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Physico-chemical characteristics of Figs Herbal Tea (Ficus racemosa L.) as a functional antidiabetic drink

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ABSTRACT

(Ficus racemosa L.) contain secondary metabolite compounds such as flavonoids, saponins, alkaloids, steroids, and tannins that have potential as a source of antioxidants. This study aims to determine the drying temperature variations on physicochemical characteristics of figs as an antidiabetic functional drink. The research methods begin by drying figs at various temperature (50°C, 60°C, and 70°C). The phytochemical test was followed by qualitative color change. The moisture content measurement was done using the thermogravimetric method. Then, the FTIR instrument identified the functional groups of organic compounds. Phytochemical analysis revealed the presence of flavonoids and tannins in all tea samples, regardless of drying temperature. FTIR spectroscopy confirmed the presence of phenolic compounds, characterized by O-H, Csp, and C=O enol groups. The pH of the tea at 50°C, 60°C, and 70°C, was 6.13; 5.64; and 5.59, the acidity of the pH obtained was indicated by the presence of phenolic compounds in all samples. The tea's moisture content was found to be within the Indonesian National Standard (<8%) at 60°C and 70°C, were 5.50% and 4.10%. Thus, fig tea, dried at 60°C or 70°C, can be developed as a functional antidiabetic drink.

Keywords:
Antidiabetic; drying temperature; figs; Ficus racemosa; functional drink.

Introduction

The current human lifestyle is sedentary, with minimal physical activity, but daily food contains calories. Because sophisticated technology makes it easier for humans to work, it does not require much physical movement. The availability of various online food applications also causes humans to be more consumptive. Especially when they order junk food containing refined carbohydrates and saturated fats, it can cause physical quality to decrease due to a lack of body mobility, which can lead to obesity, hyperglycemia, and even diabetes mellitus. High-calorie food intake can cause oxidative stress in the body, which can be handled by antioxidants. Oxidative stress damages the function of pancreatic β-cells through several complex molecular mechanisms. It will interfere with insulin production and the entry of proinsulin into the plasma membrane (B. L. Tan et al., 2018; Yaribeygi et al., 2020).

Oxidative stress and inflammation play a significant role in the pathogenesis of diabetes because they increase ROS production. To prevent ROS accumulation, intervention from antioxidant compounds is needed to control oxidative stress Clinical improvement for oxidative stress can be achieved by increasing the body's antioxidant defenses by consuming supplements or foods with antioxidant potential (Wronka et al., 2022). Some antioxidant supplements derived from food can be obtained from fruits and vegetables that contain high levels of vitamin C and vitamin E. Several secondary metabolites have the potential to act as antioxidants, including phenolic compounds. Phenolic compounds have more effective antioxidant potential than vitamin C, E, and carotenoids. In addition, several metabolite compounds with antioxidant potential include tannins, terpenoids, and saponins (Desta et al., 2022; Salimi et al., 2022; Setyorini & Antarlina, 2022).

Figs (Ficus racemosa L.) contain secondary metabolite compounds that have the potential to be a source of antioxidants. Previous studies have found that parts of the Figs plant, starting from the leaves, bark, fruit, roots, and sap, are rich in active phytochemical compounds (Pahari et al., 2022). This plant has been used in India to treat diarrhea, stomach, dysentery, diabetes, jaundice, gallbladder problems, inflammation, edema, toothache, and bronchitis (H. Sharma et al., 2023). Previous research shows that the root bark contains high flavonoid compounds, quercetin, and racemosic acid. The ethanol extract of figs contains flavonoid compounds, saponins, and alkaloids (Suryani & Gustiana, 2023). Meanwhile, the methanol extract of figs contains flavonoids, steroids, saponins, and tannins with antioxidant capacity giving IC_{50} value of 65.042 ppm with a strong antioxidant category (Hidayanti et al., 2023).

The potential benefits of antioxidant compounds in figs and their existence as ethnobotany allow researchers to explore their benefits as functional food ingredients. One of them is a drink that has properties to prevent oxidative stress in the body. In order to be able to maximize the use of bioactive compounds in a natural ingredient, it is necessary to apply it to a daily diet to keep the body fit and prevent degenerative diseases such as heart disease, cancer, and diabetes (Saras, 2023). Maintaining nutrient intake can be very effective in metabolic control in diabetics. One possible effort is to develop functional drinks in herbal tea that can be an alternative drink in the daily diet as an antidiabetic drink. Previous research on using fig plants as functional drinks has not been explored.

Herbal tea is a functional beverage with distinctive sensory properties in color, aroma, and taste. In addition, herbal tea also contains nutrients that can meet food needs and maintain the immune system and vitality of the body, preventing free radical attacks, aging, and degenerative diseases (Tavita et al., 2022). Tea also has several pharmacological activities such as antioxidant, antiviral, antibacterial, anti-inflammatory, antimutagenic, antistress, antihypertensive, antiaging, and anticancer (Umesh, 2023).

