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RESEARCH ARTICLE

Chemical Characteristics Profile of *Temulawak* (*Curcuma xanthorrhiza*) Extract Processed Using a Miniplant-Scale Extractor with Variations in Temperature and Time

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ABSTRACT

Temulawak (*Curcuma zanthorrhiza*) is a herbal plant native to Indonesia that contains bioactive compounds, such as curcuminoids, which possess antioxidant and anti-inflammatory properties. This study aims to examine the effect of varying extraction temperatures (70, 75, and 80°C) and extraction times (10, 20, 30, 40, 50, and 60 minutes) on the antioxidant activity and total phenol content of *temulawak* extract. The extraction was carried out using the conventional method, and the analysis was performed using the DPPH assay for antioxidant activity and the Folin-Ciocalteu method for total phenol content. The results showed that an extraction temperature of 75°C for 60 minutes yielded was the highest antioxidant activity at 63.73%, with the total phenolic concentration of 63.56 mg GAE/g. At 70°C, antioxidant activity increased from 15.39% at 10 minutes to 60.84% at 60 minutes; however, this temperature was less efficient than 75°C. The extraction at 80°C resulted in the highest pH (7.95) yet increased the risk of bioactive compounds degradation, as indicated by the results ofantioxidant activity. Overall, the 75°C and 60 minutes of extraction conditions provided optimal results, producing an extract with high antioxidant activity and total phenolic content without significant degradation. This study provides valuable insights for optimizing the *temulawak* extraction process in the health and pharmaceutical industries.

KEYWORDS: *Temulawak, Extraction, Temperature, Antioxidant Activity, Total Phenol Content*

Introduction

Indonesia, as a tropical country with abundant biodiversity, has various herbal plants beneficial for health, one of which is Curcuma xanthorrhiza (*temulawak*). *Temulawak* contains key active compounds, such as curcuminoids, which act as antioxidants and anti-inflammatory agents (Shanty, 2016). As public awareness of natural medicine increases, *temulawak* production in Indonesia reached 24.1 million kg in 2023 (Badan Pusat Statistik, 2024). *Temulawak* has long been used in traditional medicine and is widely utilized as a raw material in health products, including supplements, herbal drinks, and natural medicines. Its antioxidant content helps neutralize free radicals, which contribute to degenerative diseases such as cancer, heart disease, and premature aging (Widyaningsih et al., 2017).

Extraction is a crucial step in obtaining bioactive compounds from *temulawak*. Extraction methods vary from conventional techniques, such as maceration and Soxhlet, to modern approaches like ultrasonic and supercritical fluid extraction. Extraction temperature plays a key role, as it can affect the stability of active compounds. Although high temperatures can accelerate extraction rates, they also pose a risk of antioxidant

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degradation, such as curcuminoids. Conversely, low temperatures may lead to suboptimal release of active compounds. Additionally, extraction time is another critical factor, as prolonged durations can cause oxidation of bioactive compounds, whereas shorter times may result in lower yields of beneficial substances (Sholikhah et al., 2023).

This study aims to examine the effect of temperature and extraction time variations on antioxidant activity and total phenol content in *temulawak* extract using a mini-plant scale extractor. By analyzing these factors, optimal extraction conditions can be determined to produce high-quality extracts for use in the herbal beverage and health product industries.

Materials and Method

Materials

The materials used in this study are *temulawak,* distilled water, filter paper, ethanol, DPPH, methanol, Folin, and sodium carbonate.

Sample Preparation

This review was written by combining experimental research results published from 2019 to 2024, which are obtained from Google Scholar search. The keywords used for searching included the words "velvet bean", "jack bean", "*Mucuna pruriens*", "*Canavalia ensiformis*", and "antioxidant". Articles that emerged from the searching result was pre-screened based on title and abstract. Further screening was done by examining the selected articles to find articles that provide the most reliable and complete data and discussions to be further analyzed and reviewed. Exclusion criteria are review articles, book chapters, non-experimental sources as well as studies with insufficient information, while inclusion criteria are research articles with clear data and analysis that highlight antioxidant properties and capacities of velvet bean and jack beans, as well as factors affecting their values.

Sample Extraction

The extraction process of dried *Curcuma xanthorrhiza* (*temulawak*) is carried out using an extractor machine at the SCU BSB campus miniplant. The extraction is performed with temperature variations set on the extractor at 70˚C, 75˚C, and 80˚C, and extraction times of 10, 20, 30, 40, 50, and 60 minutes with an agitation speed of 60 rpm. The extraction uses 1 kg of dried *temulawak* and 20 liters of water. The water-to-material ratio is designed to simulate the miniplant process. The obtained extract is then collected and analyzed according to the required tests.

