Characterization of *Tamarindus indica* L. Leaves Herbal Tea as a Functional Beverage

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Abstract

Tamarindus indica leaves possess great potential as they are rich in antioxidants and suitable for consumption as a functional beverage. Processing *T. indica* leaves into herbal tea can enhance their usability and benefits. This study aimed to investigate the effect of drying time and temperature on the quality of *T. indica* leaves herbal tea and the antioxidant characteristics of its infusion. A Randomized Block Design (RBD) was employed with two factors: drying time (2 and 3 hours) and drying temperature (40°C, 50°C, 60°C), resulting in six treatment combinations, each replicated three times. The parameters analyzed in the tea powder included moisture content, ash content, and color intensity (L, a*, b*), while the infusion was analyzed for antioxidant activity, pH, and organoleptic properties (color, aroma, and taste). The results showed that both drying time and temperature significantly affected the moisture content, ash content, color intensity (L, a*, b*), antioxidant activity, pH, and sensory attributes. The best treatment was drying for 2 hours at 40°C, producing a tea with moisture content of 3.13%, ash content of 5.20%, color intensity L = 57.12, a* = 6.10, b* = 16.68, antioxidant activity of 8.24%, pH of 2.70, and organoleptic scores (neutral) for color (3.36), aroma (3.32), and taste (3.36).

Keywords

Tamarindus indica L. leaves, herbal tea, drying time, drying temperature, Antioxidant.

Introduction

Tamarindus indica leaves are compound leaves with long petioles and even-pinnate leaveslets, dark green to light green in color, elongated in shape, and aligned in parallel. They are rich in lipids, fatty acids, vitamins, and flavonoids, making them important dietary sources in several countries. *T. indica* leaves contain secondary metabolites such as flavonoids, saponins, tannins, and vitamins, which provide great potential for functional food and traditional medicine. Previous studies have reported their biological activities, including antioxidant, antidiabetic, anti-

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inflammatory, antihyperlipidemic, and antibacterial properties (Husain et al., 2022;Wiyono et al., 2022).

Although *T. indica* leaves—locally called *sinom*—have health benefits like the fruit, they remain underutilized as a food ingredient. Some studies have indicated their use in herbal remedies for reducing fever and stimulating appetite (Fahima et al., 2022). Processing the leaves into herbal tea increases their practicality and usability. Unlike conventional tea derived from *Camellia sinensis*, herbal teas (or tisanes) can be prepared from various plant materials. The principle of tea processing involves drying, which prevents microbial growth and biochemical changes (Yetti et al., 2022). However, improper drying time and temperature may degrade or damage bioactive compounds (Putra et al., 2025). Therefore, this study aimed to determine the effects of drying time and temperature on the quality and antioxidant characteristics of *T. indica* leaves herbal tea.

Methodology

- **Materials**

The primary material used in this study was *T. indica* L. leaves, collected from Selotambak Village, Kraton District, Pasuruan, East Java, Indonesia. The chemicals included distilled water, ethanol 96% (250 ml), DPPH (2,2-diphenyl-1-picrylhydrazyl) 0.0100 mg, ascorbic acid ($C_6H_8O_6$) 0.0100 mg, ethanol 250 ml, and 100 ml of distilled water. All reagents applied in this research were of analytical grade.

- **Preparation of *Tamarindus indica* L. Leaves Herbal Tea**

The preparation of *T. indica* leaves herbal tea was carried out with slight modifications of the method described by Sari et al. (2020). Fresh *T. indica* leaves (5 kg) were sorted, thoroughly washed, and drained. The cleaned leaves were subsequently withered and dried using a cabinet dryer. After drying, the leaves were packed for further analysis and infused in 200 ml of distilled water at 80°C.

- **Sample and Data Analysis**

Samples were characterized by physic and chemical. Physically analysis is moisture and ash content, then color analysis. Chemically analysis is pH and antioxidant activity. Next, the samples were analyzed sensory with 25 untrained panelists. The panelists were asked to evaluate the color, aroma, and taste of the herbal tea. All experimental data were analyzed statistically using analysis of variance (ANOVA) with Minitab 19 software, followed by Tukey's test at a 95% confidence level ($\alpha = 0.05$) to determine significant differences among treatments. The overall best treatment was determined using the Effectiveness Index method proposed by De Garmo (1984), as modified by Susrini (2003).

Results and Discussion

Physical Analysis

The average moisture content ranged from 3.08% to 3.13%. The highest moisture content (3.13%) was observed in the treatment with 2 hours of drying at 40°C, while the lowest value

(3.08%) was obtained at 3 hours of drying at 60°C. A longer drying duration and higher drying temperature resulted in a decrease in the moisture content of the herbal tea. This is due to the increased rate of water evaporation under prolonged exposure and elevated temperatures, leading to a lower final moisture level in the product. These findings are consistent that longer drying times reduced the moisture content of red salak peel herbal tea, as the water naturally evaporates during the drying process (Smith et al., 2024). Based on the obtained values, the moisture content of *T. indica* leaves herbal tea under all treatments met the Indonesian National Standard (SNI 3836:2013), which specifies a maximum of 8% for dried tea products.