Methods

Tools and Materials

The tools used in this study were glassware, hot plate (Thermo Fisher Scientific), iron spatula, test tube rack, iron clamp, baking pan, porcelain cup, analytical balance (KERN), 60 mesh sieve, glass bottle, micropipette (Eppendorf), oven (Memmert), FT-IR instrument (Shimadzu IRSpirit), grinder, portable pH (Toolmann), thermometer, and plastic spoon. The materials used in this study were fig fruit simplicia (Ficus racemosa L.), 32% hydrochloric acid (Sigma Aldrich), Mg powder p.a (Merck), ferric chloride p.a (Merck), methanol p.a (Merck), ethanol, silica gel, tea bag, filter paper, and distilled water.

Research Procedure

Sample Preparation

Figs as much as ± 250 g of medium size and reddish color, washed with running water until clean. Next, dry with dry tissue.

Making Dry Herbal Tea

Figs are thinly sliced using a knife and then arranged on an iron baking sheet and oven at temperatures of 50°C (A_{T50}), 60°C (B_{T60}), and 70°C (C_{T70}) for ± 6-8 hours. The dried figs are blended and sieved using a 60 mesh sieve. The dried simplicia is placed in tea bags in a tightly closed glass container. Labels are given stating the sample's name and the initial storage date. Simplicia is stored at room temperature and is avoided by direct sunlight.

Determination of Sample Yield

The sample that had been dried for ±8 hours was weighed and the % yield was calculated using the equation below:

$$\% \text{ yield} = \frac{sample\ mass\ after\ drying}{sample\ mass\ before\ drying} \text{ x } 100\% \quad (1)$$

Qualitative Phytochemical Test

Flavonoid test using Shinoda test by dissolving 1 g of simplicia in ethanol solvent, then heated and filtered. Next, ±0.5–1 g of Mg powder and ±2–5 drops of concentrated HCl solution are added to the filtrate. The appearance of orange to magenta pink indicates the presence of flavonoids (Enin et al., 2023).

The tannin test is done by dissolving 1 g of the simplicia in ethanol solvent. The filtrate obtained is transferred into a test tube. Add 5% $FeCl_3$ solution as much as ± 5–10 drops. The appearance of blackish brown or blackish green indicates the presence of phenolic tannin content.

Determination of Moisture Content

Simplisia ± 3 g is heated in an oven at a temperature of 105°C for 1.5 - 3 hours. It lasts for ± 15-20 minutes until the simplisia is cold and weighed. Continued oven for 30 minutes - 1 hour until a constant weighing mass is obtained. The moisture content value is calculated using the equation:

$$\% \text{ moisture content} = (W_{\text{before drying}} - W_{\text{after drying}}) \text{ x } \frac{100}{\text{W (before drying)}} \quad (2)$$

Determination of pH Value

Each brewed tea was cooled to room temperature. Then, the pH value was measured using a pH meter. The observation was repeated 3 times.

Analysis of Functional Groups of Organic Compounds

Dry tea simplicia was brewed using hot distilled water with a ratio (1:5 w/v) for 6 minutes (Ma et al., 2024) at a temperature of 90°C (Ferreira et al., 2023). The filtrate obtained was tested for the possibility of functional group fingerprints using an FT-IR instrument at a wave number of 4000 - 400 cm-1.

Results and Discussions

Percentage Yield

The results of calculating the yield values for variations of fig tea are presented in Table 1. Based on Table 1, the large % yield obtained shows that the higher the tea drying temperature, the smaller the yield value. The higher the % yield value indicates the possibility of more bioactive content to be obtained during extraction.

Table 1. % Yield

Drying Temperature (^{0}C)	Sample Mass (g)		Yield (%)
	Before	After	
50	50.92	7.19	14.12
60	50.02	6.93	13.85
70	50.44	6.42	12.73

Phytochemical Test Results

The phytochemical tests carried out on the fig tea samples were tests to determine the presence or absence of secondary metabolite compounds of flavonoids and tannins, which are presented in Table 2.

Based on Table 2, the fig tea samples with drying temperature variations of 50°C, 60°C, and 70°C contained secondary metabolite compounds in the form of flavonoids. It is to the results of the qualitative phytochemical screening study on fig extracts in aqueous methanol and 96% ethanol solvents, which positively contained flavonoids, alkaloids, tannins, saponin, and phenolic compounds. Despite the difference in drying temperature of the samples, no differences in the observed colors were observed. All samples showed a uniform(S. Sharma & Kumar, 2021; Suryani & Gustiana, 2023) color, namely pink.

