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EFFECT OF POSTHARVEST DRYING METHODS ON TOTAL FLAVONOID CONTENT, TOTAL PHENOLIC CONTENT, ANTIOXIDANT ACTIVITY, AND SENSORY ACCEPTANCE OF COFFEE MISTLETOE (*Scurrula ferruginea* [ROXB. ex JACK] DANSER) TEA

Nofrizal[1,2,*], Shinta Angelia Astharie[2], Lusia Eka Putri[2]
[1] Department of Clinical Pharmacy, Universitas Baiturrahmah, Padang, West Sumatra, Indonesia
[2] Department of Pharmacy, Universitas Dharma Andalas, Padang, West Sumatra, Indonesia

*Corresponding Email: nofrizal@fikes.unbrah.ac.id

ABSTRACT

Postharvest drying is a critical step in herbal tea processing as it affects the quality of simplicia, phytochemical content, biological activity, and sensory characteristics of the product. This study aimed to evaluate the effect of postharvest drying methods on total flavonoid content, total phenolic content, antioxidant activity, and sensory acceptance of coffee mistletoe (Scurrula ferruginea [Roxb. ex Jack] Danser) leaf tea. Coffee mistletoe leaves were dried using three different methods: sun drying, oven drying at 40°C, and room-temperature air drying. The dried samples were characterized physicochemically and analyzed for total flavonoid content ($AlCl_3$ method), total phenolic content (Folin–Ciocalteu method), and antioxidant activity using the DPPH radical scavenging assay (IC_{50}). A sensory acceptance test involving 20 panelists was conducted to evaluate aroma, color, and taste of the tea infusion. The results showed that the drying method significantly affected all evaluated parameters ($p < 0.05$). Sun drying produced the highest total flavonoid content (2.15 mmol QE/100g sample) and the highest sensory acceptance. Room-temperature drying resulted in the highest total phenolic content (51.41 mmol GAE/100g sample) and the strongest antioxidant activity with the lowest IC_{50} value (86.4 µg/mL). Oven drying was the most effective in reducing moisture content but led to the greatest losses in flavonoids, phenolics, antioxidant activity, and sensory quality. In conclusion, room-temperature drying is more suitable for maximizing antioxidant potential, whereas sun drying is preferable for producing herbal tea with better consumer acceptance.

Keywords : Antioxidant Activity, Coffee Mistletoe, Postharvest Drying, Total Flavonoids, Total Phenolics.

PENGARUH PROSES PENGERINGAN PASCAPANEN TEH BENALU KOPI (*Scurrula ferruginea* (Roxb. Ex Jack) Danser) TERHADAP KADAR FLAVONOID TOTAL, FENOLIK TOTAL, AKTIVITAS ANTIOKSIDAN DAN UJI HEDONIK

Nofrizal[1,2,*], Shinta Angelia Astharie[2], Lusia Eka Putri[2]
[1] Jurusan Farmasi Klinis Universitas Baiturrahmah, Padang, Sumatera Barat
[2] Jurusan Farmasi Universitas Dharma Andalas, Padang, Sumatera Barat