Table 1. Moisture content, ash content, and color values (L, a, b*) of T. indicaus indica* L. leaves herbal tea

Drying Time (hours)	Temperature (°C)	Moisture Content (%)	Ash Content (%)	Color		
				L*	a*	b*
2	40	3.13±0.02^{a}	5.20±0.67^{c}	57.12±0.37^{a}	5.33±0.02^{b}	16.68±0.28^{a}
	50	3.12±0.01^{ab}	6.30±0.60^{bc}	56.13±0.20^{ab}	5.69±0.18^{ab}	16.38±0.08^{ab}
	60	3.11±0.02^{ab}	6.80±0.95^{abc}	55.17±0.67^{b}	5.84±0.02^{a}	16.18±0.07^{bc}
3	40	3.10±0.01^{ab}	5.80±0.60^{bc}	55.94±0.61^{ab}	5.63±0.40^{ab}	16.27±0.03^{ab}
	50	3.09±0.01^{b}	7.50±0.53^{ab}	55.17±0.65^{b}	5.79±0.04^{ab}	15.96±0.29^{bc}
	60	3.08±0.02^{b}	8.30±0.74^{a}	54.75±0.37^{b}	6.10±0.05^{a}	15.74±0.05^{c}

The highest ash content (8.3%) was obtained from the treatment with 3 hours of drying at 60°C, whereas the lowest value (5.1%) was recorded at 2 hours of drying at 40°C. Prolonged drying and higher drying temperatures resulted in increased ash content. According to Novelina et al. (2024), ash content is influenced by several factors, including the type of raw material, the ashing method, drying duration and temperature. Ebifa-Othieno et al. (2020) also reported that *T. indica* leaves are naturally rich in minerals, particularly potassium, phosphorus, calcium, and magnesium. Based on the results of this study, the ash content of *T. indica* leaves herbal tea met the Indonesian National Standard (SNI 3836:2013), which stipulates a maximum ash content of 8% for dried tea products—except for the treatment at 3 hours and 60°C, which slightly exceeded the standard.

The lowest brightness was observed in the treatment with 3 hours of drying at 60°C. Prolonged drying time and higher drying temperature caused a decrease in brightness values, suggesting darker tea powder. This finding is consistent with the report of Sari et al. (2018), who also found that extended drying reduced brightness values in herbal tea products. The a* values of *T. indica* leaves herbal tea ranged from 5.33 to 6.10, reflecting its degree of redness. The highest a* value (6.10) was obtained from the treatment with 3 hours of drying at 60°C, while the lowest value (5.33) was recorded at 2 hours of drying at 40°C. The increase in redness at higher drying times and temperatures may be associated with pigment changes, particularly the degradation of chlorophyll into pheophytin, which imparts a brownish tone, and the formation of the degradation of chlorophyll into pheophytin, which the formation of red-brown polyphenol pigments derived from tannin oxidation, which contribute to the reddish coloration in tea infusions (Tanaka, 2025).

- **Chemical Analysis**

The average antioxidant activity values obtained from different treatment combinations are presented in Table 2**.** The average antioxidant activity of *T. indica* leaves herbal tea under different

drying times and temperatures ranged from 8.09% to 8.24%. The highest antioxidant activity (8.24%) was obtained from the treatment with 2 hours of drying at 40°C, whereas the lowest value (8.00%) was observed in the treatment with 3 hours of drying at 60°C. As shown in Table 2, antioxidant activity decreased with longer drying times and higher drying temperatures.

Table 2. Antioxidant activity and pH of *T. indica* leaves herbal tea under different drying treatments

Drying Time (hours)	Temperature (°C)	Antioxidant Activity (%)	pH
2	40	8.24 ± 0.03^{a}	2.70 ± 0.10^{d}
	50	8.22 ± 0.06^{a}	2.80 ± 0.10^{d}
	60	8.09 ± 0.03^{ab}	2.90 ± 0.10^{cd}
3	40	8.23 ± 0.01^{a}	3.10 ± 0.10^{bc}
	50	8.21 ± 0.01^{a}	3.30 ± 0.10^{ab}
	60	8.00 ± 0.02^{b}	3.50 ± 0.10^{a}

Antioxidants are bioactive compounds that provide various health benefits, particularly in scavenging free radicals; however, their stability is often affected by temperature changes. The decline in antioxidant activity observed in this study is consistent with the findings of Juwitaningtyas & Amalia (2022), who reported that higher temperatures and longer heating durations significantly reduced the antioxidant activity of red rose herbal tea due to the degradation of active antioxidant compounds. Heat treatment promotes oxidation of bioactive components, thereby lowering antioxidant activity. Similarly, Putra et al. (2025) reported that antioxidant compounds are generally unstable when exposed to elevated temperatures, and their reduction is attributed to the oxidation of bioactive molecules. *T. indica* leaves are well known for their richness in antioxidant compounds that play an important role in protecting cells from oxidative damage caused by free radicals. Several studies have identified secondary metabolites in *T. indica* leaves are flavonoids, polyphenols, tannins, and other phenolic compounds (Muhammad Dahiru et al., 2023; Husain et al., 2022).