Antioxidant Activity Test

The antioxidant activity of Curcuma xanthorrhiza (*temulawak*) extract is analyzed using the DPPH method. The extracted *temulawak* is dissolved in methanol and mixed with a DPPH solution in a 1:1 ratio. The absorbance measurement is then performed at a wavelength of 517 nm. The antioxidant activity is determined using the equation from Inggrid et al. (2018).

$$\%\ Antioxidant\ Activity = 1 - \left(\frac{Sample\ Absorbance}{DPPH\ Absorbance}\right) x\ 100\%$$

Total Phenol Test

The total phenol test procedure follows the research by Sundu et al. (2022) and Adriani & Murtisiwi (2018). The total phenol content is measured using the Folin-Ciocalteu reagent

with gallic acid as the standard. A total of 1 mL of extract is added to 10 mL of deionized water and 1.0 mL of Folin-Ciocalteu reagent. After 5 minutes, 20 mL of 20% sodium carbonate is added to the mixture. The solution is then kept in a dark condition for 1 hour, and the absorbance is measured at a wavelength of 750 nm using a spectrophotometer.

pH Test

The pH test is conducted using a pH meter (Fasya et al., 2018). First, the pH meter is calibrated. The electrode of the pH meter is then immersed in the t*emulawak* extract sample. The detected pH value is observed until it stabilizes, and the final pH reading is recorded.

Data Analysis

The collected data will be tabulated using Microsoft Excel. The data will then be processed and analyzed using SPSS version 27.0. To determine the relationship between variables and the extraction results of dried Curcuma xanthorrhiza *(temulawak),* regression analysis will be used. The extraction results under different extraction temperature variations will be analyzed using analysis of variance (ANOVA).

Results and Discussion

pH of Curcuma Extract

Velvet bean is often used as raw material for many traditional medication and pharmaceutical industries due to its ability to exhibit antioxidant, antiinflammation, antihypertension, and antidiabetic capacities. These bioactive capacities are mostly caused by the presence of polyphenol, flavonoid, tannin, alkaloid, saponins, and glycoside components (Sowdhanya *et al.*, 2023). Furthermore, according to Ishmayana *et al.* (2023), levodopa or L-DOPA (L-3,4-dihydroxyphenilalanine) also plays role in its antioxidant capacity. L-DOPA is an amino-acid-group-containing bioactive compound that is found abundantly in velvet bean that contains two hydroxyl group located in adjacent to each other on a single aromatic ring (also known as catechol structure). This structure was reported be the one responsible for the compound's free radical fighting activities. However, it is advised to limit consumption of L-DOPA despite its antioxidant, anti-stress, neuroprotective and anti-Parkinson activities, as it may exhibit negative effects towards thyroid.

Kumbhare *et al.* (2023) concluded that methanolic extract of velvet bean seeds exhibit higher antioxidant capacity compared to the leaves, stem, and roots parts, which was also proven by its higher values of total phenolic and total flavonoid content and its lower IC_{50} value for DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging activity. Similar result was also observed in the study done by Shelke *et al* (2022), who compared antioxidant activity of velvet bean seeds and its leaves. The result showed higher inhibition percentage of DPPH from ethanolic extract of velvet bean seeds compared to its leaves. Antioxidant capacity and the phytochemical profile of velvet bean seed are summarized in Table 1.

Table 1. pH of *Curcuma xanthorrhiza* extract

Time (minutes)	pH		
	70 °C	75 °C	80 °C
10	7.71 ± 0.14^{A1}	7.17 ± 0.34^{A1}	7.53 ± 0.28^{A1}
20	7.75 ± 0.09^{A1}	7.47 ± 0.26^{A1}	7.53 ± 0.50^{A1}

30	7.88 ± 0.12^{A1}	7.73 ± 0.26^{A1}	7.86 ± 0.05^{A1}
40	7.88 ± 0.16^{A1}	7.60 ± 0.38^{A1}	7.95 ± 0.00^{A1}
50	7.74 ± 0.09^{A1}	7.82 ± 0.09^{A1}	7.61 ± 0.09^{A1}
60	7.79 ± 0.29^{A1}	7.64 ± 0.13^{A1}	7.66 ± 0.20^{A1}

Description:
- All values are mean ± stdev
- Values with a superscript letter A in each column indicate that there is no significant difference between heating time and pH
- Values with a superscript number 1 in each row indicate that there is no significant difference between heating time and pH

According to the research findings, there was no significant difference in the pH values of Curcuma xanthorrhiza extract at various extraction temperatures and durations. However, the highest pH (7.95) was observed at an extraction temperature of 80˚C for 40 minutes. A similar pH value (7.88) was found at 70˚C with extraction times of 30 and 40 minutes. Measurements were conducted using a pH meter with tap water as the solvent to assess the stability of bioactive compounds such as curcuminoids and xanthorrhizol, which are influenced by the extract's pH (Wahyuni et al., 2023).