Table 2. Phytochemical Test

Drying Temperature (°C)	Reagen	Result	References	Info
A (50)	Flavonoid test (HCl + Mg powder)	Pink	Pink to red (Maheshwaran et al., 2024)	+
B (60)		Pink		+
C (70)		Pink		+
A (50)	Tannin test ($FeCl_3$ 5%)	greenish black	Blue black, greenish black (Hamzah et al., 2020)	+
B (60)		greenish black		+
C (70)		greenish black		+

The observed color change, namely pink, is caused by the benzopyrone core reaction between concentrated HCl solution and Mg powder with flavonoid compounds in the form of flavonol groups. Reduction of the benzopyrone core occurs due to the reduction of the carbonyl group (C=O) in the benzopyrone core of the flavonol compound by Mg powder, which can occur in an acidic environment (Harborne, 1998). A concentrated HCl solution aims to provide an acidic atmosphere in this reaction. The result of the reduction reaction will produce a flavylium salt that has color characteristics such as red or pink. Their color in aqueous environments shifts from red in very acidic environments to pink in weakly acidic environments (Maheshwaran et al., 2024). The density of the resulting color will depend on the specific type of flavonoid contained in the sample.

The results of the tannin content test on fig tea samples at all drying temperature variations showed that the fig tea samples were positive for tannin. It is to the results of the qualitative phytochemical screening study on fig fruit extracts in methanol and 96% ethanol solvents, which were positive for tannin (Hidayanti et al., 2023; Suryani & Gustiana, 2023). Tannin compounds are included in the polyphenol compound group with free phenolic hydroxyl groups. The presence of this hydroxyl group can form a complex bond with metal ions such as iron ions (Fe^{3+}) derived from the $FeCl_3$ compound. The presence of the complex bond that is formed causes a color change, such as, dark blue, greenish black, or other dark colors that tend to adjust to the type of tannin compound and the reaction conditions that occur (Javed et al., 2020). The chemical reaction between the tannin compound and 5% $FeCl_3$ forms a complex compound Fe-tannin (Harborne, 1998). Flavonoids and tannins can function as antioxidants that can prevent the formation of free radicals in the body. So that research can continue on quantitative tests of flavonoid levels and antioxidant activity.

Moisture Content

The analysis of water content in this study used the Thermogravimetry method. The results of the water content test are presented in Figure 1. Based on the graph in Figure 1, tea's highest moisture content value is in tea with a drying temperature of 50°C, and the lowest is at a drying temperature of 70°C. The higher the drying temperature, the lower the moisture content value of the tea obtained. In addition, when compared to the Indonesian National Standard (SNI) regarding the moisture content value in packaged dry tea, the drying temperature of 60°C and 70°C met the standard, namely a moisture content of <8% (Badan Standardisasi Nasional, 2013). These results are in accordance with previous research, where kedondong leaves are dried at a temperature of 50-90°C. During the drying process, water evaporation occurs, which reduces the water content of the material. Evaporation occurs because of the difference in water vapor pressure between the water in the material and the water vapor in the air. The water vapor pressure of the material is generally more significant than the water vapor pressure of the air, causing the transfer of water mass from the material to the air. It is related to the higher the temperature in the drying process, the greater the heat energy taken so that more air mass evaporates from the surface of the dried material (Ismanto et al., 2020).

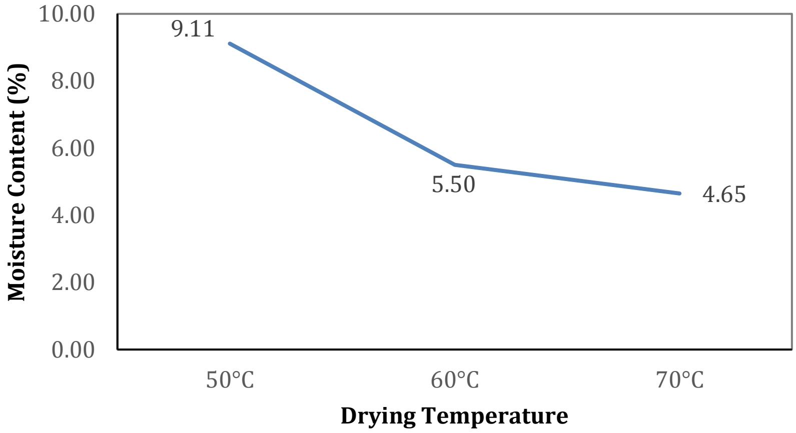

Figure 1. Graph of the effect of drying temperature on moisture content (Group A=50°C, B=60°C, and C=70°C)

Although the decrease in moisture content is directly proportional to the increase in drying temperature, it is not recommended to use drying temperatures that are too high. Heating or drying temperatures that are too high can damage secondary metabolite compounds in a natural material, one of which is flavonoids (Gusti Ngurah Sujana Kusuma et al., 2019). Flavonoid compounds are phenolics that have many hydroxyl groups and double bonds. Hydroxyl groups and double bonds are generally thermolabile or susceptible to interactions with high temperatures (Mulia et al., 2018). It can cause oxidation and degradation reactions in the structure of flavonoid compounds (Widayanti et al., 2023). Several studies show data that flavonoid levels decrease after passing temperatures above 50°C. This is due to the degradation of the sensitive flavonoid structure (S. P. Tan et al., 2014).

