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Enhancing the functional beverage qualities of *teter* leaf (*Solanum erianthum*) with various drying temperatures

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Abstract. *Putra IGAM, Dewi PJN, Yuarini DAA, Braja IWRS, Saraswati IGAKW, Kartika DP. 2026. Enhancing the functional beverage qualities of* teter *leaf (*Solanum erianthum*) with various drying temperatures. Asian J Agric 10 (1): g100183. https://doi.org/10.13057/asianjagric/g100183.* *Teter* plant (*Solanum erianthum*) is cultivated and widely available in Taro Village, Bali, Indonesia, and its leaves have been known for their bioactive compounds with health benefits. Traditionally, the leaf is processed by the local community into *loloh don teter*, a herbal beverage prepared without preservatives with a short shelf life. To enhance stability and functional potential, this study developed *teter* leaf herbal tea and evaluated the effect of drying temperature on its chemical and sensory characteristics. A Completely Randomized Design (CRD) was used with four drying temperatures (40, 50, 60, and 70°C) for 24 h, with four replications; a total of 16 experimental units. The parameters analyzed included yield, moisture content, antioxidant activity (DPPH), total phenols, tannins, flavonoids, vitamin C, and sensory attributes (color, aroma, taste, and overall acceptance). Data were analyzed using Analysis of Variance (ANOVA) followed by Tukey's post hoc test (α=0.05). Drying temperature had no substantial effect on yield but significantly influenced moisture content, antioxidant activity, total phenols, tannins, flavonoids, vitamin C, and overall sensory acceptance. *Teter* leaf dried at 50°C (T2) produced the best quality. It was evident from the stable panelist preference scores in the neutral category for color (3.41), aroma (3.36), taste (3.23), and overall acceptance (3.27). The T2 sample showed the best performance across various parameters, with a primary focus on 19.49% yield, 8.60% moisture content, 85.55% antioxidant activity, total phenols at 40.72 mg GAE/g, tannins at 0.80 mg TAE/g, flavonoids at 28.76 mg QE/g, and vitamin C at 8.13 mg AAE/g. In conclusion, drying at 50°C represents an optimal processing condition that preserves bioactive compounds and maintains acceptable sensory quality, supporting the development of *teter* leaf herbal tea as a stable functional beverage with high antioxidant potential.

Keywords: Antioxidant activity, drying temperature, functional beverage, herbal tea, *Solanum erianthum*

INTRODUCTION

Teter plants (*Solanum erianthum*) are cultivated in Taro Village, Bali, Indonesia, and are known to contain bioactive compounds with health benefits, particularly in their leaves. The leaf contains various bioactive compounds, including phenolics, flavonoids, tannins, and vitamin C (Alawode et al. 2017). Increasing the phenolic content of a material generally enhances its antioxidant capacity, as phenolic compounds act as bioactive molecules that donate electrons or hydrogen atoms to neutralize free radicals. (Djebali et al. 2023; Mohanty et al. 2024). A previous study reported that *teter* leaf extract contains 175.151 mg GAE/g of phenols, 12.30 mg TAE/g of tannins, 82.60 mg QE/g of flavonoids, and 82.30 mg AAE/g of vitamin C (Putra et al. 2021). A decoction of *teter* leaf is traditionally used as a diuretic and for the treatment of leprosy, and sexually transmitted diseases, as well as to stimulate liver function (Babalola et al. 2016).
Teter leaves are traditionally used to prepare *loloh*, a herbal beverage believed to enhance immunity and relieve ailments such as internal heat and headaches. *Loloh don teter* contains 0.86 mg GAE/100 mL total phenols, 26.39 mg/100 mL vitamin C, and 47.05% antioxidant activity (Braja et al. 2021). *Loloh don teter* is prepared without preservatives, resulting in a short shelf life. This limitation prompted the development of *teter* leaf herbal tea as a more stable product. Unlike conventional tea from *Camellia sinensis*, herbal tea is produced from medicinal plant materials, such as leaves, seeds, roots, flowers, or fruits,

and is valued for its health-promoting properties (Amrute et al. 2025). Based on previous studies, the extract of *Terminalia prunioides* fruit herbal tea contains phenolic compounds ranging from 8184.304-12,319.880 mg GAE/g (Mosii et al. 2023). *Terminalia prunioides* fruit herbal tea has high antioxidant activity due to the ability to scavenge DPPH radicals (IC_{50}=0.1600±0.0489 μg/mL). Bioactive components are sensitive to high temperatures. Therefore, appropriate processing methods are used to minimize damage and preserve the components in herbal tea.

Drying is a key step in herbal tea processing that reduces leaf moisture, extends shelf life by inhibiting microbial, enzymatic, and oxidative deterioration (Rumicha et al. 2025). Improper drying temperatures can degrade bioactive compounds through thermal degradation, oxidation, and the loss of volatile compounds, thereby reducing their retention (ElGamal et al. 2023; Santos et al. 2025). Consequently, each ingredient has a different drying temperature to avoid unnecessary loss. A study on dried mint leaf herbal tea bags at 50°C for 2 hours produced an antioxidant activity of 54.55% and total phenols of 6.50 mg GAE/g (Sucianti et al. 2021). A study by Gultom et al. (2023) showed that matoa fruit peel herbal tea dried at 90°C for 3 hours had the highest antioxidant content, namely 61.74%. However, drying at 50°C for red dragon fruit peel herbal tea is the most effective condition for maintaining total phenolic content (92.5±2.1 mg GAE/g) and total flavonoid content (34.7±1.8 mg QE/g), while drying at 55°C produced the highest antioxidant activity (47.29±5.78 mmol Fe^{2+}/g) (Rohmah et al. 2025).