At 70˚C, the pH remained relatively stable, indicating minimal degradation of sensitive compounds such as curcuminoids and essential oils. This stability is crucial since curcuminoids can degrade in alkaline conditions (pH 8.5–10.0) into ferulic acid and feruloylmethane, reducing their bioactive potential (Dwiseptianti et al., 2019).The main functional groups of curcuminoids that act as antioxidants are the hydroxyl group (-OH) and methoxy group (-OCH_3) in the fire ring, as well as the dienone system which can donate electrons and capture free radicals. At 75˚C, pH fluctuations were more pronounced at the beginning of the process, indicating a faster release of bioactive compounds, such as phenol compounds and curcuminoids. The pH drop at 40 minutes was due to the initial degradation of active compounds, while the increase at 50 minutes suggested the release of additional components (Sattar et al., 2020). The 80˚C extraction resulted in the highest pH but also posed a risk of bioactive compound decomposition due to high temperatures (Chen et al., 2014). Overall, an extraction temperature of 70˚C was more effective in maintaining the stability of Curcuma xanthorrhiza bioactive compounds.

Effect of Processing Treatments Towards Antioxidant Capacities of Velvet Bean and Jack Bean

Table 2. Antioxidant activity of *Curcuma xanthorrhiza* extract based on extraction temperature and time

Time (minutes)	Antioxidant activity (%)		
	70 °C	75 °C	80 °C
10	15.39 ± 10.63^{A1}	6.54 ± 2.73^{A1}	9.48 ± 5.24^{A1}
20	27.30 ± 4.78^{B1}	17.72 ± 3.24^{B2}	21.11 ± 2.10^{B12}
30	32.68 ± 8.41^{B1}	27.57 ± 2.98^{C1}	31.04 ± 3.65^{C1}
40	35.26 ± 7.12^{B1}	44.86 ± 3.11^{D12}	47.02 ± 2.77^{D2}
50	54.21 ± 2.41^{C1}	55.02 ± 0.86^{E1}	56.35 ± 2.11^{E1}

60	60.84 ± 2.28^{C12}	63.73 ± 1.66^{F2}	61.78 ± 6.88^{E1}

Description:
- All values are mean ± stdev
- Values with different superscript letters (A, B, C, D, E, and F) in each column indicate that there is a significant difference between heating times.
- Values with different superscript numbers (1, 2, and 3) in each row indicate that there is a significant difference between extraction temperatures.

Curcuma xanthorrhiza contains key bioactive compounds, primarily curcuminoids, especially curcumin, which acts as a potent antioxidant (Purwanto, 2022). The extraction process, with variations in temperature and duration, significantly affects antioxidant activity. At 70˚C, antioxidant activity increased from 15.39% (±10.63) at 10 minutes to 60.84% (±2.28) at 60 minutes. This increase indicates that a longer extraction time allows more bioactive compounds to dissolve, although extraction efficiency is lower at lower temperatures (Yasacaxena et al., 2023; Mashita et al., 2014).

At 75˚C, optimal results were observed, with antioxidant activity reaching 63.73% (±1.66) at 60 minutes, accompanied by a low standard deviation, reflecting consistent results. This temperature effectively dissolves active compounds without significant degradation (Rosidi et al., 2014). In contrast, at 80˚C, antioxidant activity initially increased significantly to 9.48% (±5.24) at 10 minutes and reached 61.78% (±6.88) at 60 minutes. However, increased variability indicates the risk of active compound degradation due to high temperatures (Amelinda et al., 2018; Budiati et al., 2018).

Factors contributing to increased antioxidant activity include the release of bioactive compounds due to cell wall breakdown by heat and interactions between phenoli compounds and thermally activated flavonoids (Aisyah et al., 2014; Chaaban et al., 2017). However, high temperatures pose a risk of thermal decomposition, reducing antioxidant activity (Maslukhah et al., 2016). Extraction methods such as Soxhlet extraction and the use of organic solvents have been proven to enhance extraction efficiency (Setyowati & Suryani, 2013; Simamora et al., 2023). Other studies indicate that extraction time and extract concentration significantly influence antioxidant activity, with higher concentrations being more effective than prolonged extraction times (Rosidi et al., 2014).

