolic and polyphenolic compounds (Pasanda et al., 2022). Based on ANOVA calculations with a level of 5%, if the treatment had a significant effect on the antioxidant activity, then continued with the HSD test which can be seen in Table 2.

Table 2. Antioxidant activity value

Sample	Antioxidant Activity
Tikung Honey	35.39 ± 2.52^{ab}
Amblycarpa Lime (jeruk Sambal) Extract	49.57 ± 39.81^{bc}
Bajakah Rod Extract	75.92 ± 2.77^{bc}
Bajakah Herbal Tea	90.32 ± 1.67^{c}

Note: Numbers followed by the same letter are not significantly different at the 5% HSD test level

Combination herbal tea has the highest antioxidant activity of the raw materials with the highest value ranging from 90.32 and the lowest 35.39. Bajakah rod herbal tea has the greatest antioxidant activity because herbal tea raw materials such as Bajakah rod extract already have high antioxidant activity. When these herbal teas are combined, the phenolic compounds in honey and *Amblycarpa lime* (jeruk Sambal) extract will increase the antioxidant activity of the Bajakah rod herbal tea drink.

Antioxidants work as inhibitors to prevent oxidation by binding to reactive free radicals, producing more stable free radicals. Some effective antioxidants include vitamins C, and E, beta-carotene, selenium, and flavonoids. Bajakah rods contain flavonoid compounds, namely catechins (Munggari et al., 2022). Honey is a health benefits herbal drink due to its nutritional content, including antioxidants, enzymes,

vitamins, and minerals. The antioxidants in honey are flavonoids, tannins, alkaloids, and phenolic compounds (Rasyiid & Susandarini, 2020). *Amblycarpa lime* (jeruk Sambal) has the main antioxidant, namely vitamin C or ascorbic acid, vitamin C will prevent oxidative stress caused by free radicals. Vitamin C will neutralize unpaired molecules or atoms by donating electrons, making them more stable (Hasna et al., 2021). *Amblycarpa lime* (jeruk Sambal) juice also contains phenolic acids, alkaloids, tannins, and saponins (Yanti & Chandra, 2021), compounds with antioxidant properties.

The proximate analysis carried out in this research was tested for water content, ash content, fat content, and carbohydrates. Proximate analysis is used to see the total content of macro substances in a food ingredient (Ganogpichayagrai & Suksaard, 2020).

Table 3. Proximate analysis of Bajakah herbal tea drinks

Component	Total (%)
Water	55.52±4.21
Ash	0.44±0.02
Fat	3.23±0.16
Protein	0.38±0.02
Carbohydrate	40.43±4.3

The highest proximate content is water content, followed by carbohydrates, fat, ash, and protein. The greater water content of other macro substances is influenced by the processing of herbal tea drinks using the Bajakah rod extract. Bajakah rod extract requires a significant amount of water during the brewing process, approximately 80%, resulting in a tea beverage with a higher water content than other ingredients. Total carbohydrates are determined using the carbohydrate by difference method, namely carbohydrate content = 100 – (fat content—protein content—ash content—water content). Table 4 shows the amount of herbal tea consumed equivalent to 50 g of glucose for IG and OGTT tests.

Table 4. Amount of food for IG and OGTT research subjects

Bajakah Herbal Tea (g)	Bajakah Extract (g)	Tikung Honey (g)	Amblycarpa Lime Extract (g)
123,67	46.38	57.97	19.32

Oral Glucose Tolerance Test (OGTT) combination and single preparation

The oral glucose tolerance test (OGTT) evaluates how effectively the body processes and metabolizes glucose. This test can be used to see the effect of a substance that is thought to have the ability to lower blood glucose levels (Ifada et al., 2019). Bajakah rod herbal tea is given equivalent to its carbohydrate content (50 g), namely 123.67 g, and single preparations such as orange (19.32 g), Bajakah extract (46.38 g), and honey (57.97 g). Blood glucose starts at the 30th minute, then there is a decrease in blood glucose at the 60th, 90th, and 120th minute. The difference in blood glucose increase from the 30th to the 120th minute is between 78.3-58.8 mg/dL. The rise in blood glucose can be seen in the graph of the average increase in blood glucose (Figure 1). The respondents' blood glucose values were subjected to an ANOVA test every minute (α=5%). The 120th-minute test results showed that the treatment affected reducing blood glucose levels (sig<0.05).

