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The Effect of Microwave Time and Power on the Tannin Extraction Process from Gambier (*Uncaria gambir* Roxb.) Using the Microwave Assisted Extraction (MAE) Method

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Abstract. *Dry gambier extract obtained from gambier plants contains tannins at relatively low levels. Tannins can be obtained by extracting dry gambier using water to achieve high yields within a relatively short processing time. This study aims to analyze the interaction between extraction time and microwave power in the tannin extraction process from gambier using the microwave-assisted extraction (MAE) method to maximize tannin yield. The research method employed was a factorial design (AxB). Factor A was extraction time, consisting of five treatments (1; 2; 3; 4; and 5 minutes) and factor B was microwave power, consisting of five variations (180W; 300W; 450W; 600W and 850W). The results showed that the gambier extraction process using MAE demonstrated an interaction between extraction time and microwave power on the yield produced, but not on the tannin content. The most optimal temperature and power that can be used is 4 minutes at 600W microwave power with a yield of 44.66%. The treatment of temperature and microwave power in the gambier extraction process showed a significant interaction with the extract yield.*
Keywords: *gambier; microwave-assisted extraction (MAE); tannins.*

Type of the Paper: Regular Article.

1. Introduction

West Sumatra Province produces 80% of the national demand for gambier. The areas of gambier production include Pesisir Selatan District (9,963.00 ha), Padang Pariaman District (23.00 ha), Agam District (986.00 ha), Lima Puluh Kota District (17,299.50 ha), Pasaman District (389.00 ha), and Padang District (52.00 ha) [1]. The main chemical contents of gambier are catechins and tannins. Tannins are active secondary metabolites that offer various benefits, including applications in the health sector [2], skin tanners [3], particleboard adhesives [4], and the production of rigid foam [5,6].

Tannins are high molecular weight phenol compounds that contain hydroxyl and other functional groups, such as carboxyl, which enable them to form effective complexes with proteins and other macromolecules under certain environmental conditions. Tannins are a class of polyphenol colorants with various functional applications, including food coloring [7,8]. Tannins are complex compounds comprising proteins, starch, cellulose, and minerals. Their structure is represented by the empirical formula $C_{72}H_{52}O_4$ [9]. The utilization of tannins includes their use as ingredients in the production of adsorbents, adhesives, cosmetics, pharmaceuticals, heavy metal

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adsorbents, and industrial food applications. Tannins are found in acacia plants [3,10], Quercus infectoria (Manjakani) [11], bark extracts of European softwood species [9], maritime pine (Pinus pinaster) [12], pine bark [13,14], quebracho wood and gambier [15]. Tannins can be obtained through the extraction process.

Tannin extraction is typically carried out using conventional methods that require a long time. However, with technological developments, several rapid and efficient extraction techniques have been developed. One such method is microwave assisted extraction (MAE). The MAE process utilizes energy generated by microwaves at a frequency of 0.30300 GHz in the form of electromagnetic non-ionizing radiation [16,17]. Ultrasonic-assisted extraction is another green and efficient method for recovering large amounts of phenolics and flavonoids [18,19]. The advantages of MAE include its broad applicability for extracting various compounds, including heat-labile compounds. In addition, it offers higher extraction rates, reduced solvent consumption, and a significant reduction in extraction time compared to conventional extraction [20,21].

The microwave method enables direct interaction between particles and microwave radiation, resulting in greater surface contact between solid and liquid particles, reduced extraction time, lower solvent consumption, and increased extraction yield [12,19,22]. The advantages of this method include reduced solvent use, more concentrated extracts, and greater recovery of active compounds [23,24]. Another advantage of microwave extraction is its simplicity, ease of use, and the significant reduction in both extraction time and solvent required. Therefore, microwave-assisted extraction is a recommended alternative for obtaining tannin extracts [22,25]. The working principle of the microwave extraction method involves microcavitation around the material being extracted. This process heats the material, ultimately releasing the target compounds [26,27].

Observations of treatments in the gambier extraction process usually focus on a single factor, such as temperature or time. This study is expected to demonstrate that the interaction between extraction time and microwave power has a positive correlation with a yield of high tannin extracts from gambier. The novelty of this research lies in analyzing the interaction between time and microwave power in the gambier tannin extraction process using the microwave-assisted extraction (MAE) method to maximize both yield and tannin content.