In another study, it was found that the flavonoid content in citrus peel extract will decrease if the drying temperature is lowered (<80°C) and will increase if the drying temperature is increased (>90°C). However, drying temperatures>100°C will damage the flavonoid components in it (Chen et al., 2011). During drying, increasing the drying temperature can cause a reduction in the free phenolic content. The tendency to decrease for free flavonoids was only observed at drying temperatures above 60°C. The content of bound phenolics and flavonoids will be higher at drying temperatures of 60°C and 80°C when compared to other temperatures (Lang et al., 2019).

pH Value

The acidity test of the fig tea solution in this study is presented in Figure 2. Based on Figure 2, the highest pH value is in tea with a drying temperature of 50°C, and the lowest value is at a drying temperature of 70°C. The higher the drying temperature, the lower the pH value of the tea obtained. Measuring the pH value of beverage products is important because it aims to ensure the beverages' safety. Beverages that enter the body will affect the regulation of the body's acid-base balance. The pH value of normal body fluids is around 7.35-7.45 and this condition can decrease or increase with external influences in the form of food or drinks (Fathul & Boediono, 2008).

The reference for pH values in bottled drinking water in SNI 3553:2015, revised as a reference for mineral water, states that the quality requirements for drinking water are 6.0-8.5 (Badan Standardisasi Nasional, 2015). The pH value at drying at 60^{O}C and 70^{O}C is below 6.0. However, the standard pH range required for tea is not specifically determined by BSN. The more acidic pH range for carbonated beverages is at least 4.0.

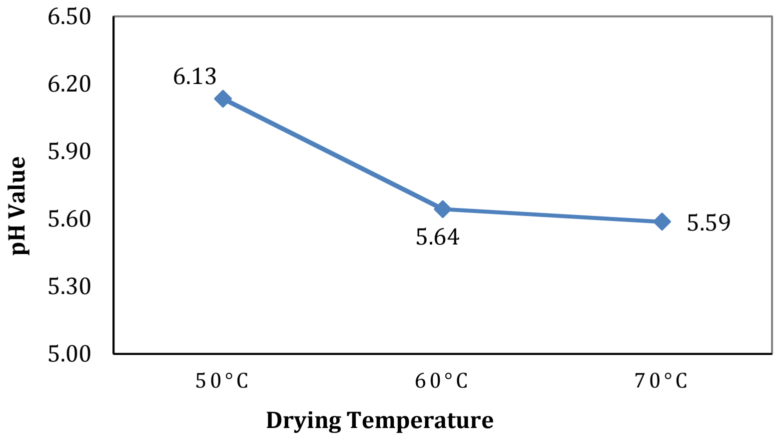

Figure 2. Graph of the effect of drying temperature on pH value

Several other studies also explain that the pH value observed for ready-to-drink fig tea is below 4.03; this is related to the concentration of acid in it or the presence of acidulant as an acidifying agent (Leticia & Lina, 2014). The presence of phenolic compounds can release a proton (H^+), which can lower the pH of the brewed tea solution and cause it to acidize (Muzaki et al., 2015). A study on Dried Roselle explained that the total phenolic compounds would decrease at temperatures of 100^{0}C and 120^{0}C. The highest phenolic content was obtained at a temperature of 80^{0}C. This content can be reduced by up to 60% when dried at 60^{0}C (Nguyen & Chuyen, 2020). This supports the results of our study, where the pH of the drying sample at 70^{0}C is more acidic than the drying sample at 60^{0}C and 50^{0}C, which could be due to the presence of more phenolic compounds.

Other studies present pH results for fruits such as mandarins, lemons, roses, apples, and blackberries made into tea, with pH values ranging from 2.7 to 3.62. Generally, tea from fruit contains organic acids, which can be citric, malonic, and oxalic acids, so they naturally provide an acidic atmosphere when brewing (Serap & Aysen, 2010). The pH range for herbal drinks or herbal medicine products sold in Nigeria is around 3.00-5.09 for herbal medicines and 3.45-8.65 for herbal mixtures. The study suggests that the pH range for decoctions should be at pH 3.5-7.0. For tea formulations with a pH <5.5, the label should include advice to rinse the mouth, drink water after consuming the product, or consume the product after meals. It aims to prevent gastric irritation, inflammation, and ulcers (Kumadoh et al., 2024).

Functional Group Content of Organic Compounds

Functional groups in an organic compound can be detected by the interaction between electromagnetic radiation in the form of IR (Infrared) rays with material in the form of organic compound molecules with covalent bonds. The difference in electronegativity between atoms bound to a molecule will produce a vibration that will be presented in the form of spectra with a certain intensity at a wave number of around 4000 cm^{-1} – 400 cm^{-1}. The result of FTIR spectra from figs tea is presented in Figure 3.

Based on Figure 3, the functional groups observed from fig tea samples with variations in drying temperature are hydroxyl groups (O-H), stretching vibration types with moderate spectral intensity. This type of vibration generally occurs along the bonds between atoms in an organic compound molecule. The hydroxyl functional group has a distinctive property that can be observed in the wave number range of 3200-3500 cm^{-1}.