Based on the ANOVA test (Table 5), the blood glucose value at the 120th minute, the highest blood glucose value in the Bajakah rod herbal tea test food was 58.90 mg/dL and the lowest was Bajakah rod extract, namely 27.90 mg/dL. At the 120th minute, the HSD test was carried out, the results can be seen in Table 5.

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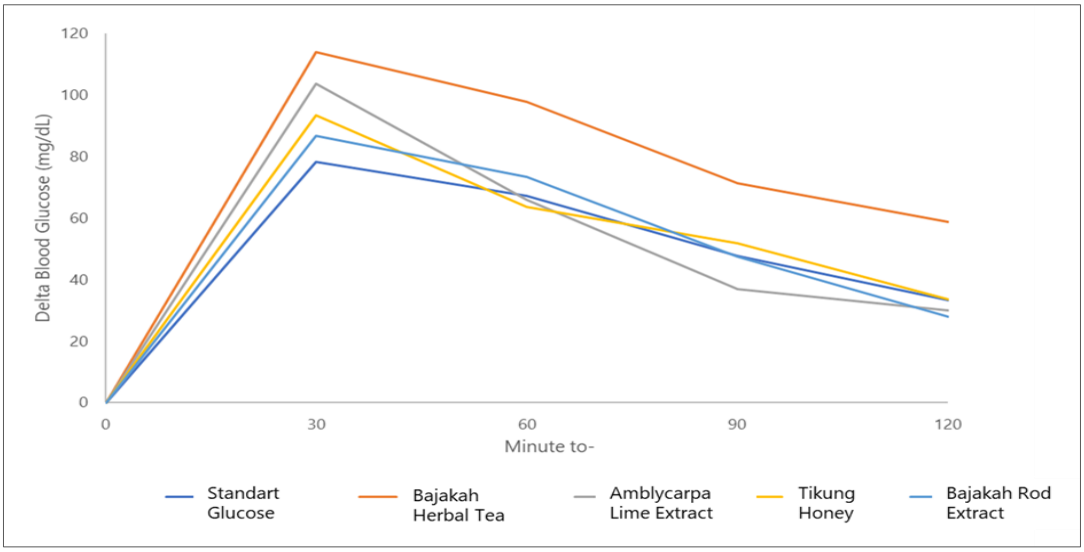

Figure 1. Increase in average blood glucose (OGTT)

The results of the HSD test at 120 minutes (Table 5) explain that the single preparation is not significantly different from glucose, but is substantially different from Bajakah rod herbal tea. Even though there is a difference in each minute, the average blood glucose of Bajakah rods herbal tea is still higher than that of the control. These results explain that neither the single preparation nor herbal tea can lower blood glucose or have anti-hyperglycemic activity. This means that the phytochemical compounds in Bajakah rod herbal tea are not able to reduce or inhibit the absorption of high blood glucose when combined simultaneously with honey.

Table 5. Results of ANOVA test and HSD test of blood glucose levels every minute

Type of Food	Delta Blood Glucose In Minutes To- (mg/dL)			
	30	60	90	120
Glucose	78.30±17.68 [a]	67.2±23.52 [a]	47.6±14.41 [a]	33.40±12.73[a]
Bajakah Herbal Tea	112.4±31.82 [b]	92.2±47.10 [a]	68.8±34.16 [b]	58.90±19.48[b]
Amblycarpa Lime Extract	103.6±27.90 [ab]	66±17.78 [a]	36.8±12.51 [ab]	29.90±12.87[a]
Tikung Honey	93.3±30.24 [ab]	63.5±27.22 [a]	51.7±22.78 [ab]	33.50±18.52[a]
Bajakah Rod Extract	86.7±10.63 [ab]	73.3±28.48 [a]	47.5±18.13 [ab]	27.90±16.12[a]

Note: Numbers followed by the same letter are not significantly different at the 5% HSD test level

The blood glucose table in trapezium 4 and the total AUC area have the largest values in the Bajakah rod herbal tea test food treatment, namely 1915 and 9085.5. These two areas show that the Bajakah rod herbal tea drink is significantly different from the control and the single preparation, however, the values for both areas are still far above the control (glucose). Judging from these results, it shows that both the single preparation and the Bajakah rod herbal tea were unable to reduce blood glucose below control (glucose). The results show that no treatment has hypoglycemic/anti-hyperglycemic capabilities because none have lower blood glucose levels than control (glucose).