Moderate drying temperatures (40-50°C) were hypothesized to better preserve bioactive compounds and antioxidant activity in *teter* leafherbal tea while maintaining acceptable sensory properties, compared with higher temperatures (60-70°C). Studies on the effects of drying temperature on the bioactive compounds and sensory properties of *teter* leaf herbal tea remain limited. Most previous research has focused on extracts, traditional preparations, or other plant materials, leaving the optimal drying conditions for *teter* leaf herbal tea largely unexplored. Therefore, this study aimed to determine the optimum drying temperature to preserve bioactive compounds, maintain high antioxidant activity, and produce herbal tea with desirable sensory characteristics, thereby enhancing its potential as a functional beverage.

MATERIALS AND METHODS

Time and place

This study was conducted at the Laboratory of Food Processing and Analysis, Faculty of Agricultural Technology, Universitas Udayana, Indonesia. It was carried out from April to June 2024.

Materials and tools

The materials used in this study were *teter* leaves that were free of physical defects. The leaf was characterized by a dark green color, specifically the third to ninth from the top. The samples were collected from Taro Villages, Gianyar Regency, Bali Province, with relatively high humidity and rainfall, at an altitude of approximately 600-750 m above sea level. A representative image of the fresh *teter* plants leaves used as the plant material in this study is presented in Figure 1.

The chemicals used included distilled water (Rofa, Indonesia), Folin-Ciocalteu reagent (Merck, Germany), concentrated HCL (Merck, Germany), 5% $NaNO_2$ (Merck, Germany), 4% NaOH (Merck, Germany), Na_2CO_3 (Merck, Germany), Folin-Denis reagent (Merck, Germany), sulfuric acid (Merck, Germany), sodium phosphate (Merck, Germany), ammonium molybdate (Merck, Germany), DPPH pro analysis (Sigma-Aldrich, USA), sodium carbonate (Merck, Germany), 10% $AlCl_3$ (Phyfo Technology Laboratories, USA), quercetin (Sigma-Aldrich, USA), and gallic acid (Sigma-Aldrich, USA). Meanwhile, the tools used were measuring cups (Pyrex), a food dehydrator (Getra ST-02), an analytical balance (Shimadzu), a blender (Philips), a spatula, a stirrer, filter paper, a glass, test tubes (Pyrex), tweezers, beakers (Pyrex), a knife, a 40-mesh sieve, a tablespoon, and tea bags.

Procedures of the study

Sample preparation

Fresh, mature *teter* leaves from the third to ninth from the top were picked in the morning to reduce respiration, then sorted to select the intact leaves. Stems and any damaged portions were discarded. The selected leaves were cleaned to remove surface dirt and then cut (Putra et al. 2021).

Steaming (enzyme inactivation)

Steaming was performed at 70°C for 2 minutes. The steamed samples were then cooled at room temperature for 5 minutes before further processing (Aprilia et al. 2020).

Drying

Drying was carried out at 40, 50, 60, and 70°C for 24 hours using a food dehydrator (GETRA ST-02) with a 1500-W heating system, with 4 replications, following the modified procedure previously used by Putra et al. (2025). Each treatment weighed 100 g. The dried *teter* leaf was crushed in a blender. sieved through a 40-mesh sieve to obtain herbal tea powder, then weighed at 2 g and packaged in a 6.5 cm × 5.5 cm bag to produce a tea bag product.

Figure 1. *Teter* leaves (*Solanum erianthum*)

Variables of the study

The variables observed in this study included the analysis of moisture content (Fikriyah and Nasution 2021), antioxidant activity (Shah and Modi 2015), and total phenol (Rahmawati and Kaswati 2023) using the gravimetric, DPPH, and modified Folin-Ciocalteu methods, respectively. Additionally, sensory tests were conducted using the hedonic method to assess characteristics such as color, aroma, taste, and overall acceptance (Lawless and Heymann 2010). *Teter* leaf herbal tea has considerable potential for advancement as a functional beverage, owing to its high content of bioactive components, including flavonoids, tannins, and vitamin C, which contribute to significant health-promoting properties, particularly as a potent antioxidant.

Yield

The yield of *teter* leaf herbal tea was calculated according to a previous study (Putra et al. 2024) using the following equation:

$$\text{Yield (\%)} = \frac{\text{weight of sample after drying (g)}}{\text{weight of sample before drying (g)}} \times 100\%$$

Moisture content

The moisture content of *teter* leaf was determined using a modified gravimetric method (Fikriyah and Nasution 2021) with 4 replications. Two grams of the sample were placed in a weighed aluminum dish, dried at 105°C for 4 hours, then placed in a desiccator for 15 minutes, and weighed. After obtaining the first weighing result, the dish containing the sample was dried for an additional 30 minutes. The sample was subsequently placed in a desiccator for 15 minutes and weighed. This procedure was repeated until a stable weight was achieved, showing equilibrium moisture (±0.001g). The reduction in sample weight was the moisture content, which was calculated using the following equation:

$$\text{Moisture content (\%)} = \frac{\text{weight of sample before drying (g)} - \text{weight of sample after drying (constant) (g)}}{\text{weight of sample before drying (g)}} \times 100\%$$

Antioxidant activity

Antioxidant activity was analyzed using a modified 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Shah and Modi 2015) with 4 replicates. 0.05 g of the sample was diluted with methanol in a 10 mL volumetric flask, and centrifuged for 10 minutes. 0.004 g of DPPH crystals was dissolved in 100 mL of methanol p.a. Then, 50 µL of the sample was added to 450 µL of methanol, followed by the addition of DPPH solution in a 1:1 ratio in a test tube, and the mixture was incubated at room temperature for 30 minutes. The absorbance was measured by UV-Vis spectrophotometry at 517 nm, and the antioxidant activity of the sample was determined based on the percentage of free radical inhibition, which was calculated using the following equation:

$$\text{Inhibition (\%)} = \frac{\text{Absorbance (blanko)} - \text{Asborbance (sampel)}}{\text{Absorbance (blanko)}} \times 100\%$$

