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RESEARCH PAPER

The effect of drying temperature on the physico-chemical characteristics of herbal tea preparation of red dragon fruit skin (*Hylocereus polyrhizus*) in whole form and powder form

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Abstract

Hylocereus polyrhizus skin, often discarded, is rich in antioxidants, making it a promising ingredient for herbal tea. This study evaluates the effect of drying temperature on the physicochemical characteristics of dragon fruit skin herbal tea in whole and powdered forms. The research employed a completely randomized design (CRD) with two factors—drying temperature (45°C, 50°C and 55°C) and formulation form (whole and powder), resulting in six treatments with four replications each. Data were analyzed using ANOVA, followed by DMRT at a 5% significance level. The results showed that the interaction between drying temperature and product form significantly affected yield, moisture content, pH, lightness (L*), total phenols, total flavonoids, total tannins, and antioxidant activity. A drying temperature of 50°C in the whole form was most effective in preserving total phenols (92.5±2.1 mg GAE/g) and total flavonoids (34.7±1.8 mg QE/g), while 55°C resulted in the highest antioxidant activity of 47.29±5.78 mmol Fe^{2+}/g. However, temperatures beyond this may degrade heat-sensitive antioxidants due to oxidation. These findings suggest that 50°C is the optimal drying temperature for maintaining the nutritional quality of dragon fruit skin herbal tea.

1. Introduction

Indonesia is known as a country rich in natural resources, especially medicinal plants, and tropical fruits that are beneficial for health. One of the popular and nutritious tropical fruits is dragon fruit. Currently, there are four types of dragon fruit, namely red dragon fruit (*Hylocereus polyrhizus*), white-fleshed dragon fruit (*Hylocereus undatus*), dark red-fleshed dragon fruit (*Hylocereus costaricensis*), and yellow dragon fruit (*Selenicereus megalanthus*) (Wahyuni, 2016). In 2022, Indonesia produced 367,300 tons of dragon fruit, with the red dragon fruit variety being the most widely cultivated, while other varieties remain less common (BPS Indonesia, 2023)

The public widely consumes it because of its refreshing taste and health benefits. However, people generally only consume the flesh, while the skin is discarded as waste. Dragon fruit skin weighs 22 g per 100 g of fruit weight (Jamilah *et al*., 2011). The antioxidant activity of dragon fruit skin is greater than the antioxidant activity of dragon fruit flesh, so it has the potential to be developed into a source of natural antioxidants. From the literature, 1 mg/ml of red dragon fruit skin can inhibit DPPH by 83.48±1.02% compared to 1.0 mg/l BHA. Red dragon fruit flesh can only inhibit DPPH by 27.45±5.03% (Nurliyana *et al*., 2010). Red dragon fruit skin extract was reported to contains antioxidants in vitamin C, flavonoids, tannins, alkaloids, steroids, and saponins based on the results of phytochemical and FTIR tests (Noor *et al*., 2016).

Dragon fruit skin has enormous potential if utilized optimally. One of the uses of dragon fruit skin waste is to process it into herbal drinks. The public often consumes herbal drinks because they have many benefits (Ali, 2016). Utilization of dragon fruit skin can be used as herbal drink because dragon fruit skin contains antioxidant compounds. One of the important processing methods in maintaining product quality is the drying temperature. The drying process causes the water content in the material to evaporate faster, and the use of Temperature in the drying process can affect the bioactive compounds produced. Purnomo *et al*. (2016) reported that the temperature and drying time affect the antioxidant activity of red dragon fruit skin herbal tea,

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and the best treatment was at a temperature of 50°C for 18 hours with an IC_{50} value of 2.713 ppm. The resulting form of herbal drinks also affects the bioactive compounds produced. The reduction in the size of the material causes the breakdown of cell walls and membranes to be damaged, which can facilitate the compounds in the material to dissolve more easily in water.