The type of spectra for hydroxyl functional groups varies depending on the chemical environment of the hydroxyl group and the possible interactions between molecules. Generally, free hydroxyl groups (free O-H) tend to form spectra with broad or shouldered intensity (Donald L. Pavia, 2009). Each sample of fig tea showed the presence of hydroxyl group absorption, namely

3316.37, 3335.50, and 3313.69 cm^{-1}, with stretching vibration type and medium qualitative spectral appearance intensity.

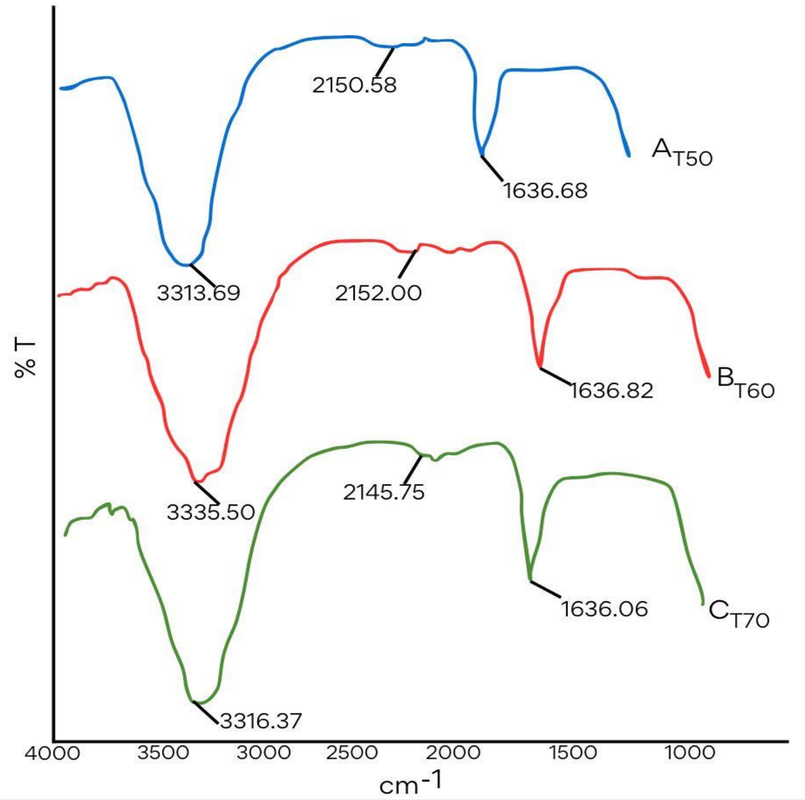

Figure 3. IR spectra of A_{T50}, B_{T60}, C_{T70} sample

The enol carbonyl group is an isomeric form of the ketone or aldehyde carbonyl group. This isomerism can occur because a Hydrogen atom is directly bound to the alpha carbon, which moves to the oxygen atom and forms a double bond between the carbon and oxygen atoms. The enol carbonyl group generally shows absorption at wave numbers around 1650 - 1620 cm^{-1}.

The range of wave numbers can shift depending on the environment around the carbonyl group and the possibility of conjugation with other functional groups in the organic compound (Donald L. Pavia, 2009). Based on the structure of phenolic compounds, both flavonoids and tannins can form carbonyl enol groups. Each sample of fig tea showed the absorption of carbonyl enol groups, namely 1636.68, 1636.82, and 1636.06 cm^{-1}.

The alkyne group (Csp) is a triple bond between carbon and carbon, generally providing absorption at wave numbers around 2260 – 2100 cm^{-1} (Ahluwalia, 2023; Donald L. Pavia, 2009). In general, alkyne groups are rarely found in the basic structure of flavonoid compounds. However, alkyne group absorption detected in fig tea samples indicates the presence of polyacetylene compounds. This compound is a natural organic compound with a triple carbon chain. It is commonly found in plants with various biological activities such as antioxidants, antimicrobials, anticoagulants (Tahar et al., 2023), and insecticides and allelopathy (weed inhibitors) (Tampubolon et al., 2018). The summary of the obtained wave number absorption is presented in Table 3.

The presence of the above groups confirms the presence of phenolic compounds. Flavonoids and tannins are phenolic compounds that can play a role in preventing diabetes. The biological properties of phenolic compounds, especially antioxidant activity that can prevent oxidative stress. In general, oxidative stress occurs due to an imbalance in the production of free radicals. The most common compounds are known as reactive oxygen species (ROS). These free radicals are known to cause damage to proteins, lipid membranes, and nucleic acids, ultimately leading to cell death. The mechanisms that phenolics can do to control oxidative stress include: i) neutralization/reduction of ROS formation, either by modulating the activity of several enzymes or by chelating trace elements involved in ROS formation; ii) cleaning up ROS, and iii) restoring redox homeostasis by enhancing the endogenous defense system. The ability of (poly)phenols to capture free radicals is mainly due to their aromatic rings and highly conjugated systems with many hydroxyl groups, which make them good electron or hydrogen atom donors (Silva et al., 2017).