[*]Email Korespondensi : nofrizal@fikes.unbrah.ac.id

ABSTRAK

Pengeringan pascapanen merupakan tahap penting dalam pengolahan teh herbal karena memengaruhi mutu simplisia, kandungan fitokimia, aktivitas biologis, dan karakteristik sensoris produk. Penelitian ini bertujuan untuk mengevaluasi pengaruh metode pengeringan pascapanen terhadap kadar flavonoid total, kadar fenolik total, aktivitas antioksidan, dan tingkat kesukaan teh daun benalu kopi (Scurrula ferruginea [Roxb. ex Jack] Danser). Daun benalu kopi dikeringkan menggunakan tiga metode, yaitu pengeringan langsung di bawah sinar matahari, pengeringan dengan oven pada suhu 40°C, dan pengeringan suhu ruang. Simplisia yang diperoleh dikarakterisasi secara fisik dan kimia, kemudian ditetapkan kadar flavonoid total (metode $AlCl_3$), kadar fenolik total (metode Folin–Ciocalteu), dan aktivitas antioksidan menggunakan metode peredaman radikal DPPH (IC_{50}). Uji hedonik dilakukan terhadap 20 panelis untuk menilai aroma, warna, dan rasa seduhan teh. Hasil penelitian menunjukkan bahwa metode pengeringan berpengaruh signifikan terhadap seluruh parameter yang diuji ($p < 0,05$). Pengeringan langsung menghasilkan kadar flavonoid total tertinggi (2,15 mmol QE/100g sampel) dan tingkat kesukaan sensori tertinggi. Pengeringan suhu ruang menghasilkan kadar fenolik total tertinggi (51,41 mmol GAE/100g sampel) dan aktivitas antioksidan terbaik dengan nilai IC_{50} terendah (86,4 µg/mL). Pengeringan oven paling efektif menurunkan kadar air, tetapi menyebabkan penurunan terbesar pada kandungan flavonoid, fenolik, aktivitas antioksidan, dan penerimaan sensori. Pengeringan suhu ruang lebih sesuai untuk memaksimalkan potensi antioksidan, sedangkan pengeringan langsung lebih sesuai untuk menghasilkan produk teh herbal dengan penerimaan konsumen yang lebih baik.

Kata kunci : *Aktivitas Antioksidan, Benalu Kopi, Fenolik Total, Flavonoid Total, Pengeringan Pascapanen.*

INTRODUCTION

Mistletoe is a hemiparasitic plant that grows attached to host plants, from which it absorbs water and organic nutrients, while still being capable of photosynthesis due to the presence of chlorophyll (G. W. Chang et al., 1999). Phytochemical studies have shown that mistletoe contains flavonol compounds such as quercetin, quercitrin, and 4″-O-acetylquercitrin glycosides, which contribute to its biological activities, including antioxidant and anticancer effects (Lohezic-Le Devehat et al., 2002). Phenolic compounds in mistletoe have also been reported to exhibit a synergistic relationship with antioxidant activity (Leksono et al., 2018).

One type of mistletoe commonly utilized by the local community is coffee mistletoe (*Scurrula ferruginea*), particularly its leaves, which are traditionally used as herbal medicine by boiling and consuming them as tea. Herbal tea is classified as a functional beverage because it contains bioactive components, especially flavonoids and phenolics, which act as natural antioxidants (Wildman, 2001). Therefore, coffee mistletoe leaves have potential to be developed as a functional herbal tea product.

Postharvest processing, particularly drying, is a critical step in herbal tea production because it strongly influences the content of bioactive compounds and the sensory characteristics of the final product. Improper drying may lead to significant losses of active compounds (Rababah et al., 2015). Various drying techniques such as sun drying, room-temperature air drying, and oven drying have been reported to produce herbal products with different chemical and sensory profiles (Bernard et al., 2014).

The levels of flavonoids and phenolic compounds in plants are affected by multiple factors, including postharvest treatment, plant variety, extraction method, and environmental conditions (Turkmen et al., 2009; Yang et al., 2018). However, information regarding the effect of drying methods on phytochemical content and antioxidant activity of coffee mistletoe leaves remains limited.

Therefore, this study aimed to evaluate the effect of different postharvest drying methods on total flavonoid content, total phenolic content, antioxidant activity, and sensory acceptance of coffee mistletoe leaf tea in order to identify the most appropriate drying method for producing a functional herbal tea with optimal quality.

METHODS

Materials and Instruments

The materials used in this study included coffee mistletoe (*Scurrula ferruginea* [Roxb. ex Jack] Danser) leaves, ethanol (analytical grade), aluminum chloride ($AlCl_3$), Folin–Ciocalteu reagent, gallic acid, quercetin, sodium acetate, DPPH (2,2-diphenyl-1-picrylhydrazyl), vitamin C, and distilled water. The main instruments used were a drying oven (Memmert®), a UV–Visible spectrophotometer (Genesys® 10S UV–Vis), and standard laboratory glassware.