Red dragon fruit skin waste can be used as an herbal drink; however, the drying temperature can affect the content of bioactive components. Higher drying temperatures are suspected to enhance certain bioactive compounds, such as total phenols, total flavonoids, and antioxidant activity, but may also lead to the degradation of heat-sensitive compounds. Therefore, this study aims to evaluate the effect of drying temperature on yield, color analysis, moisture content, ash content, pH, total phenols, total tannins, total flavonoids, and antioxidant activity in red dragon fruit skin herbal drinks in whole form and powder form.

2. Materials and methods

2.1 Sample preparation

The red dragon fruit skin was sorted and separated from the flesh and scales. Then, the red dragon fruit skin was washed and cleaned with running water. The red dragon fruit skin was sliced into 2 mm thinly slices and arranged into a drying pan. The drying process was carried out for 6 hours at 45°C, 50°C and 55°C. After drying, the red dragon fruit skin in whole form (2 g) was packed using a plastic ziplock. The red dragon fruit skin in powder form was produced through a refining process using a grinder and sieved using a 40-mesh sieve. The powder obtained (2 g) was packed into tea bags, and then sealed using a sealer. Each sample of powder and whole form was put into a beaker, and 100 ml of hot water at a temperature of 100°C was added for 5 minutes. The results of the whole form brew were filtered, and the results of the powder brew were separated from the tea bag packaging.

2.2 Yield

The yield calculation was obtained from the dry weight of the red dragon fruit skin herbal tea produced with the weight of the red dragon fruit skin used (Nugroho *et al.,* 2018).

2.3 Moisture content

Moisture content was determined using the moisture balance method. The device was set to 105°C, and 2±0.01 grams of the sample was placed on an aluminum plate in the moisture analyzer. After the process was complete, the device automatically displays a constant number, which was displayed as a percentage of moisture content (Herayati *et al.,* 2022).

2.4 Ash content

Ash content was determined using the gravimetric method. The porcelain cup was first heated using an oven for 30 minutes, then in a desiccator for 15 minutes. About 2 g of the sample was carefully weighed and put in the porcelain cup, and then ashing was carried out using an electric furnace at a temperature of 550°C for 5 hours. The sample was cooled in a desiccator for 30 minutes, then weighed, and the results are recorded (Yudhayanti and Restiani, 2019).

2.5 pH

The pH measurement was carried out using a pH meter calibrated using pH four and pH seven buffers. The pH meter was inserted into the red dragon fruit skin herbal tea infusion to determine the pH of the solution. The pH value can be known after the number shown was stable on the pH meter (Rahmi *and* Susanti, 2023).

2.6 Color analysis

Color intensity was measured with a calibrated chromameter based on Hunter's Lab Colorimetric color system. Hunter color notation system is characterized by three values, namely L (Lightness), a* (hue), and b* (chroma). Lightness color value, white = 100, black =0, a* value, (+ a*= red, -a*= green). While the b* value (+b*= yellow, -b*= blue). A sample of 25 grams was placed in a clear container, and the surface was evenly leveled. The chromameter light eye was attached and illuminated as close to the sample as possible. The Hunter color notation system was read and displayed three color factors: L*, a*, and b* (Caliskan and Dirim, 2016).

2.7 Total phenolic content

Determination of total phenolic content was carried out using the Folin-Ciocalteu reagent. The first step was to create a gallic acid calibration curve with concentration variations of 4, 8, 12, 16, and 20 ppm. One mL of the test sample was added with 1 mL of Folin-Ciocalteu reagent (dilution result with 1:10 aquadest) and 2 mL of 7.5% sodium carbonate solution. The mixture was left for 15 minutes, and then the absorbance was measured at a wavelength of 725 nm. The linear regression equation of the gallic acid calibration curve was used to calculate total phenols. The measurement results were expressed in an equivalent weight of gallic acid per sample weight (Siah *et al*., 2011).