Total phenol

The determination of total phenolic content was performed using a modified Folin-Ciocalteu method (Rahmawati and Kaswati 2023) with 4 repetitions. 0.05 g of the sample was diluted to 200 µL with methanol in a 10 mL tube. Then, 400 µL of Folin-Ciocalteu reagent was added. The mixture was left to stand for 5 minutes. The solution was mixed with 4.2 mL of Na_2CO_3, vortexed, and incubated for 30 minutes. The absorbance was measured at 760 nm using a UV-Vis spectrophotometer. The total phenol concentration was quantified by comparison with a standard curve of gallic acid (0, 100, 200, 400, 600, 800 ppm), yielding a calibration equation of y = 0.0012x + 0.0571 and a coefficient of determination (R^2) of 0.9915. The standard preparation procedure was carried out using the same process as the sample. The total phenol content in the sample is expressed in mg GAE/g, calculated using the following equation:

$$\text{Total Phenol (mg GAE/g)} = \frac{C \times V \times FP}{W\ (g)}$$

Where:

C: Sample concentration from linear regression results (mg/L)

FP: Dilution factor

V: Sample volume (L)

W: Sample weight (g)

Total tannin

The total tannin content of the herbal tea leaf was determined using the Folin-Denis method (Suhardi 1997) with 4 repetitions. A 0.1 g sample was diluted in 5 mL of hot distilled water, and a 0.25 mL aliquot of the solution was transferred into a test tube. It was followed by the addition of Folin-Denis reagent (0.25 mL), vortexing, and combining with 2 mL of 5% Na_2CO_3 solution. The reaction mixture was incubated for 30 minutes, and absorbance was measured at 725 nm using a spectrophotometer. The tannin concentration was quantified by comparison with a standard curve of tannic acid (0, 5, 10, 20, 30, 40, 50 ppm), yielding a calibration equation of y = 0.0183x + 0.0486 and a coefficient of determination (R^2) of 0.9912. The standard preparation procedure was carried out using the same process as the sample, while total tannin content was calculated using the equation:

$$\text{Total Tannin (mg TAE/g)} = \frac{C \times V \times FP}{W\ (g)}$$

Where:

C: Sample concentration from linear regression results (mg/L)

FP: Dilution factor

V: Sample volume (L)

W: Sample weight (g)

Total flavonoids

The total flavonoid content was determined using the $AlCl_3$ method through spectrophotometric analysis (Singh et al. 2012), with 4 repetitions. A 0.1 g sample was weighed and diluted to 5 mL with 70% ethanol. Subsequently, 1 mL of the diluted sample was mixed with

4 mL of distilled water, followed by the addition of 0.3 mL of 10% $NaNO_2$ solution, and the mixture was incubated for 5 minutes. Approximately 0.3 mL of 10% $AlCl_3$ solution and 2 mL of 1% NaOH solution were added. The absorbance of the resulting mixture was measured at 510 nm using a spectrophotometer. The results were compared with the quercetin standard curve (0, 100, 200, 400, 600, 800 ppm), forming a calibration curve with the equation y = 0.0011x + 0.0376 and a coefficient of determination (R^2 = 0.9937). The standard preparation procedure was carried out using the same process as the sample, and total flavonoids were calculated using the equation:

$$\text{Total Flavonoids (mg QE/g)} = \frac{C \ x \ V \ x \ FP}{W \ (g)}$$

Where:
C: Sample concentration from linear regression results (mg/L)
FP: Dilution factor
V: Sample volume (L)
W: Sample weight (g)

Vitamin C

The total vitamin C content was determined using a spectrophotometer with 4 repetitions (Vuong et al. 2014). 0.1 g of the material was dissolved in 5 mL of distilled water to obtain a homogeneous solution. It was followed by the addition of 3 mL of reagent (a mixture of 500 mL of 0.6 M sulfuric acid, 5.3128 g of sodium phosphate, and 2.471 g of ammonium molybdate) to 0.3 mL of the sample solution. The resulting mixture was incubated in a water bath at 95°C for 90 minutes. The solution was cooled in water for 5 minutes, and the absorbance was measured at 695 nm using a spectrophotometer. The results were compared with the ascorbic acid standard curve (0; 20; 40; 60; 80; 100; 150; 200; 250 ppm), yielding a calibration curve with the equation y = 0.0041x - 0.0149 and a coefficient of determination (R^2) of 0.9974. The standard preparation procedure was carried out using the same process as the sample. The total vitamin C content was expressed as ascorbic acid equivalents (mg AAE/g extract) and calculated using the following equation:

$$\text{Vitamin C (mg AAE/g)} = \frac{C \ x \ V \ x \ FP}{W \ (g)}$$

Where:
C: Sample concentration from linear regression results (mg/L)
FP: Dilution factor
V: Sample volume (L)
W: Sample weight (g)

Table 1. Hedonic test criteria

Criteria	Scale
Liked	5
Slightly Like	4
Neutral	3
Slightly Disliked	2
Disliked	1

Sensory evaluation

Sensory evaluation includes hedonic testing to determine panelists' preference for the parameters being tested (color, aroma, taste, and overall acceptance) (Lawless and Heymann 2010). It was conducted by 30 semi-trained panelists, aged 20-25 years, with a 60%: 40% split of women to men, who had received sensory evaluation training. The testing was conducted by asking the panelists to rate their individual preferences for the herbal tea product prepared from *teter* leaf using the established hedonic scale. The panelists were given 4 cups of herbal tea samples with 4 separate treatments, each with a different number during the testing process to ensure blinding to the sample treatments, thereby maintaining the objectivity of the hedonic evaluation and reducing potential bias. The hedonic test criteria and numerical scales for color, taste, aroma, and overall acceptance are shown in Table 1.