Sample Collection and Identification

Fresh coffee mistletoe leaves were collected from Batang Kapas District, Pesisir Selatan Regency, West Sumatra, Indonesia. The plant material was taxonomically identified at Herbarium ANDA, Universitas Andalas.

Postharvest Drying Treatments

The collected leaves were washed, drained, and divided into three groups for postharvest drying:

1. Sun drying: 500 g of leaves were dried under direct sunlight for approximately 3 days until the leaves became brittle.
2. Oven drying: 500 g of leaves were dried in an oven at 40°C for 48 hours.
3. Room-temperature drying: 500 g of leaves were air-dried at room temperature (25–31°C; relative humidity 75–80%) for approximately 5 days.

After drying, the leaves were ground into powder and sieved to obtain homogeneous samples.

Characterization of Simplicia

The dried samples were characterized based on organoleptic properties (appearance, color, odor), loss on drying, water-soluble extractive value, ethanol-soluble extractive value, and total ash content, according to the Indonesian Herbal Pharmacopeia (Kementerian Kesehatan Republik Indonesia, 2017).

Determination of Total Flavonoid Content

One gram of powdered sample was infused with 100 mL of hot distilled water (90°C) for 15 minutes, filtered, and diluted as required. A 0.5 mL aliquot of the sample solution was mixed with 1.5 mL ethanol, 0.1 mL of 10% $AlCl_3$, 0.1 mL of 1 M sodium acetate, and 2.8 mL distilled water. The mixture was incubated for 30 minutes at room temperature, and absorbance was measured at the maximum wavelength (439 nm). Total flavonoid content was calculated from a quercetin calibration curve and expressed as quercetin equivalents (mmol QE/100g sample) (Kementerian Kesehatan Republik Indonesia, 2017).

Determination of Total Phenolic Content

Sample infusions were prepared as described above. One milliliter of the sample solution was mixed with 5 mL of diluted Folin–Ciocalteu reagent (7.5% in water) and allowed to react for 8 minutes. Then, 4 mL of 1% NaOH was added and the mixture was incubated for 1 hour. Absorbance was measured at approximately 730 nm. Total phenolic content was calculated from a gallic acid standard curve and expressed as gallic acid equivalents (mmol GAE/100g sample) (Kementerian Kesehatan Republik Indonesia, 2017).

Antioxidant Activity Assay (DPPH Method)

Sample solutions were prepared at various concentrations (156.25–5000 μg/mL). A 0.2 mL aliquot of each sample solution was mixed with 3.8 mL of 50 μM DPPH solution, incubated for 30 minutes in the dark, and the absorbance was measured. The percentage of radical scavenging activity was calculated, and IC_{50} values were determined from the concentration–inhibition curve and shown as final concentration (μg/mL) (Nofrizal et al., 2017).

Sensory Acceptance

A sensory acceptance test was conducted with 20 untrained panelists. Tea infusions were prepared by steeping 2 g of dried tea in 250 mL of hot water (90–95°C) for 3 minutes. Each panelist evaluated three coded samples for aroma, color, and taste using a five-point sensory acceptance scale (1 = dislike very much to 5 = like very much) (Adrianar et al., 2015).

Statistical Analysis

Data were analyzed using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test for normally distributed data, and Kruskal–Wallis and Mann–Whitney U tests for non-parametric data. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Characteristics of Simplicia

Table 1. Effect of Postharvest Drying Methods on the Organoleptic Properties of Coffee Mistletoe (*Scurrula ferruginea* [Roxb. ex Jack] Danser) Leaf Tea Simplicia

Postharvest Treatment	**Organoleptic Characteristics**		
	Appearance	**Color**	**Odor**
Sun Drying	Powder	Greenish Brown	Characteristic
Oven Drying	Powder	Brown	Characteristic
Room-Temperature Drying	Powder	Greenish Brown	Characteristic