2.8 Total flavonoid content

Total flavonoid content was determined using a colorimetric method. A 3 mL of methanol and 2 mL of sample were mixed separately with 0.15 mL of 5% $NaNO_2$ (sodium nitrite) solution. After 6 minutes, 0.15 mL of 10% $AlCl_3$ (aluminum chloride) solution was added and left for 6 minutes, then 2 mL of 1 M NaOH solution was added to the mixture. Distilled water was added until the final volume reached 5 mL, and the mixture was left for another 15 minutes. The absorbance of the mixture was then measured at 510 nm against the blank. The linear regression equation of the quercetin calibration curve was used to calculate total flavonoids (Sariburun *et al*., 2010).

2.9 Total tannin content

Measurement of tannin content was carried out using the modified Folin-Ciocalteu method. The first step was to make a calibration curve of tannic acid, with concentration variations of 4, 8, 12, 16, and 20 ppm. A 1 mL sample was diluted with methanol in a 10 mL measuring flask. Then 0.4 mL of the sample solution was taken and added with 2 ml of 10% Folin-Ciocalteu reagent, then vortexed and left for 5 minutes. A 1.6 ml of 7.5% Na_2CO_3 was added to the solution, vortexed again, then incubated in a dark place for 30 minutes. After that, the absorbance was measured at a wavelength of 755 nm. The linear regression equation of the tannic acid calibration curve was used to calculate total tannins (Fibrianto *et al*., 2020).

2.10 Antioxidant activity FRAP method

Antioxidant activity testing using the modified FRAP method was performed with $FeSO_4.7H_2O$ as a standard. FRAP reagent was made by mixing 0.3 M acetate buffer solution (pH 3.6), 10 mM TPTZ (2,4,6-tripydyls-triazine) solution in 40 mM HCl, and 20 mM $FeC1_3.6H_2O$ solution with a volume ratio of 10:1:1. A total of 0.4 mL of sample was added with 3 mL of FRAP reagent, vortexed and then left for 30 minutes in a dark room at room temperature. The absorbance of the sample was measured at a wavelength of 593 nm (Fauziyyah, 2018).

2.11 Statistical analysis

This study used a completely randomized design with two factors. The first factor, drying temperature, had three treatment levels (45°C, 50°C and 55°C). The second factor, formulation form, had two treatment levels (whole and powder) with four replications. Data were analyzed using Two-Way ANOVA, followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. This research uses SIGMAPLOT software version 15.0.

3. Results and discussion

3.1 Yield

Yield is the percentage of the weight of dried dragon fruit skin produced from the weight of the materials used. The yield produced in this study ranged from 5.47 - 8.19% (Figure 1). The drying treatment at 55°C results in a lower yield compared to drying at 45°C and 50°C. The higher the drying temperature, the greater the amount of evaporated water. The powdered form yields lower results than the whole form at each drying temperature treatment.

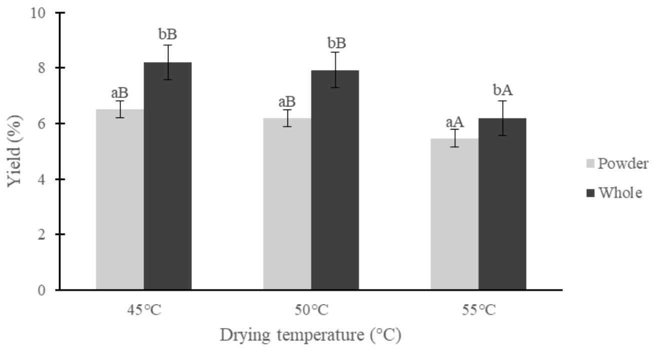

Figure 1. Yield of red dragon fruit skin herbal drink.

In Figure 1, the drying temperature treatment of 45° C in whole form gives the highest yield of 8.19%. In the study by Yanty and Siska (2017), the yield percentage of red dragon fruit skin whole form produced during drying was 8.25%. The higher the temperature used in the drying process, the lower the percentage of yield produced. According to Naibaho *et al.* (2012), the higher the drying temperature, the greater the amount of water that evaporates on the material's surface. The evaporation causes the weight of the material to decrease, so the yield obtained also decreases. The yield in powder form was lower than the yield in whole form, and this was thought to be due to the sieving process, which causes some materials not to pass the sieving so that it can reduce the final weight of the red dragon fruit skin powder produced (Naibaho *et al*., 2021).