Table 3. Functional Group Analysis

Sample	Wave Number (cm^{-1})	Functional Groups, Types of Vibrations	Intensity
A_{T50}	3316.37	O-H, streching	medium
	2150.58	Csp, streching	weak
	1636.68	C=O, enol group	strong
B_{T60}	3335.50	O-H, streching	medium
	2152.00	Csp, streching	weak
	1636.82	C=O, enol group	strong
C_{T70}	3313.69	O-H, streching	medium
	2145.75	Csp, streching	weak
	1636.06	C=O, enol group	strong

The ability of flavonoid or phenolic compounds as antidiabetic has been tested in a study related to the antidiabetic effects of crude extracts, partition fractions and isolated compounds from *Bauhinia strychnifolia* stems. This study found that the ethyl acetate fraction contained the highest total phenolic content (TPC) and total flavonoid content (TFC). This fraction was then tested against the activity of the α-glucosidase enzyme, resulting in the highest inhibition compared to other fractions, namely IC_{50} of 1.51 μg/mL. This inhibitory activity was higher than acarbose as a positive control with IC_{50} 329.48 μg/mL (Praparatana et al., 2022).

Conclusion

Variations in drying temperature of 50°C, 60°C, and 70°C qualitatively did not affect the detection of flavonoid and tannin compounds in the sample or its functional groups. The optimal drying temperature for antioxidant-based fig tea. Simplicia starts at 60°C and 70°C so that the moisture content obtained is good. Fig tea with drying temperature at 60°C has a pH value of 5.64 and a moisture content 5.50. Meanwhile, fig tea, with a drying temperature of 70°C, has a pH value and moisture content of 5.59 and 4.65, respectively.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

References

Ahluwalia, V. K. (2023). Infrared Spectroscopy. In *Instrumental Methods of Chemical Analysis* (pp. 179–231). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-38355-7_23

Badan Standardisasi Nasional. (2013). *SNI 3836-2013 teh-kering*.

Badan Standardisasi Nasional. (2015). *SNI 3553:2015 Air mineral*. www.bsn.go.id

Chen, M. L., Yang, D. J., & Liu, S. C. (2011). Effects of drying temperature on the flavonoid, phenolic acid and antioxidative capacities of the methanol extract of citrus fruit (Citrus sinensis (L.) Osbeck) peels. *International Journal of Food Science and Technology*, *46*(6), 1179–1185. https://doi.org/10.1111/j.1365-2621.2011.02605.x

Desta, K. T., Yoon, H., Shin, M. J., Lee, S., Wang, X. H., Choi, Y. M., & Yi, J. Y. (2022). Variability of Anthocyanin Concentrations, Total Metabolite Contents and Antioxidant Activities in Adzuki Bean Cultivars. *Antioxidants*, *11*(6). https://doi.org/10.3390/antiox11061134

Donald L. Pavia, G. M. L. G. S. K. J. R. V. (2009). *Introduction to Spectroscopy* (4th ed.). Cengage Learning.

Enin, G. N., Antia, B. S., Shaibu, S. E., & Nyakno, I. (2023). Comparison of the Chemical Composition, Nutritional Values, Total Phenolics and Flavanoids Content of the Ripe and Unripe Solanum ningrum Linn, Fruits from Nigeria. *World Journal of Pharmacy and Pharmaceutical Sciences*, *12*(8), 1–18. https://doi.org/10.20959/wjpps20238-25410

Fathul, F., & Boediono, A. (2008). Keasaman Cairan Tubuh dan Rasio Kelamin Anak Domba Garut (Ovis aries) yang Diberi Kation-Anion Ransum yang Berbeda. *Media Peternakan*, *31*(2), 87–98. https://doi.org/10.5398/medpet.v31i2.1086

Ferreira, R. M., Wessel, D. F., Silva, A. M. S., Saraiva, J. A., & Cardoso, S. M. (2023). Infusion from Opuntia ficus-indica Peels: The Effects of Drying and Steeping Conditions. *Beverages*, *9*(4). https://doi.org/10.3390/beverages9040097

Gusti Ngurah Sujana Kusuma, I., Nengah Kencana Putra, I., & Putu Trisna Darmayanti, L. (2019). Pengaruh Suhu Pengeringan Terhadap Aktivitas Antioksidan Teh Herbal Kulit Kakao (Theobroma cacao L.). *Jurnal Ilmu Dan Teknologi Pangan*, *8*(1), 85–93.

Hamzah, B., Rahmawati, S., Suwena, W. S., Hardani, M. F., & Hardani, R. (2020). Analysis of tannin in sapodilla fruit (Manilkara zapota (l) van royen). *Rasayan Journal of Chemistry*, *13*(4), 2243–2248. https://doi.org/10.31788/RJC.2020.1345753

Harborne, J. B. (1998). *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis.* (3rd ed.). Springer Science & Business Media.