Data collection

Experimental design

The data collection in the study included direct experiments. The experimental design was a simple Completely Randomized Design (CRD) with four levels of drying temperature as the treatment.

The levels of treatment in this design are as follows:
T1: Drying temperature 40°C
T2: Drying temperature 50°C
T3: Drying temperature 60°C
T4: Drying temperature 70°C

Each level of treatment was repeated 4 times, forming 16 experimental units with treatment allocation randomly assigned to minimize bias. These units were evaluated based on the observed parameters and subjected to statistical data analysis.

Statistical analysis

Data validation was performed through normality and homogeneity analysis using the Shapiro-Wilk and Levene's test. Statistical analysis of normally distributed, homogeneously distributed data ($P>0.05$) was performed using Analysis of Variance (ANOVA) in RStudio. During the detection of a significant treatment effect ($P<0.05$), Tukey's post hoc test was conducted at the 95% confidence level to determine differences in means among treatments.

RESULTS AND DISCUSSION

Evaluation of the acceptance of sensory and characteristics of *teter* leaf herbal tea

The results of the sensory evaluation of *teter* herbal tea are presented in Table 2. It showed that drying temperature had no significant effect ($P>0.05$) on color, aroma, and taste attributes. Still, it did have a significant effect ($P<0.05$) on the overall acceptability of *teter* leaf herbal tea.

Color

The panelists' preference scores for the color of *teter* herbal tea ranged from 3.41 (Neutral) to 3.77 (Slightly Liked), and the highest average hedonic score was T4 (70°C) at 3.77 (slightly liked), while the lowest was recorded in T1 (40°C) and T2 (50°C) at 3.41 (neutral). Drying temperature plays a significant role in determining the color characteristics of tea infusions, with higher temperatures tending to produce darker coloration. This phenomenon is attributed to prolonged heat exposure during the drying process, which alters leaf pigments and promotes non-enzymatic browning reactions. Elevated temperatures can induce Maillard reactions and accelerate chlorophyll degradation, leading to the formation of brownish pigments in *teter* leaf (Yuliani et al. 2023). According to the Indonesian National Standard (SNI 4324–2014), acceptable green tea color ranges from clear to yellowish hues. The sensory evaluation results showed that the color of *teter* leaf herbal tea across all treatments remained within an acceptable range and was generally well received by panelists.

Aroma

Panelists' preferences for the aroma of herbal tea leaf ranged from 2.82 (Neutral) to 3.36 (Neutral). The highest average hedonic aroma score was observed in treatment T2 (50°C) at 3.36 (Neutral), while the lowest score was in T4 (70°C) at 2.82 (Neutral). The results of sensory tests on aroma parameters showed an average decrease in aroma intensity with increasing drying temperature of *teter* leaf. Aroma is a volatile compound that readily evaporates under certain treatments, including high-heat exposure, which can cause it to degrade (Wahyuningsih et al. 2024). The higher the drying temperature, the less distinctive the tea aroma becomes, because volatile compounds have already evaporated (Patin et al. 2018). In addition to heat exposure, aroma degradation in tea is influenced by phenolic compounds. It is supported by a study showing that the aroma of binahong leaf tea is influenced by the phenolic compounds (Langi et al. 2018). Drying at high temperatures can damage the phenolic compounds in the material, thereby increasing the risk of aroma degradation. It is consistent with the mechanism described by Schieber and Wüst (2020), which states that thermal processing can accelerate the oxidation of phenolic compounds into reactive quinones and may promote the decarboxylation of phenolic acids (e.g., ferulic acid), leading to the formation of volatile phenols such as 4-vinylguaiacol and guaiacol. Although these compounds can impart desirable aroma characteristics in certain applications, excessive concentrations are often associated with an undesirable smoky flavor in various types of foods and beverages. A previous study by Sari et al. (2020) showed that the lowest hedonic aroma was produced by tin leaf tea processed at 65°C for 6 hours.

Taste

The results showed that the scores for taste preference ranged from 2.73 (neutral) to 3.36 (neutral), indicating a neutral acceptance. The highest mean hedonic score was observed in treatment T3 (60°C), while the lowest was recorded in T4 (70°C). Variations in taste perception are primarily associated with the intrinsic chemical composition of *teter* leaf, particularly the bioactive constituents. The characteristic bitterness of *teter* leaf tea is mainly attributed to flavonoids, which are known to impart bitter and astringent sensations (Ye et al. 2022). The presence of tannins, quantified at 7.30-13.08 mg TAE/g, further contributes to bitterness through protein-binding interactions that influence oral perception (Putra et al. 2021). Higher drying temperatures may enhance sensory attributes by altering the stability and extractability of phenolic compounds. Despite the inherent bitterness, *teter* leaf herbal tea remained sensorially acceptable across all treatments.

Overall acceptance

The overall hedonic scores of the sensory evaluation for acceptance ranged from 2.82 (neutral) to 3.59 (slightly liked). The drying treatment at 40°C (T1) achieved the highest overall acceptance score (3.59), indicating that the panelists liked the product slightly. This value was not significantly different from the type obtained for treatments T2 (50°C) and T3 (60°C), which recorded respective mean scores of 3.27 and 3.39, both classified as neutral. Meanwhile, the lowest mean score was observed in T4 (70°C; 2.82), which was within the neutral category.

The combined perception of key sensory attributes, including taste, aroma, and color, influences overall sensory acceptance (Moreira et al. 2024). The results showed that panelists tended to favor *teter* leaf tea dried at 40°C. Drying at 40°C was considered effective in preserving the natural characteristics of *teter* leaf, thereby preventing excessive sensory alterations. This acceptance reflects a favorable balance among the primary sensory attributes, all of which remained within an acceptable range.