2. Materials and Methods

2.1. Materials and tools

The raw materials used were pure dried gambier obtained from Jorong Lambuk, Nagari Halaban, Lareh Sago Halaban District, Lima Puluh Kota Regency, and distilled water solvent from the Laboratory of Andalas University. The equipment included a Samsung-brand microwave, AS R plus analytical balance, Memmert UN30 oven, desiccator, RE-100P rotary evaporator, cabinet dryer archives, and UV-Vis spectrophotometer.

2.2. Methods

This study was conducted using a factorial design (AxB) with two replications. Factor A was the extraction time, consisting of five treatments (1 minute, 2 minutes, 3 minutes, 4 minutes, and 5 minutes) and factor B was microwave power, consisting of five variations (180W, 300W, 450W, 600W, and 850W).

2.3. Extraction [28]

Extraction was performed using distilled water as a solvent in a 1:20 ratio. The tannin extraction process was carried out with five variations of microwave power and varying extraction times according to the treatment. The extraction solution was then filtered using a suction pump to separate the residue. The gambier extract was subsequently concentrated using a rotary vacuum evaporator at 70°C for 20 minutes. This process continued until the solvent in the separator flask stopped dripping, and the crude extract, suspected to contain, was obtained. The extracts were then analyzed for yield [3], tannin content using the skin flour method [29], as well as temperature changes and solvent loss [13].

2.4. *Data analysis*

Data analysis was performed using two-factor Anova with replication, followed by Duncan's multiple range tests.

3. Results and Discussion

3.1. Extract yield

The yield of gambier extract using variation of time and microwave power is presented in Table 1. Statistical analysis showed an interaction between the extraction time and the microwave power on the yield of tannin extract. Extraction times of up to 5 minutes at microwave powers of 180W, 300W, and 450W increased the extract yield. However, the use of higher microwave power resulted in a decrease in extract yield.

Table 1. Average data of tannin yield percentage with variation of microwave time and power

Time (minute)	Tannin Yield from Different Microwave Power				
	180 W	300 W	450 W	600 W	850 W
1	22.26^{g}	21.47^{g}	21.07^{g}	23.16^{f}	25.50^{e}
2	22.57^{g}	23.47^{f}	22.71f^{g}	25.43^{ef}	33.65^{c}
3	23.34^{f}	24.68^{f}	30.64^{cd}	42.94^{a}	42.18^{a}
4	23.14^{f}	30.21^{d}	36.85^{b}	44.66^{a}	27.84^{de}
5	26.07^{e}	28.06^{d}	36.25^{b}	28.38^{d}	25.50^{e}

Description: The numbers in the same column followed by different lowercase letters are significantly different according to the DNMRT test at the 5% real level.

Tannin extraction at 600W for 4 minutes produced the highest yield of 44.66%. Prolonged extraction time reduced the yield. Similarly, at 850W, the maximum extraction time was 3 minutes, yielding 42.18%. These findings indicate that longer extraction times and higher microwave power can reduce the yield of tannin extract. According to Namira [2], extended exposure and increased microwave power can negatively affect tannin yield. In this study, a 1-minute extraction using microwave powers of 100W, 180W, 300W, 450W, and 600W resulted in a 32.70% decrease in tannin extract yield.

Several studies have examined the tannin extraction process. For example, Naima et al. [10] reported that microwave power and extraction time affected the tannin yield from *Acacia mollissima* bark, with a 5-minute extraction producing the highest yield of 47.64%. Research by Pratini [13] showed that the highest tannin yield from pine wood extract was 27.21%, obtained using 100 W microwave power for 3 minutes. According to Iriyany [30], the combination of microwaves radiation and heat during the extraction process contributes to the high extract yield. The use of MAE has been shown to shorten extraction time and increase yield compared to conventional methods [31].

3.2. Extract tannin content

The tannin content of gambier extract using variations in microwave time and power is presented in Table 2.