Hidayanti, B. R., Suryani, N., & Dewi, Y. K. (2023). Phytochemical Screening and Antioxidant Activity Test of Ara Fruit Extract (Ficus racemosa Linn.) Using DPPH Method. *SPIN: Jurnal Kimia & Pendidikan Kimia*, *5*(2), 177–191. https://doi.org/10.20414/spin.v5i2.7306

Ismanto, S. D., Rahmi, I. D., & Febrian, A. (2020). The influence of drying temperature on chemical components of herbal tea leaves (Spondiasdulcis soland). *IOP Conference Series: Earth and Environmental Science*, *583*(1). https://doi.org/10.1088/1755-1315/583/1/012030

Javed, B., Nawaz, K., & Munazir, M. (2020). Phytochemical Analysis and Antibacterial Activity of Tannins Extracted from Salix alba L. Against Different Gram-Positive and Gram-Negative Bacterial Strains. *Iranian Journal of Science and Technology, Transaction A: Science*, *44*(5), 1303–1314. https://doi.org/10.1007/s40995-020-00937-w

Kumadoh, D., Amekyeh, H., Archer, M. A., Kyene, M. O., Yeboah, G. N., Brew-Daniels, H., Adi-Dako, O., Osei-Asare, C., Adase, E., & Appiah, A. A. (2024). Determination of consistency in pH of some commercial herbal formulations in Ghana. *Journal of Herbal Medicine*, *45*. https://doi.org/10.1016/j.hermed.2024.100876

Lang, G. H., Lindemann, I. da S., Ferreira, C. D., Hoffmann, J. F., Vanier, N. L., & de Oliveira, M. (2019). Effects of drying temperature and long-term storage conditions on black rice phenolic compounds. *Food Chemistry*, *287*, 197–204. https://doi.org/10.1016/j.foodchem.2019.02.028

Leticia, B. F. L., & Lina, N. H. (2014). Evaluation of the pH and titratable acidity of teas commercially available in Brazilian market. *Rev Gaúcha Odontol*, *62*(1), 59–64.

Maheshwaran, L., Nadarajah, L., Senadeera, S. P. N. N., Ranaweera, C. B., Chandana, A. K., & Pathirana, R. N. (2024). Phytochemical Testing Methodologies and Principles for Preliminary Screening/ Qualitative Testing. *Asian Plant Research Journal*, *12*(5), 11–38. https://doi.org/10.9734/aprj/2024/v12i5267

Ma, Y.-Y., Wang, J.-Q., Gao, Y., Cao, Q.-Q., Wang, F., Chen, J.-X., Feng, Z.-H., Yin, J.-F., & Xu, Y.-Q. (2024). Effect of the type of brewing water on the sensory and physicochemical properties of light-scented and strong-scented Tieguanyin oolong teas. *Food Chemistry: X*, *21*, 101099. https://doi.org/10.1016/j.fochx.2023.101099

Mulia, S., Sri, D., & Munifatul, I. (2018). *Pengaruh Suhu Pengeringan Terhadap Kadar Air, Kadar Flavonoid dan Aktivitas Antioksidan Daun dan Umbi Rumput Teki (Cyperus rotundus L.)* (Vol. 20, Issue 1).

Muzaki, D., Wahyuni, R., Pangan, T., Universitas, P., Pasuruan, Y., & Teh, A. (2015). Pengaruh Penambahan Gingger Kering (Zingiber officinale) Terhadap Mutu Dan Daya Terima Teh Herbal Daun Afrika Selatan (Vernonia amygdalina). In *Jurnal Teknologi Pangan* (Vol. 6, Issue 2).

Nguyen, Q. V., & Chuyen, H. Van. (2020). Processing of herbal tea from roselle (Hibiscus sabdariffa l.): Effects of drying temperature and brewing conditions on total soluble solid, phenolic content, antioxidant capacity and sensory quality. *Beverages*, *6*(1), 1–11. https://doi.org/10.3390/beverages6010002

Pahari, N., Majumdar, S., Karati, D., & Mazumder, R. (2022). Exploring the pharmacognostic properties and pharmacological activities of phytocompounds present in Ficus racemosa linn.: A concise review. In *Pharmacological Research - Modern Chinese Medicine* (Vol. 4). Elsevier B.V. https://doi.org/10.1016/j.prmcm.2022.100137

Praparatana, R., Maliyam, P., Barrows, L. R., & Puttarak, P. (2022). Flavonoids and Phenols, the Potential Anti-Diabetic Compounds from Bauhinia strychnifolia Craib. Stem. *Molecules*, *27*(8). https://doi.org/10.3390/molecules27082393

Salimi, F., Almasi, F., Mohammadipanah, F., & Abdalla, M. A. (2022). A Comparative Review of Plant and Microbial Antioxidant Secondary Metabolites. *Applied Food Biotechnology*, *9*(2), 173–194. https://doi.org/10.22037/afb.v9i2.36170

Saras, T. (2023). *Antioksidan: Keajaiban Molekul Pelindung Tubuh*. Unhawas Press.