Table 2. Evaluation of the acceptance of sensory and characteristics of *teter* leaf herbal tea

Drying temperature	Color	Aroma	Taste	Overall acceptances
T1	3.41±1.03a	3.18±1.11a	3.09±1.00a	3.59±0.65a
T2	3.41±0.94a	3.36±1.15a	3.23±1.04a	3.27±0.81ab
T3	3.73±0.75a	3.14±0.87a	3.36±0.93a	3.32±0.82ab
T4	3.77±1.04a	2.82±1.34a	2.73±1.17a	2.82±1.03b

Note: T: Drying Temperature, T1: 40ºC, T2: 50°C, T3: 60°C, T4: 70°C. The same notation for the mean value in the same column shows no significant differences (P>0.05), n=4. Hedonic Test Criteria: 5: Very Liked, 4: Slightly Liked, 3: Neutral, 2: Slightly Disliked, and 1: Very Disliked

Relatively low drying temperatures are crucial for maintaining the stability of volatile aroma compounds and minimizing excessive degradation of bioactive components that contribute to taste perception (Wahyuningsih et al. 2024). Furthermore, drying at this temperature helps preserve the clarity and natural appearance of the tea infusion by limiting non-enzymatic browning reactions that can cause undesirable color darkening (Zhao et al. 2024). Preservation of aroma, taste, and color improved sensory balance and enhanced panelist acceptance, indicating that drying *teter* leaf at 40°C is a potentially optimal condition for producing herbal tea with favorable sensory quality and acceptability.

Chemical characteristics of *teter* leaf herbal tea

The results of the chemical characterization analysis of *teter* leaf herbal tea are presented in Figures 2-8. The findings showed that drying temperature did not significantly affect (P>0.05) yield; however, it did significantly affect (P<0.05) moisture content, antioxidant activity, total phenols, tannins, flavonoids, and vitamin C of *teter* leaf herbal tea.

Yield

The yields of *teter* leaf herbal tea at various heating temperatures are presented in Figure 2. The yields ranged from 18.44% to 19.78%, with treatment T1 (40°C) producing the highest (19.78%), and T4 (70°C) producing the lowest (18.44%). The yields of T2 (50°C, 19.49%) and T3 (60°C, 18.49%) were not significantly different from the other treatments. Yield is a crucial parameter due to its direct relationship to the amount of the final product. The results showed that increasing drying temperature tended to decrease the yield, although not significantly. Drying materials with uniform initial moisture content and applying drying temperatures within a relatively narrow range yield results that do not differ significantly among treatments (Mardiana et al. 2022).

Drying at high temperatures tends to reduce yield due to greater moisture reduction and partial loss of volatile compounds, indicating higher drying efficiency, as higher temperatures accelerate heat transfer and enhance water evaporation from the *teter* leaf. Lower yield values obtained at higher temperatures may therefore reflect lower residual moisture content, which is beneficial for improving product stability and extending shelf life. However, excessive drying temperatures may degrade heat-sensitive compounds and lead to the loss of desirable volatiles, potentially affecting product quality (Roslan et al. 2020). In this study, yield decreased with increasing drying temperature, but the differences were not statistically significant. The yield results suggested that the applied temperature range remained moderate, enhancing drying efficiency without causing substantial loss of product mass or quality.

Moisture content

The moisture content of *teter* leaf herbal tea at various heating temperatures is presented in Figure 3. The moisture content after the drying process ranged from 6.50% to 9.61%, with the highest value observed in treatment T1 (40°C) at 9.61%, which did not differ significantly from T2 (50°C) at 8.60%. The lowest moisture content was obtained in T4 (70°C) at 6.50%, while the initial moisture content of fresh *teter* leaf was 21.87% (Uzoekwe et al. 2021).

The decline in moisture content due to higher drying temperatures accelerates water evaporation, resulting in lower moisture levels in the material (Ariva et al. 2020). A previous study by Mardiana et al. (2022) showed that the moisture content decreased as the drying temperature increased in soursop leaf herbal tea, from 29% at 50°C to 23.9% at 60°C. Similarly, a study on ambarella (*Spondias dulcis*) leaf showed that moisture content decreased with increasing drying temperature (Ismanto et al. 2016). This phenomenon occurs due to differences in vapor pressure between the water in the leaf and the surrounding air. In general, a higher vapor pressure within the material than in the surrounding air drives moisture transfer from the material to the air. Increasing the drying temperature enhances heat absorption, intensifies convective heat and mass transfer, and accelerates surface water evaporation, thereby increasing the moisture removal rate. The moisture content values obtained in this study complied with the Indonesian National Standard (SNI 4324:2014) for green tea in tea bags, which requires a maximum moisture content of 10%.

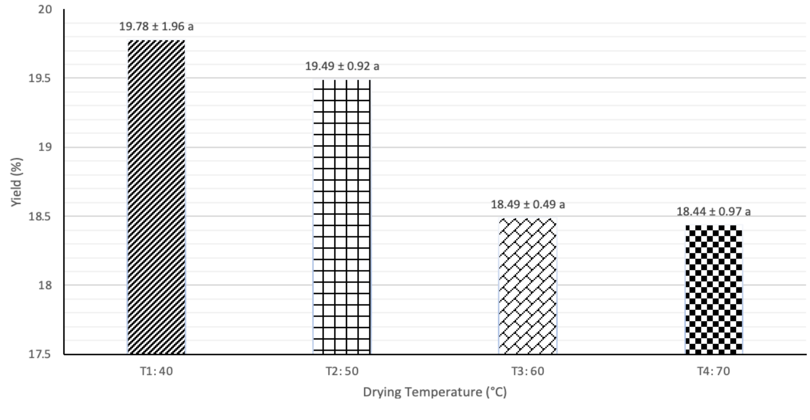

Figure 2. Yield of *teter* leaf herbal tea at various drying temperatures. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