Table 2. Data from the analysis of tannin content of gambier extract with variations in microwave time and power

Time (minute)	Microwave Power				
	180 W	300 W	450 W	600 W	850 W
1	44.85	51.73	45.15	51.51	55.29
2	46.96	51.51	45.74	44.87	47.62
3	52.13	51.29	62.48	48.61	43.35
4	55.51	53.47	56.84	50.79	48.62
5	56.62	55.56	42.63	47.85	45.31

Statistical analysis showed no interaction between extraction time and microwave power difference on tannin content. This indicates that variations in time and microwave power did not affect the tannin content of the extract. The highest tannin content was obtained at 180W for 5 minutes, followed closely by extraction at 850W for 1 minute. These findings suggest that lower microwave power requires a longer extraction time, whereas high power, such as 850W, achieves comparable tannin content in a shorter duration. According to Rhazi [32], microwave-assisted extraction (MAE) offers several advantages for extracting compounds such as tannins from plants, including shorter extraction time, reduced solvent usage, higher extract yields, and lower costs. The MAE method produces a mechanical effect that directly heats the solvent mixture and interacts with water in the material, causing plant tissue rupture in the plant and the active compounds dissolve into the solvent. Pratini and Delazar et al. [13,16] reported that tannin concentration increased at low microwave power, but decreased with longer extraction times and higher power, likely due to degradation of tannins. The gambier tannin extract is shown in Fig. 1.

Fig. 1. The resulting gambier tannins

The tannin content of gambier extracts using water as a solvent varied depending on the extraction time and microwave power applied. Setyowati [33,34] reported that the highest tannin content was obtained at 180W power. Swara [35] added that tannin compounds are thermolabile; prolonged extraction time and increased microwave power in the MAE method generate excessive heat due to electromagnetic waves, which can degrade tannin compounds. The optimal temperature for tannin extraction is 70^{o}C, while significant increases in temperature due to higher microwave power may lead to oxidation of tannins, particularly at temperatures between 98.89^{o}C and 101.67^{o}C.

3.3. Effect of microwave power on extraction temperature

Fig. 2 illustrates the effect of varying microwave power and extraction time on solvent temperature during the tannin extraction process from gambier.

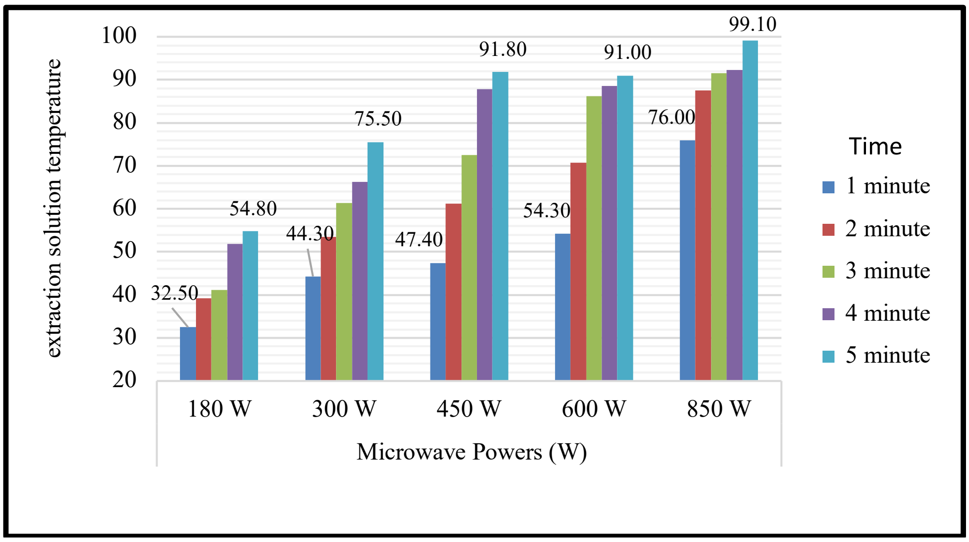

Fig. 2. Relationship graph between microwave power and extract time against extraction temperature

Fig. 2 shows that the solvent temperature increases with both higher microwave power and longer extraction time. The results showed that as microwave power and extraction duration increase, the temperature of the extract solution also rises. This demonstrates a direct relationship between microwave power and extraction temperature. According to Afalobi [36], temperature is controlled by microwave power, as higher power generates greater energy, which is converted into heat in the materials. At higher temperatures, the solvent extraction capacity increases; however, can also lead to a reduction in solvent volume due to evaporation.

The temperature of the extract during solvent extraction increased with both longer extraction times (up to 5 minutes) and higher microwave power. Using water as the solvent, the extraction temperature at 100W was 32.50°C increasing to 76.6°C at 850W. After 5 minutes, the temperature at 100W increased to 54.60°C, and at 850W to 99.60°C. An increase in extraction time up to 5 minutes led to higher tannin extract yields; however, beyond this point, particularly at higher power levels, the yield decreases. This reduction is attributed to elevated temperatures and prolonged exposure to microwave radiation, which may lead to thermal degradation of tannins.