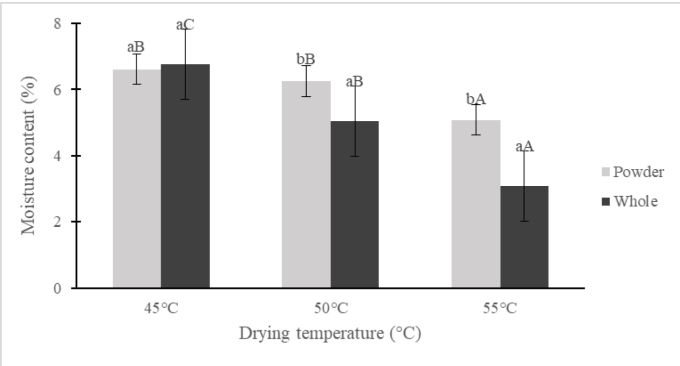

Figure 2. The moisture content of red dragon fruit skin herbal drink.

3.2 Moisture content

The water content of food can affect the final product yield and its shelf life because water content is one of the most important characteristics of food. If the water content is high, bacteria, yeast, and mold can breed quickly, which can cause changes in food ingredients (Wulansari, 2018). The water content produced in this study ranged from 3.09 – 6.76% (Figure 2). The drying treatment at 55°C in whole form produces the lowest moisture content

The highest water content was obtained in whole form samples at a drying temperature of 45°C, which

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was 6.76%. The higher the drying temperature, the more water content in the dragon fruit skin is evaporated, resulting in a lower water content in the dried dragon fruit skin. This is based on the research by Aiyuni *et al*. (2017), who reported that the higher the drying temperature, the more water molecules evaporate.

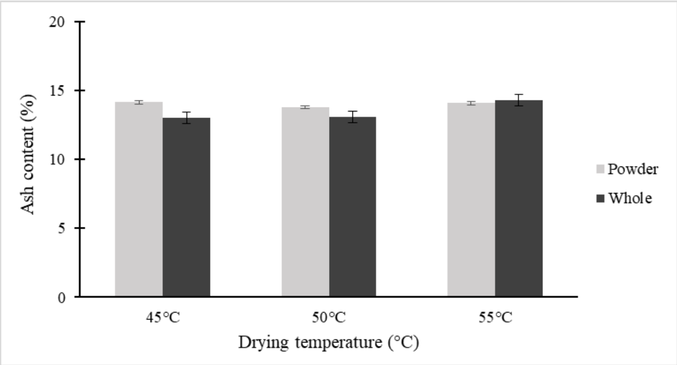

Figure 3. Ash content of red dragon fruit skin herbal drink.

3.3 Ash content

The ash content of red dragon fruit skin herbal drink ranged from 13.00% to 14.30% (Figure 3). The treatment and interaction of drying temperature and dosage form did not significantly affect the ash content of the red dragon fruit skin herbal drink.

The highest ash content was obtained at a drying temperature of 55°C in whole form which was 14.30%. The high ash content in red dragon fruit skin herbal drinks is due to the high mineral content in red dragon fruit skin. The ash content in food ingredients indicates the amount of minerals contained in the food ingredients (Smith *et al*., 2023). Purnomo *et al*. (2016) reported that dried dragon fruit skin has a total ash content ranging from 12.72% -15.45% (w/w). The red dragon fruit skin contains ash between 16 and 21%. Dragon fruit skin also has a mineral content of 1.82% calcium and phosphorus of 0.00208% (Daniel *et al*., 2015).