The average pH values across treatments, as presented in Table 2, ranged from 2.7 to 3.5. These results indicate that the tea infusions were relatively acidic. A similar finding was reported by Pandian et al. (2024), who noted that *T. indica*-based products typically exhibit low pH values, approximately 2.74, which reflects their high acidity and aligns with the characteristics of sour beverages. Furthermore, it was observed that increasing drying time and temperature led to an increase in the pH of *T. indica* leaves herbal tea infusions.

Sensory evaluation Characteristics of *T. indicaus indica* L. Leaves Herbal Tea

Table 3. Sensory evaluation (color, aroma, and taste) of *T. indica* leaves herbal tea under different drying treatments

Drying Time (hours)	**Temperature (°C)**	**Color**	**Aroma**	**Taste**
2	40	3.36 ± 0.03^{a}	3.32 ± 0.10^{b}	3.36 ± 0.10^{b}
	50	4.20 ± 0.06^{b}	3.48 ± 0.10^{a}	3.36 ± 0.10^{b}
	60	3.00 ± 0.03^{c}	3.27 ± 0.10^{c}	3.36 ± 0.10^{b}

	40	3.24±0.01[b]	3.20±0.10[b]	3.50±0.10[a]
3	50	3.48±0.01[b]	3.80±0.10[a]	3.68±0.10[a]
	60	3.00±0.02[c]	3.56±0.10[c]	3.55±0.10[a]

As shown in Table 3, the mean sensory scores for color ranged from 3.00 (neutral) to 4.20 (like). The panelists' preference increased when the drying temperature was raised from 40°C to 50°C, but decreased again at 60°C. This decline was likely due to the darkening of tea leaves at higher drying temperatures, particularly at 60°C. Panelists' acceptance may also have been influenced by changes in the a* values (Table 1), where higher drying temperatures produced more intense red hues. According to Putra et al. (2025), drying induces color changes as chlorophyll degrades into pheophytin under the influence of heat, resulting in darker tea products.

Based on Table 3, the mean sensory scores for aroma ranged from 3.27 (neutral) to 3.58 (like). The highest aroma preference was obtained from treatments at 50°C for both 2 and 3 hours, with scores of 3.58 and 3.46, respectively. In contrast, the lowest scores were observed at higher temperatures (60°C for 2 and 3 hours). Panelists preferred tea dried at 50°C, likely due to the preservation of a more pleasant aroma. Higher drying temperatures may promote the loss or alteration of volatile compounds. *T. indica* leaves are known to be rich in tannins (Arina & Harisun, 2019). catechins within tannins can oxidize into red-brown polyphenol pigments during drying, contributing to the characteristic aroma of the tea (Sari D.K. et al., 2019).

As shown in Table 3, the mean scores ranged from 3.36 (neutral) to 3.68 (like). The taste preference of tea infusions dried for 2 hours was relatively consistent across different temperatures, which may be due to the inherent bitter and sour taste of the infusion. This taste profile is attributed to the presence of bioactive compounds such as flavonoids and tannins (Devi & Boruah, 2020).

The selection of the best treatment was based on physicochemical parameters (moisture content, ash content, and color intensity), chemical attributes (pH and antioxidant activity), and sensory characteristics (color, aroma, and taste). The effectiveness index method by De Garmo (1984), modified by Susrini (2003), was used by assigning weighted values to each parameter. The treatment with the highest effectiveness index was drying for 2 hours at 40°C, which yielded the following characteristics: moisture content 3.13%, ash content 5.20%, color intensity L* = 57.12, a* = 6.10, b* = 16.68, antioxidant activity 8.24%, pH 2.70, and sensory scores of 3.36 (neutral) for color, 3.32 (neutral) for aroma, and 3.36 (neutral) for taste.

Conclusion

Drying time and temperature significantly affected the physicochemical (moisture content, ash content, color parameters L*, a*, b*), chemical (antioxidant activity and pH), and sensory (color, aroma, taste) characteristics of *T. indica* leaves herbal tea. The best treatment was obtained at 2 hours of drying at 40°C, which produced tea with favorable physicochemical and sensory attributes: moisture content 3.13%, ash content 5.20%, L* = 57.12, a* = 6.10, b* = 16.68, antioxidant activity 8.24%, pH 2.70, and sensory scores indicating neutral acceptance for color (3.36), aroma (3.32), and taste (3.36).

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