Table 2. Effect of Postharvest Drying Methods on Specific and Non-Specific Quality Parameters of Coffee Mistletoe (*Scurrula ferruginea* [Roxb. ex Jack] Danser) Leaf Tea Simplicia

Postharvest Treatment	**Parameters**			
	Loss on Drying (% w/w)	**Total Ash Content (% w/w)**	**Water-Soluble Extractive (% w/w)**	**Ethanol-Soluble Extractive (% w/w)**
Sun Drying	10.46 ± 0.25	2.05 ± 0.78	13.27 ± 2.07	7.22 ± 2.04
Oven Drying	9.57 ± 0.21	2.85 ± 0.74	8.31 ± 5.09	11.22 ± 5.96
Room-Temperature Drying	11.34 ± 0.30	3.62 ± 0.39	7.98 ± 2.07	6.21 ± 1.49
Specification *)	≤ 10	≤ 4.0	≥ 7.4	≥ 4.8

*)Specifications based on the Monograph of Mistletoe Leaf Simplicia (Benalu) (Kementerian Kesehatan Republik Indonesia, 2017); n=3

As shown in Table 1, all drying treatments produced powdered simplicia with a characteristic odor, indicating that the drying process did not alter the basic identity of the plant material. However, differences in color were observed among treatments. Oven-dried samples exhibited a more pronounced brown color, whereas sun-dried and room-temperature-dried samples retained a greenish-brown appearance. This change suggests enhanced pigment degradation and non-enzymatic browning reactions during oven drying, likely due to prolonged exposure to elevated temperature, as also reported for dried tea leaves and other herbal materials (Roshanak et al., 2016).

The physicochemical parameters of the simplicia (Table 2) further demonstrate the impact of drying methods. Oven drying resulted in the lowest loss on drying (9.57%), meeting the pharmacopeial requirement (≤10%), whereas sun drying (10.46%) and room-temperature drying (11.34%) slightly exceeded this limit. This indicates that oven drying was the most efficient in reducing residual moisture, while natural drying methods were more influenced by environmental conditions such as humidity and air circulation.

Nevertheless, moisture reduction efficiency did not correlate directly with the preservation of bioactive compounds. Differences in water- and ethanol-soluble extractive values suggest that drying conditions modified the extractability and possibly the composition of polar and semi-polar constituents, reflecting changes in the plant matrix during drying.

Total Flavonoid, Phenolic Contents and Antioxidant Activity

Table 3. Effect of Postharvest Drying Methods on Phytochemical Content and Antioxidant Activity of Coffee Mistletoe (*Scurrula ferruginea* [Roxb. ex Jack] Danser) Leaf Tea

Postharvest Treatment	Total Flavonoid Content (mmol QE/100 g sample)*)	Total Phenolic Content (mmol GAE/100 g sample)*)	Antioxidant Activity (IC_{50}) (μg/mL)*)
Sun Drying	2.15 ± 0.06^c	39.95 ± 1.80^b	98.52 ± 5.67^a
Oven Drying	0.42 ± 0.13^a	20.73 ± 1.10^a	178.03 ± 9.95^b
Room-Temperature Drying	1.00 ± 0.02^b	51.41 ± 1.71^c	86.40 ± 3.51^a

*) All three postharvest treatments had a significant effect on the ANOVA test results;
a,b, and c Different superscript letters indicate significant differences based on the Duncan post hoc test ($p < 0.05$); n=3

As presented in Table 3, the drying method significantly affected total flavonoid and total phenolic contents ($p < 0.05$). Sun drying yielded the highest total flavonoid content (2.15 mmol QE/100g sample), whereas oven drying resulted in the lowest (0.42). This pattern can be attributed to the thermal sensitivity of flavonoids, which are prone to degradation through oxidation and hydrolysis under prolonged heating (Chang et al., 2002).