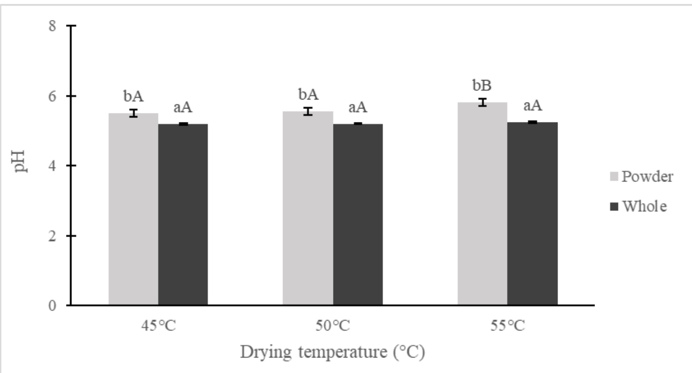

Figure 4. pH of red dragon fruit skin herbal drink.

3.4 pH

The pH value is used to determine the acidity or alkalinity of a product. The pH values of the herbal drink made from red dragon fruit skin ranged from 5.19 to 5.81 (Figure 4). Increasing the drying temperature can raise the pH value in whole form and powder.

The highest pH value was obtained at a drying temperature of 55°C in powder form, which was 5.81, while the lowest was obtained at a drying temperature of 45°C and 50°C in the form of whole form, which was 5.19. The red dragon fruit skin has a pH value of 5.06 (Jamilah *et al*., 2011). The higher the pH value, the lower the acidity level of a product, while the lower the pH value, the higher the product's acidity. Generally, food ingredients' pH values ranged from 3 to 8.

3.5 Color analysis

Color analysis aims to determine the color changes in herbal drinks made from red dragon fruit skin dried at different temperatures in powder and whole forms. The color analysis involves three main parameters: L*, a*, and b*.

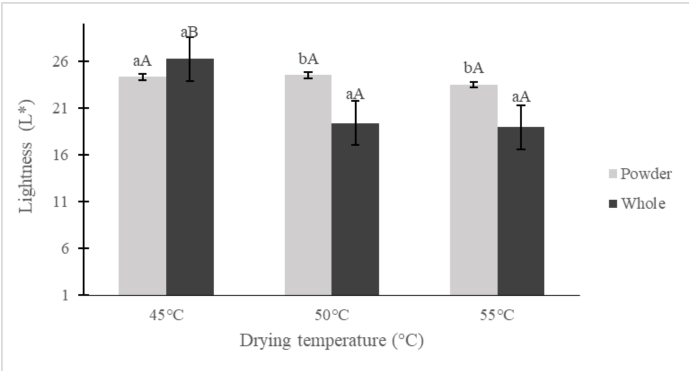

Figure 5. Lightness (L*) of red dragon fruit skin herbal drink.

Figure 5 shows that the L* value ranged from 18.94 to 26.23. The highest L* value was obtained at a drying temperature of 45°C using whole form, which was 26.23. The whole form dried at a temperature of 55°C obtained the lowest L* value of 18.94. The drying treatment at 45°C in whole form produces the highest L* color value. A decrease in the L* color value or brightness level indicates that the dried red dragon fruit skin sample undergoes a color change, becoming darker due to the increased drying temperature. The increase influenced the decrease in the L* value in drying temperature (Hartanto *et al*., 2021).

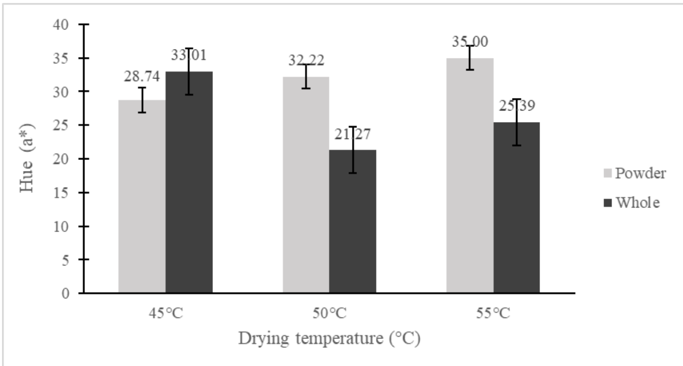

Figure 6. Hue (a*) of red dragon fruit skin herbal drink.