Antioxidant activity

The antioxidant activity of *teter* leaf herbal tea from various heating temperatures is presented in Figure 4. The antioxidant activity across treatments ranged from 73.93% to 85.55%, with the highest value in t T2 (85.55%), not significantly different from T1 (84.93%), and the lowest was in T4 (73.93%). These results show that increasing the drying temperature decreases the antioxidant activity of *teter* leaf herbal tea. A study on *sambiloto* tea products reported that antioxidant activity decreased with increasing drying temperatures (Patin et al. 2018). Antioxidants become unstable when exposed to temperature changes (Putra et al. 2024); they degrade at high temperatures. Similarly, Putra et al. (2024) reported that the antioxidant activity of *takokak* leaf tea decreased as the drying temperatures increased. The degradation of bioactive components was influenced by several factors, including heat exposure, oxidation, hydrolysis, pH, enzymes, and light (ElGamal et al. 2023). Therefore, increasing the drying temperature of *teter* leaf herbal tea reduces the levels of bioactive compounds with antioxidant activity.

Total phenol

The total phenol content of *teter* leaf herbal tea at various heating temperatures is presented in Figure 5. The total phenolic content ranged from 30.11 to 41.41 mg GAE/g, with the highest value in T1 (41.41 mg GAE/g), not significantly different from treatment T2 (40.72 mg GAE/g), and the lowest in T4 (30.11 mg GAE/g. These results show that the total phenolic content in *teter* leaf herbal tea decreases with increasing drying temperature.

The phenolic content is positively correlated with antioxidant activity (Allo et al. 2022), but these compounds are heat-sensitive and prone to oxidation at high temperatures. This result is consistent with a study on green tea infusion from *Manilkara zapota* L. leaves, which showed that increasing the drying temperature decreased the phenolic content (Martha et al. 2023). A previous study by Lestari and Juwitaningtyas (2023) showed that rambutan (*Nephelium lappaceum* L.) leaves dried at 40°C for 3 hours produced herbal tea with a total phenolic content of 1.78 mg GAE/g sample, whereas drying at 60°C for 3 hours yielded only 0.66 mg GAE/g sample. These results show that increasing the drying temperature reduces the total phenolic content of herbal tea. High temperatures may degrade leaf cell walls by breaking down cellulose and proteins, and leach phenolic compounds from cells, thereby decreasing total phenolic content in the leaf (Ifadah et al. 2021).

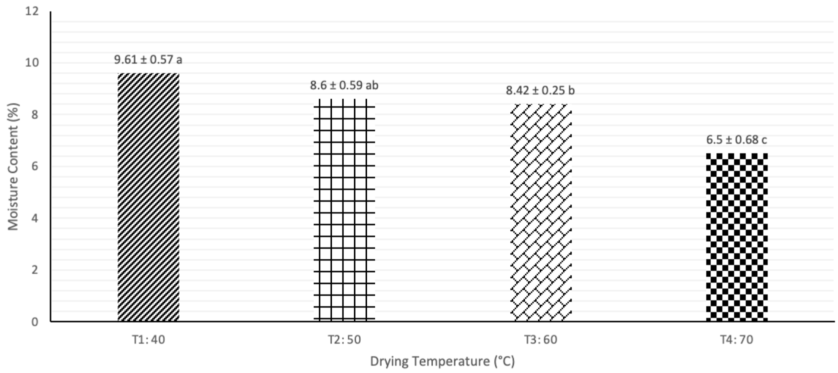

Figure 3. Moisture content of *teter* leaf herbal tea at various drying temperatures. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

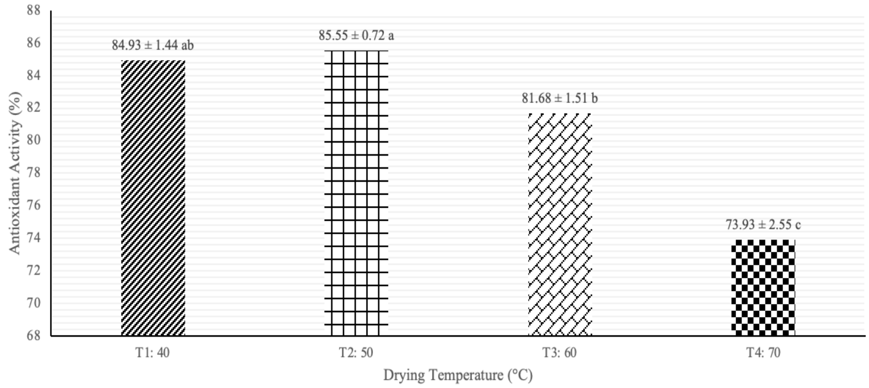

Figure 4. Antioxidant activity of *teter* leaf herbal tea at various drying temperatures. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

Tannin

The tannin content of *teter* leaf herbal tea at various heating temperatures is presented in Figure 6. The tannin content ranged from 0.69 to 1.81 mg TAE/g, with the highest value in T1 (1.81 mg TAE/g). The lowest value was in T4 (0.69 mg/g), which was not significantly different from T3 (0.72 mg/g) and T2 (0.80 mg/g).

The tannin content of *teter* leaf tea decreased with increasing drying temperature, indicating thermal degradation of heat-sensitive phenolic compounds. Tannins, as a major fraction of phenolics, are particularly prone to structural instability at elevated temperatures, leading to a reduction as drying temperature increases. This finding aligns with a previous study on *C. sinensis* (green tea), which reported a significant decrease in tannin content with increasing drying temperatures. Other studies on *Hericium erinaceus* mushrooms reported a reduction in total phenolic content, including tannins, at drying temperatures near 70°C (Juhaimi et al. 2018; Roslan et al. 2020). The same results on *teter* leaf indicated tannin degradation becomes more pronounced at temperatures close to 70°C.