Serap, A., & Aysen, Y. (2010). The pH and Neutralisable Acidity of the most-Consumed Turkish Fruit and Herbal Teas. *OHDMBSC*, *IX*(2), 75–78.

Setyorini, D., & Antarlina, S. S. (2022). Secondary metabolites in sorghum and its characteristics. In *Food Science and Technology (Brazil)* (Vol. 42). Sociedade Brasileira de Ciencia e Tecnologia de Alimentos, SBCTA. https://doi.org/10.1590/fst.49822

Sharma, H., Pathak, R., Jain, S., Bhandari, M., Mishra, R., Reena, K., Varshney, P., & Author, C. (2023). Ficus Racemosa L: A Review On Its Important Medicinal Uses. *Phytochemicals And Biological Activities*, *30*(17), 213–227. https://doi.org/10.47750/jptcp.2023.30.17.018

Sharma, S., & Kumar, R. (2021). Free Radical Scavenging Activity And Gc Methanolic Extract Of Bundelkhand Region. In *J. Phytol. Res* (Vol. 34, Issue 1).

Silva, B., Oliveira, P., Casal, S., Alves, M., & Dias, T. (2017). Promising Potential of Dietary (Poly)Phenolic Compounds in the Prevention and Treatment of Diabetes Mellitus. *Current Medicinal Chemistry*, *24*(4), 334–354. https://doi.org/10.2174/0929867323666160905150419

Suryani, N., & Gustiana, S. (2023). Profil Fitokimia dan Analisis Toksisitas Buah Ara (Ficus racemosa L.) Menggunakan Metode Brine Shrimp (Artemia salina) Lethality Test. *ALOTROP*, *7*(2), 67–77. https://doi.org/10.33369/alo.v7i2.30801

Tahar, N., Satrianegara, F., Rukmana, R., Hamzah, N., Rukmana, S., Alwi, F., Roni, A., & Mukhriani, M. (2023). Brine Shrimp Lethality, Aktivitas Antioksidan dan Kadar Total Fitokimia dari Ekstrak Etanol Kasumba Turate (Carthamus tinctorius). *JFIOnline | Print ISSN 1412-1107 | e-ISSN 2355-696X*, *15*(1), 72–78. https://doi.org/10.35617/jfionline.v15i1.71

Tampubolon, K., F. N., S., Z., P., S.T.S., S., & S. Karim. (2018). *Potensi Metabolit Sekunder Gulma sebagai Pestisida Nabati di Indonesia*.

Tan, B. L., Norhaizan, M. E., & Liew, W. P. P. (2018). Nutrients and oxidative stress: Friend or foe? In *Oxidative Medicine and Cellular Longevity* (Vol. 2018). Hindawi Limited. https://doi.org/10.1155/2018/9719584

Tan, S. P., Parks, S. E., Stathopoulos, C. E., & Roach, P. D. (2014). Extraction of Flavonoids from Bitter Melon. *Food and Nutrition Sciences*, *05*(05), 458–465. https://doi.org/10.4236/fns.2014.55054

Tavita, G. E., Linda, R., Ashari, A. M., Apindiaty, R. K., & Hartanti, L. (2022). Pengujian Kualitas Parameter Fisika Kimia dan Kandungan Total Fenol Dari Teh Herbal Cakar Kucing (Uncaria tomentosa Wild. Ex Schult) Sebagai Minuman Fungsional. *Agrisaintifika*, *6*(2), 113–121.

Umesh, C. V. (2023). Chapter 13 - Camellia sinensis. In A. Amalraj, S. Kuttappan, K. Varma A.C., & A. Matharu (Eds.), *Herbs, Spices and Their Roles in Nutraceuticals and Functional Foods* (pp. 219–231). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-323-90794-1.00009-0

Widayanti, E., Mar'ah Qonita, J., Ikayanti, R., & Sabila, N. (2023). Pengaruh Metode Pengeringan terhadap Kadar Flavonoid Total pada Daun Jinten (Coleus amboinicus Lour). *Indonesian Journal of Pharmaceutical Education*, *3*(2). https://doi.org/10.37311/ijpe.v3i2.19787

Wronka, M., Krzemińska, J., Młynarska, E., Rysz, J., & Franczyk, B. (2022). The Influence of Lifestyle and Treatment on Oxidative Stress and Inflammation in Diabetes. In *International Journal of Molecular Sciences* (Vol. 23, Issue 24). MDPI. https://doi.org/10.3390/ijms232415743

Yaribeygi, H., Sathyapalan, T., Atkin, S. L., & Sahebkar, A. (2020). Molecular Mechanisms Linking Oxidative Stress and Diabetes Mellitus. *Oxidative Medicine and Cellular Longevity*, *2020*. https://doi.org/10.1155/2020/8609213