Figure 6 shows that the a* value ranges from 21.27 to 35.00. The A* color value in all treatments was positive, indicating that the dried red dragon fruit skin tended to have a reddish color. The highest a* value was obtained in the treatment of drying temperature 55°C in powder form, which was 35.00. This result suggests that the higher the drying temperature, the higher the A* value produced. All treatments showed a positive a* value, meaning the sample tends to be red due to the betacyanin content in red dragon fruit skin. The redness increases concurred with the results obtained by Nurbaya *et al*. (2018), who reported that the reddish value (a+) indicates a high betacyanin content.

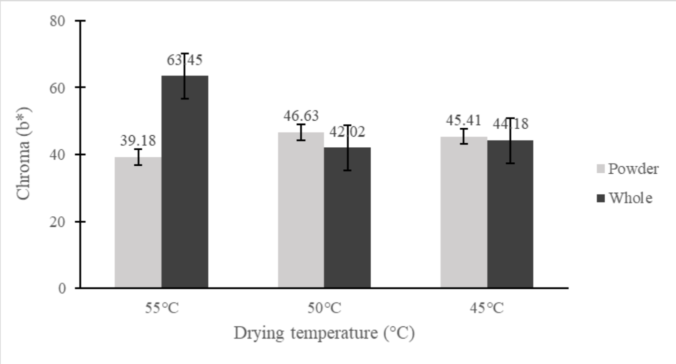

Figure 7. Chroma (b*) of red dragon fruit skin herbal drink.

Figure 7 shows that the b* value ranged from 39.18 to 63.045. The b* color value in all treatments was positive, indicating that the red dragon fruit skin had a yellowish hue. The powder treatment showed a drying temperature of 50°C, with a b* value higher than those at 45°C and 55°C. The whole form treatment with a drying temperature of 50°C decreased the b value. The highest b* value was obtained at a drying temperature of 45°C in whole form, which was 63.45, while the lowest b* value was obtained at a drying temperature of 45°C in powder form, which was 39.18.

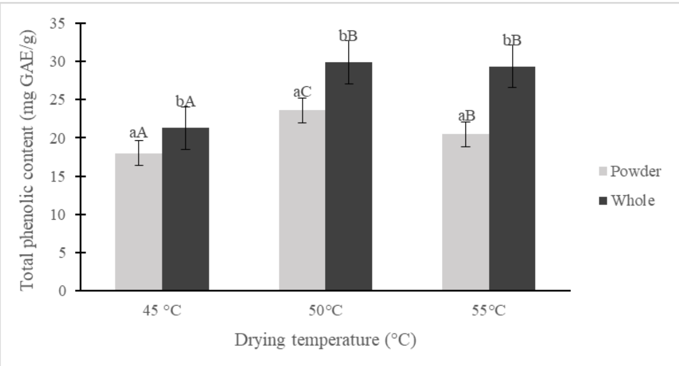

Figure 8. Total phenolic content of red dragon fruit skin herbal drink.

3.6 Total phenolic content

Figure 8 shows the total phenols produced in this study, ranging from 18.01 mg GAE/g to 29.90 mg GAE/g. The whole form has a higher total phenol content than the powder form at each drying temperature treatment. At 50°C, the highest total phenol content was 29.90 GAE/g. The total phenol content decreased slightly at 55°C, but this decrease did not show a significant difference. In the powder form treatment, the highest total phenol content was obtained in samples with a drying temperature of 50°C (23.60±1.86 mg GAE/g). An increase in the total phenol content of red dragon fruit skin infusion occurs at a drying temperature of 50°C. However, at 55°C, a decrease in total phenol content was observed. The decrease in phenolic content at 55°C was likely due to the degradation of phenolic compounds at high temperatures (Quan *et al*., 2024).