Calculation of blood glucose values every minute and also looking at the area of each trapezoid and the total AUC area using ANOVA and BNJ tests, both herbal tea drinks and their raw materials are not anti-hyperglycemic. The results of this research are in line with the previous research, the blood glucose value was above 140 mg/dL, namely 151.75 mg/dL (Ifada et al., 2019). This decrease is influenced by the simple glucose content in the honey itself. Tikung honey from Kapuas Hulu contains 71.426% glucose and 4.842% sucrose (Lestari & Dewi, 2023; Wardhani et al., 2022). This means that Bajakah herbal tea itself contributes glucose to the body when consumed, so it is thought that this causes an increase in blood glucose levels after consumption.

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Table 6. ANOVA and HSD test results AUC level 5%

Type of Food	Area of AUC on Each Trapezoid and Total AUC				
	Area 1	Area 2	Area 3	Area 4	Total AUC
Glucose	1174.5±265.24^{a}	2181,5±516.82^{a}	1722±501.58^{a}	1215±314.08^{a}	6294±1152.42^{a}
Bajakah Herbal Tea	1686±477.39^{b}	3069±1002.8^{a}	2415±1066.53^{a}	1915±707.35^{b}	9085.5±2999.55^{b}
Amblycarpa Lime Extract	1554±418.58^{ab}	2544±617.94^{a}	1542±295.73^{a}	1000±345.33^{a}	6640.5±1406.93^{a}
Tikung Honey	1399±453.59^{ab}	2352±754.81^{a}	1728±576.68^{a}	1278±480.40^{a}	6757.5±2050.39^{a}
Bajakah Rod Extract	1300.5±159.53^{ab}	2400±423.20^{a}	1812±356.59^{a}	1131±485.34^{a}	6643.5±1506.7^{a}

Note: Numbers followed by the same letter are not significantly different at the 5% HSD test level

Single preparations such as Amblycarpa lime extract, Bajakah rod extract, and Tikung honey decreased blood glucose at 120 minutes (Table 5) almost equivalent to control blood glucose. The average decrease in blood glucose in the 120th minute of a single dose ranged from 27.90-58.90 mg/dL. The blood glucose values in Bajakah rod extract and *Amblycarpa lime* (jeruk Sambal) are below the control blood glucose, however, these two single preparations are not significantly different from the control blood glucose values, so they do not have the potential to act as antihyperglycemia. The decrease in blood glucose is thought to be due to the activity of citric acid in Amblycarpa Lime (jeruk Sambal). This assumption is supported by previous research which showed that giving citric acid for 4 weeks in animal models of diabetes showed a decrease in blood glucose levels (Treki et al., 2018). Citric acid can increase insulin permeability so that blood glucose levels decrease (Lestari et al., 2024). However, in this study, Amblycarpa Lime (jeruk Sambal) extract with a consumption of 19.32 g could not reduce blood glucose levels. It is thought that a larger dose of consumption is needed to have the effect of lowering blood glucose levels. Previous research shows that giving 250 mL of freshly squeezed orange juice has the potential to reduce blood glucose levels (Paiva et al., 2019).

The genus Uncaria, one of which is Bajakah rod, contains flavonoid compounds, namely catechin (Munggari et al., 2022). The reduction in blood glucose from the Bajakah rod extract test food was in line with previous research stated that catechins from the *Elaeagnus umbellate* plant can inhibit carbohydrate digestive enzymes, namely α-amylase and α-glucosidase so that fasting blood glucose levels in diabetic mice decrease (Nazir et al., 2021). Bajakah contains the compound quercetin (Anggriani et al., 2024). Quercetin can inhibit the process of glucose absorption through the transfer of GLUT2 and SLGT1 with non-competitive inhibition (Lestari et al., 2024). This research shows that giving Bajakah rod herbal tea can increase blood glucose levels compared to other preparations (Lime extract, Bajakah rod extract, and Tikung honey). Based on this, it is suspected that certain compounds may have antagonistic effects in lowering blood glucose levels. Previous research shows that catechin and ellagic acid have antagonistic properties in their activity as antioxidants, namely that ellagic acid can inhibit catechin from donating hydrogen because the two will tend to bond with each other with hydrogen bonds between the carbonyl group of ellagic acid and the o-dihydroxyl group in catechin (Uduwana et al. al., 2023). However, similar cases have not been found in this study.

Conclusion

The combination of treatments affects the pH value, TSS, color, antioxidants, and anti-hyperglycemic of Bajakah herbal tea drinks. Bajakah herbal tea (with a content of 123.67 g was equivalent to a carbohydrate content of 50 g) and single preparations do not have anti-hyperglycemic activity. However, Bajakah rod herbal tea has the potential antioxidant activity.

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