In contrast, room-temperature drying produced the highest total phenolic content (51.41 mmol GAE/100g sample), followed by sun drying (39.95), with oven drying again showing the lowest value (20.73). Mild drying conditions may better preserve phenolic compounds or allow partial oxidative transformation that remains detectable by the Folin–Ciocalteu assay (Singleton et al., 1999; Pérez et al., 2023). Excessive heat, on the other hand, can promote phenolic degradation, explaining the reduced levels observed after oven drying. Antioxidant activity, expressed as IC_{50} values, followed a trend consistent with total phenolic content. Room-temperature-dried samples exhibited the strongest antioxidant activity (lowest IC_{50}: 86.4 μg/mL), followed by sun-dried samples (98.52), whereas oven-dried samples showed the weakest activity (178.03).

These results confirm that phenolic compounds are major contributors to antioxidant capacity in coffee mistletoe leaves, acting as hydrogen or electron donors to neutralize free radicals in the DPPH assay (Brand-Williams et al., 1995; Marvibaigi et al., 2016). The fact that sun-dried samples had the highest flavonoid content but not the lowest IC_{50} further indicates that total phenolics, rather than flavonoids alone, play a dominant role in determining antioxidant activity in this system.

Sensory Acceptance

Table 4. Effect of Postharvest Drying Methods on Sensory Acceptance of Coffee Mistletoe (*Scurrula ferruginea* [Roxb. ex Jack] Danser) Leaf Tea

Coffee Mistletoe Tea Sample	**Σ Hedonic Score**		
	Aroma$^{*)}$	**Color**$^{*)}$	**Odor**$^{*)}$
Tea 1 (Sun Drying)	46.30^{a}	39.17^{a}	44.30^{a}
Tea 2 (Oven Drying)	26.18^{b}	24.03^{b}	26.25^{b}
Tea 3 (Room-Temperature Drying)	19.02^{b}	28.30^{b}	20.95^{b}

$^{*)}$ All three postharvest treatments had a significant effect on the Kruskal–Wallis test results

$^{a\ and\ b}$ Different superscript letters indicate significant differences based on the Mann–Whitney U post hoc test ($p < 0.05$)

n=20

The hedonic test results (Table 4) showed that tea prepared from sun-dried leaves received the highest scores for aroma, color, and taste. In contrast, oven-dried and room-temperature-dried teas were less preferred. This suggests that sun drying better preserves volatile compounds and visual attributes associated with acceptable herbal tea quality, whereas oven drying may induce thermal degradation of aroma compounds, and room-temperature drying may promote oxidative changes that negatively affect sensory perception (Lim, 2011).

Overall, the results indicate a clear trade-off between functional quality and sensory acceptance. Room-temperature drying maximized total phenolic content and antioxidant activity but yielded lower sensory acceptance. Sun drying provided a balance between relatively high flavonoid content and superior sensory quality, while oven drying was most effective for moisture reduction but least favorable in terms of phytochemical retention, antioxidant activity, and consumer acceptance.

Therefore, the selection of an appropriate drying method should be guided by the intended use of the product: room-temperature drying is recommended when the primary objective is to maximize antioxidant potential, whereas sun drying is more suitable for producing herbal tea with better sensory acceptance.

CONCLUSION

Postharvest drying methods significantly influence the physicochemical characteristics, phytochemical content, antioxidant activity, and sensory acceptance of coffee mistletoe (*Scurrula ferruginea* [Roxb. ex Jack] Danser) leaf tea. Room-temperature drying resulted in the highest total phenolic content and the strongest antioxidant activity, whereas sun drying produced the highest total flavonoid content and the most favorable sensory acceptance. Oven drying was the most effective in reducing moisture content but caused the greatest losses of flavonoids, phenolics, antioxidant activity, and sensory quality.

These studies indicate that room-temperature drying is more appropriate when the primary objective is to maximize antioxidant potential, while sun drying is preferable for producing herbal tea with better consumer acceptance. Therefore, the choice of drying method should be tailored to the intended functional or sensory attributes of the final product.

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