The heating process affects the stability of curcumin, xanthorrhizol, and phenol compounds, where moderate temperatures yield optimal results with high antioxidant activity, whereas extreme temperatures can potentially degrade active compounds (Cahyono et al., 2011; Jakubczyk et al., 2020).

Total Phenol Content of *Curcuma zanthorrhiza* Extract Based on Extraction Temperature and Time

Table 3. Measurement results of total phenol content in *Curcuma xanthorrhiza* extract

Time (minutes)	Total Phenol (mg GAE/g)		
	70 °C	75 °C	80 °C
10	9.26 ± 0.47^{A1}	12.38 ± 1.05^{A1}	12.55 ± 1.92^{A1}
20	20.28 ± 2.38^{B1}	19.17 ± 1.36^{B1}	18.75 ± 0.61^{B1}
30	25.10 ± 1.16^{C1}	26.25 ± 1.73^{C1}	25.27 ± 1.91^{C1}
40	41.32 ± 0.71^{D1}	38.67 ± 1.41^{D1}	36.87 ± 2.64^{D1}
50	48.80 ± 0.75^{E1}	50.57 ± 0.42^{E1}	50.47 ± 1.38^{E1}
60	60.96 ± 2.13^{F1}	62.66 ± 1.07^{F1}	63.56 ± 0.53^{F1}

Description:
- All values are mean ± stdev
- Values with different superscript letters (A, B, C, D, E, and F) in each column indicate that there is a significant difference between heating times.
- Values with different superscript numbers (1, 2, and 3) in each row indicate that there is a significant difference between extraction temperatures.

The highest total phenol content in Curcuma xanthorrhiza extract (63.56 ± 0.53 mg GAE/g) was obtained at an extraction temperature of 80˚C for 60 minutes, while the lowest concentration (9.26 ± 0.47 mg GAE/g) was found at 70˚C for 10 minutes. Phenol compounds play a crucial role as proton and electron donors, making them effective in neutralizing free radicals and inhibiting oxidative damage to cells (Wardhani et al., 2018). During the extraction process, temperature helps break down plant cell walls, facilitating the release of phenols into the solvent; however, excessive heat may lead to degradation (Magdalena & Kusnadi, 2015).

At a 10-minute extraction time, increasing the temperature from 70˚C to 80˚C enhanced phenol concentration due to more efficient release of bioactive compounds. Increasing the temperature from 70˚C to 80˚C enhances phenol concentration by improving cell wall breakdown and solubility, but at higher temperatures, thermal degradation may reduce phenolic content.However, at 20 minutes, degradation effects became noticeable at 75˚C and 80˚C. For longer extraction times (50–60 minutes), higher temperatures resulted in increased phenol content, but 75˚C appeared to be the optimal temperature to prevent degradation (Sutarsi et al., 2023).

The quality of raw materials also influences extraction outcomes. Fresh Curcuma xanthorrhiza rhizomes contain higher phenol content. Additionally, pH and solvent type contribute to the stability and solubility of phenol compounds. The positive correlation between antioxidant activity and total phenol content indicates that these compounds play a significant role in providing health benefits such as anti-inflammatory, antimicrobial, and anticancer effects (Nurcholis & Bintang, 2017; Pratiwi & Wardaniati, 2019).

Extraction temperature and time are key parameters for optimizing phenol compound extraction. While higher temperatures enhance phenol diffusion, prolonged extraction must be carefully managed to avoid degradation. A deeper understanding of these factors is essential to maximize the antioxidant potential of Curcuma xanthorrhiza for pharmaceutical and health industry applications.

Conclusion

The antioxidant activity and total phenolic content of Curcuma xanthorrhiza extract increased with longer extraction time at all temperatures. The highest antioxidant activity (63.73 ± 1.66%) was achieved at 75˚C for 60 min, indicating optimal release of bioactive compounds without significant thermal degradation. Meanwhile, the highest total phenolic content (63.56 ± 0.53 mg GAE/g) was obtained at 80˚C for 60 min, indicating maximum phenolic extraction, although with potential degradation risk. The temperature condition of 75˚C provided efficient extraction with minimal degradation, making it a preferred temperature to optimize antioxidant activity while maintaining high phenolic content, which supports efficient extraction at the mini-factory scale.

Conflict of Interest

The authors declare no conflict of interest.

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