Drying at high temperatures can cause physicochemical changes in phenolic compounds, such as tannins. Initial heating inactivates oxidative enzymes, but prolonged exposure can damage the tannin structure and accelerate phenolic oxidation, resulting in unstable derivatives (Chen et al. 2022). It indicated that drying temperature is a critical processing parameter that influences tannin stability in *teter* leaf tea. Excessively high drying temperatures can substantially reduce tannin content, potentially affecting both the functional and sensory qualities of the herbal tea. Therefore, careful optimization of drying conditions is essential to preserve tannin levels, maintain the bioactive content, and prevent bioactive degradation in *teter* leaf tea.

Flavonoid

The flavonoids of the *teter* leaf herbal tea at various heating temperatures are presented in Figure 7. The total flavonoid content ranged from 19.45 to 29.66 mg QE/g, with the highest value in T1 (29.66 mg QE/g), which was not significantly different from T2 (28.76 mg QE/g). The lowest value was in T4 (19.45 mg QE/g), which was not significantly different from T3 (22.09 mg QE/g). These results show that the total flavonoid content of *teter* leaf herbal tea decreases as drying temperature increases.

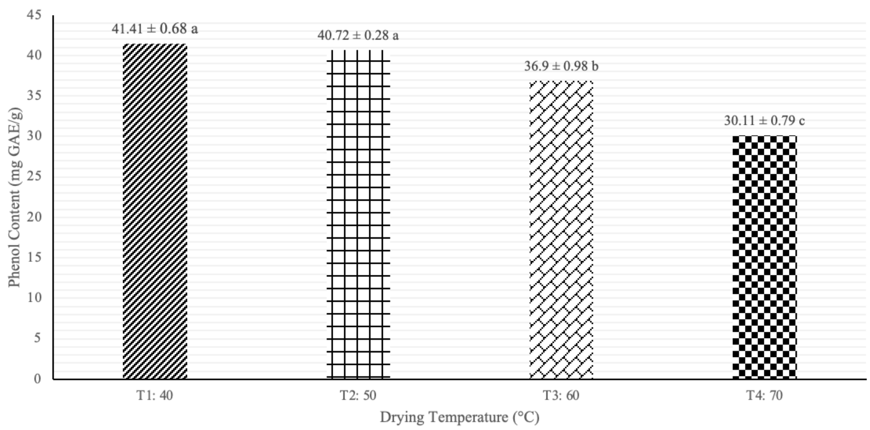

Figure 5. Total phenol of *teter* leaf herbal tea at various drying temperatures. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

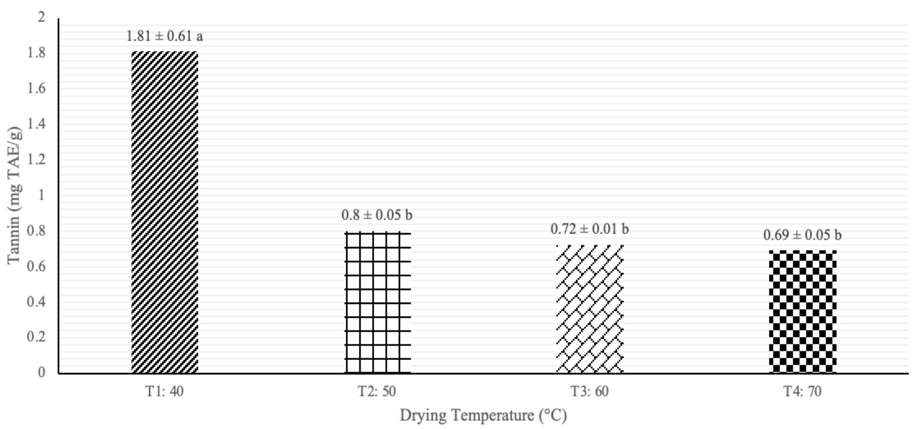

Figure 6. Tannin of *teter* leaf herbal tea at various drying temperatures. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

Flavonoids are a group of bioactive compounds widely recognized for their antioxidant and antibacterial properties. These compounds can inhibit both enzymatic and non-enzymatic oxidation reactions and exhibit antibacterial activity by interacting with microbial cell wall proteins, thereby disrupting cellular integrity (Ismanto et al. 2016). In the production of *teter* leaf herbal tea, drying at 50°C for 24 h produced a flavonoid content of 28.76 mg QE/g. It shows that moderate drying conditions are effective in retaining flavonoid compounds (Putra et al. 2025).

Processing stages such as drying during herbal tea preparation can significantly influence the stability of bioactive components, particularly flavonoids. Drying at high temperatures may induce structural damage to plant cell matrices, leading to physicochemical changes that affect flavonoid stability. Moderate heat treatment can enhance the release of phenolic compounds, including flavonoids, which are initially bound to the plant cell wall. Meanwhile, excessive thermal exposure promotes degradation reactions, such as oxidation and polymerization, leading to a net reduction of flavonoid content (Nguyen et al. 2022). This thermal sensitivity explains the observed decline in flavonoid levels with increasing drying temperature.

Vitamin C

The following are the results for vitamin C in *teter* leaf herbal tea at various heating temperatures, as shown in Figure 8. The mean vitamin C content ranged from 5.72 to 8.32 mg AAE/g, with the highest value obtained in treatment T1 (40°C) at 8.32 mg AAE/g, which was not significantly different from T2 (50°C). The lowest value was observed in T4 (70°C; 5.72 mg AAE/g), while T3 (60°C; 6.68 mg/g, AAE/g) was significantly different from all other treatments. These results show that the vitamin C content of *teter* leaf herbal tea decreases with increasing drying temperature.