High temperatures lead to greater inactivation of the polyphenol oxidase enzyme, reducing its activity and minimizing phenol degradation. However, excessively high drying temperatures can also disrupt phenol stability. As a result, the detected total phenol content initially increases until it reaches a peak, then stabilizes and tends to decline. Higher drying temperatures generally increase phenolic compounds, which is valid for quinoa seed and lemon waste samples (Multari *et al*., 2018; Patrón-Vázquez *et al*., 2019). However, excessive heat can cause degradation, as in some studies where phenolic content decreased at high temperatures (Moreno *et al*., 2018; Turkiewicz *et al*., 2021).

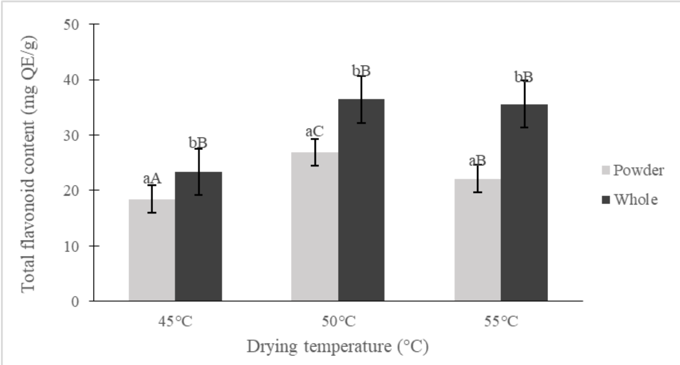

Figure 9. Total flavonoid of red dragon fruit skin herbal drink.

3.7 Total flavonoid content

Figure 9 shows that the total flavonoids of the red dragon fruit skin herbal drink infusion ranged from 18.43 to 36.45 mg QE/g. The highest total flavonoids were obtained at a drying temperature of 50°C in whole form, 36.45 mg QE/g. The total flavonoid content in the infusion of red dragon fruit skin herbal drink increases at a drying temperature of 50°C but decreases at 55°C. This indicates that a temperature of 50°C was more effective in preserving flavonoid content, especially in the whole form.

Studies suggest that lower drying temperatures, such as 50°C, can help retain more bioactive compounds compared to higher temperatures. For instance, drying at 50°C for 3 hours resulted in a relatively high retention of polyphenols (Nguyen and Ha, 2021). At a drying temperature of 55°C, there was a decrease in total flavonoids in both powder and whole form. An increase in drying temperature can reduce the total flavonoid content in red dragon fruit skin, which means that higher temperatures can damage components that are sensitive

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to heat (Quan *et al*., 2024; Tran *et al*., 2024). A drying temperature that is too low prevents total flavonoids from reaching the optimal point for inactivating the polyphenol oxidase enzyme, while a high drying temperature results in lower total flavonoid content. The decline in flavonoid compounds due to high drying temperatures leads to molecular structure damage, including oxidation or chemical bond breakage, ultimately reducing their content (Syafrida *et al*., 2018).

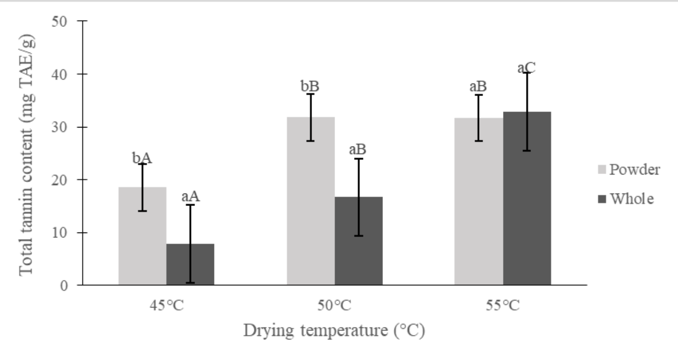

Figure 10. Total tannin of red dragon fruit skin herbal drink.

3.8 Total tannin content

Total tannins obtained in the infusion of dragon fruit skin herbal drink ranged from 7.83 to 32.88 mg TAE / g. Based on Figure 10, the treatment of the form of whole form shows an increase in total tannins along with an increase in drying temperature. While the treatment of powder form with a drying temperature of 45°C and 50° C shows an increase in total tannins, but at a drying temperature of 55°C, the decrease did not show a significant difference. The highest total tannins were obtained for the whole form sample at a drying temperature of 55°C, 32.88 mg TAE / g.