3.4. Effect of Microwave Power on solvent loss

Fig. 3 illustrates the effect of using microwave power and extraction time on solvent loss during the tannin extraction process from gambier.

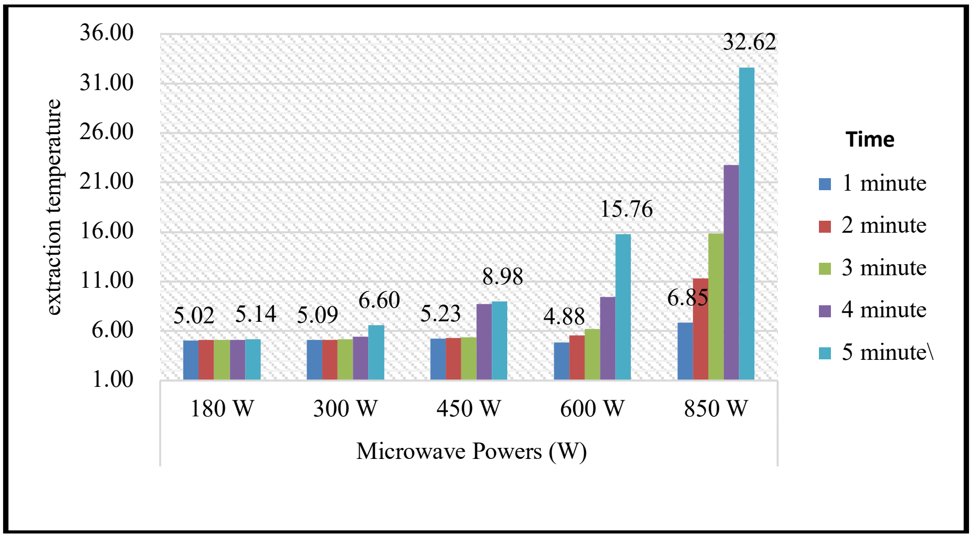

Fig. 3. Graph of the relationship between microwave power and extract time on solvent loss of gambier extraction.

Fig. 3 shows that solvent loss increases with higher microwave power given and longer extraction time. At an extraction time of 1 minute with 180W microwave power, solvent loss was 5.02 ml, while at 5 minutes it increased to 5.14 ml. As shown in Fig. 3, greater microwave power results in higher solvent loss. The highest solvent loss occurred at 5 minutes with 850W microwave power, reaching 32.62 mL.

According to Amestiasih [37], extraction using Microwave Assisted Extraction (MAE) can decrease the volume of solvent due to the heat generated by large microwave power. This finding is consistent with previous studies on ultrasonic-assisted extraction, where both MAE and the combination of ultrasonic-microwave-assisted extraction were shown to decrease solvent volume during the extraction process. This indicates that microwave-induced heat increases the extraction temperature, leading to partial solvent loss.

Indrasari [38] stated that the microwave-assisted extraction process can reduce both the amount of solvent and extract yield. Singh [39] also reported that extract yield initially increases with microwave power at lower levels, but subsequently decreases with further power and extraction time. The application of higher microwave power and prolonged extraction time can lead to a reduction in extract volume. Indrasari [38] further noted that microwave technology is recognized as a new approach for transformational natural metabolites and extracting various compounds from natural components. However, prolonged exposure to microwaves can result in solvent loss or evaporation, which negatively influences extract yield, especially for heat-sensitive compounds.

4. Conclusion

The gambier extraction process using MAE assistance demonstrated an interaction between extraction time and microwave power on the yield produced, but not on the tannin content. The most optimal condition was achieved at 4 minutes with 600 W microwave power, resulting in a yield of 44.66 %. The interaction between extraction time and microwave power influenced the temperature increase and solvent loss during the extraction process.

Abbreviations

MAE Microwave Assisted Extraction

Data availability statement

Data will be shared upon request by the readers.

CRediT authorship contribution statement

Fakhruzy: Writing – original draft. Conceptualization. Methodology. Resources. Formal analysis. Investigation. Data curation. **Anwar Kasim**: Writing – review & editing. Validation. Data curation. Formal analysis. Conceptualization. Supervision. Funding acquisition. **Alfi Asben**: Conceptualization. Supervision. Data curation. Writing – review & editing. **Aswaldi Anwar**: Formal analysis. Investigation. Writing – review & editing.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest or competing interest.

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Not available.

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