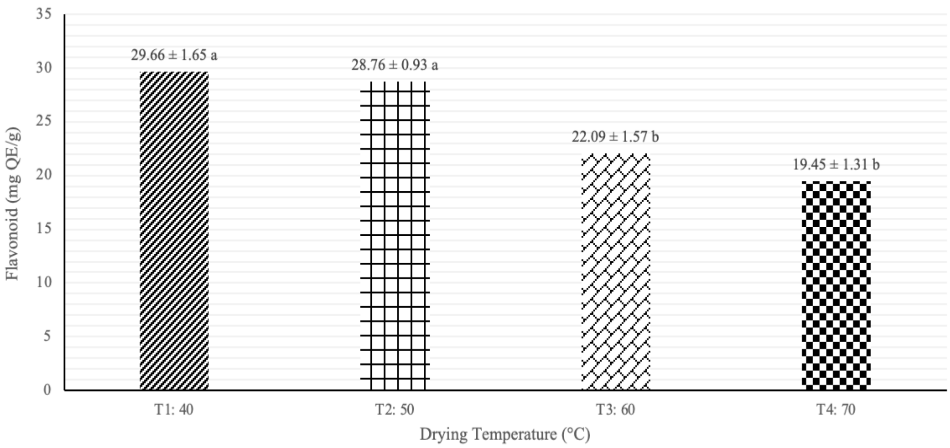

Figure 7. Flavonoids of *teter* leaf herbal tea at various drying temperatures. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

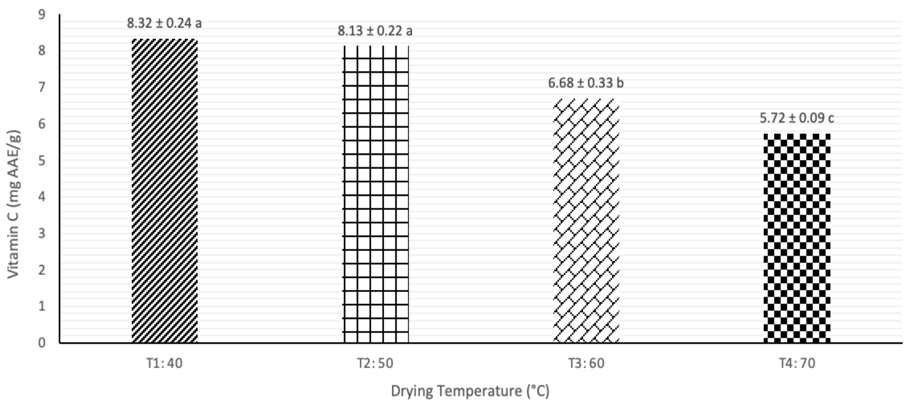

Figure 8. Vitamin C of *teter* leaf herbal tea. The same notation behind the mean value indicates that the values are not significantly different (P>0.05), n=4

Vitamin C, also known as ascorbic acid, is abundantly present in *teter* leaf. A previous study on a traditional beverage (*loloh*) prepared from *teter* leaf with tamarind added reported a vitamin C content of 26.39 mg/100 mL (Braja et al. 2021). A study by Uzoekwe et al. (2021) reported that *teter* leaf extract contains 13.11 mg/L of vitamin C, considerably higher than the levels of other vitamins such as vitamin A (3.09 mg/L), B3 (0.445 mg/L), and E (3.265 mg/L). The findings also showed that drying temperature significantly influenced the vitamin C content of *teter* leaf herbal tea, with concentrations decreasing progressively as drying temperature increased. Vitamin C is highly sensitive to heat and readily undergoes thermal degradation, which aligns with the decreasing trend observed in this study across different drying temperatures. A previous study on the drying process of moringa (*Moringa oleifera*) leaf powder showed that drying temperatures above 60°C led to substantial vitamin C degradation (Razzak et al. 2021). These results show the importance of controlling drying temperature to preserve vitamin C content and maintain the nutritional quality of *teter* leaf herbal tea.

In conclusion, *teter* leaf herbal tea represents a novel use of the *teter* (*S. erianthum* D. Don.) plant, which is abundant in Taro Village. This study showed that drying temperature had a highly significant impact on the moisture content, antioxidant activity, total phenols, tannins, flavonoids, and vitamin C of *teter* leaf herbal tea. However, drying temperature had no significant effect on yield, which ranged from 18.44% to 19.78%. The best treatment was observed at T2 (drying temperature of 50°C), with a yield of 19.49%, a moisture content of 8.60%, antioxidant activity of 85.55%, total phenols of 40.72 mg GAE/g, tannins of 0.80 mg TAE/g, flavonoids of 28.76 mg QE/g, and vitamin C of 8.13 mg AAE/g, with the sensory characteristics of the product as neutral in color (3.41), aroma (3.36), taste (3.23), and overall acceptance (3.27). Higher drying temperatures (60-70°C) consistently reduced bioactive compounds, indicating thermal degradation of heat-sensitive constituents.

Teter leaf herbal tea has strong potential to be developed as a functional food product at an appropriate drying temperature, which effectively preserves its phenolic compound content. *Teter* leaf herbal tea has strong potential to be developed as a functional food product when processed at an appropriate drying temperature, as this condition effectively preserves phenolic compounds that contribute to antioxidant activity. In addition, the product exhibited neutral sensory acceptance, indicating that it remained acceptable to the panelists. However, this study was limited to laboratory-scale drying under fixed-temperature and duration conditions, included a single harvest location, and short-term sensory evaluation. Future studies should explore the combined effects of drying time and temperature, alternative drying technologies (e.g., vacuum or infrared drying), and storage stability of the herbal tea. In addition, incorporating natural local flavoring agents will further enhance the sensory characteristics of *teter* leaf herbal tea.

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