The total tannin content in the infusion of red dragon fruit skin increases with rising drying temperatures. The higher the drying temperature, the more tannins are extracted. The high tannin content is influenced by the percentage reduction in moisture content. However, excessively high temperatures are not recommended, as tannins are not resistant to excessive heating (Yuliani *et al*., 2023). Though drying temperature affected the tannin content in dragon fruit peel tea, specifically an increase in drying temperature generally led to an increase in total tannins, this trend did not hold true at all temperatures, as seen in the powdered form at 55°C, where no increase in tannins was observed (Ilmannafian *et al*., 2024).

3.9 Antioxidant activity

Ferric reducing antioxidant power (FRAP) ranged from 8.56 ml.mol/l to 47.29 ml.mol/l (Figure 11). The FRAP value increases with rising drying temperatures, with the highest FRAP value observed at a drying temperature of 55°C in the whole form, reaching 47.29 mol Fe^{2+}/g, while the lowest FRAP value was obtained at a drying temperature of 45°C in powder. The powder form treatment did not show any significant effect between drying temperatures, while the whole form showed a significant effect between drying temperatures. The whole form consistently had a higher FRAP value than the powder at all temperature levels tested, with a very significant difference

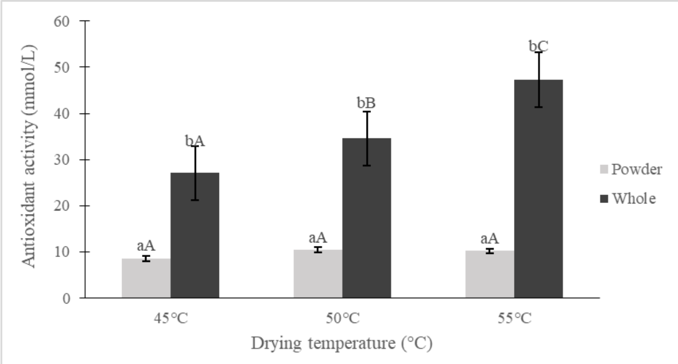

Figure 11. Antioxidant activity of red dragon fruit skin herbal drink.

The drying process and technique can influence the quality and antioxidant activity of natural materials. Antioxidant activity is affected by drying temperature, where an optimal temperature helps preserve antioxidant content, while excessively high temperatures can degrade heat-sensitive antioxidants (Sidoretno and Fauzana*,* (2018). The antioxidant activity in the whole form is higher than in the powdered form due to the heat generated during the grinding process. Antioxidant compounds are easily damaged by heat, as heat accelerates oxidation. This process reduces the antioxidant's ability to donate electrons and neutralize free radicals (Patras *et al.,* 2010).

The antioxidant activity in the infusion of red dragon fruit skin is relatively high due to its antioxidant content, which includes alkaloids, tannins, flavonoids, and steroids. Yuliawati *et al*. (2022) reported that the antioxidant activity of dragon fruit skin extract produced using the mesmerization method was 30.40 mg Trolox/g sample, and dragon fruit skin extract using the UAE method was 15.72 mg Trolox/g sample (Yuliawati *et al*., 2022).

Conclusion

Treatment of drying temperature and dosage form significantly affected the yield, water content, pH, L* color value, total phenol, total flavonoid, total tannin, and antioxidant activity of red dragon fruit skin herbal drinks. Drying at low temperatures tends to maintain water content and yield, while high-temperature drying tends to increase the content of bioactive compounds. The whole form shows better stability to temperature changes than the powder form, making it more effective in maintaining the content of functional compounds such as phenol and flavonoids and antioxidant activity. This study provides insights into the development of functional food by utilizing red dragon fruit skin waste to create an antioxidant-rich herbal drink while minimizing nutrient loss during food processing.

Conflict of interest

The authors declare no conflict of interest.

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