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The effect of microwave power, extraction time and solvent ratio of microwave assisted extraction (MAE) method on the yield of pectin from *Nephelium lappaceum*

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ABSTRACT

Pectin is a complex polysaccharide that is widely used in the food, pharmaceutical, and cosmetic industries as a thickening agent, stabilizer, and emulsifier. Extraction methods such as hot acid extraction have limitations in terms of time efficiency and yield. Therefore, the Microwave-Assisted Extraction (MAE) method is a faster and more efficient alternative. Microwave-assisted extraction is a potential method for pectin extraction from *Nephelium lappaceum*. The objectives of this study were to determine the optimal microwave power, extraction time and feed-to-solvent (f/s) ratio in the extraction process. The extraction process using microwave has a higher yield and shorter extraction time compared to conventional methods. The best extraction results were obtained at a power of 540 Watts, with an optimal extraction time of 11 minutes and a f/s ratio of 1:20, with the highest yields being 7.53%, 7.11%, and 6.48%, respectively. This research using the Microwave-Assisted Extraction (MAE) method in the extraction of pectin from *Nephelium lappaceum* can be an efficient reference for the development of a fast and energy-saving pectin extraction method.

1. Introduction

Binjai rambutan is one of the superior varieties of rambutan fruit (*Nephelium lappaceum*), making it the second most popular fresh fruit in Indonesia after bananas, with high production potential. According to the Central Bureau of Statistics and Indonesian Data in 2022, domestic production reached 884,702 tons in 2021. Rambutan fruit consists of the peel, flesh, seed, and embryo, each contributing 45.7%, 44.8%, 9.5%, and 6.1% of the total dry weight [1]

Rambutan peel contributes 50% of the total weight of the entire rambutan fruit. The utilization of rambutan peel as a source of pectin is expected to overcome the limited supply of pectin from commercial products, while reducing the amount of waste from the rambutan processing and production industry [2]. In contrast to the productivity of rambutan fruit, the need and demand for pectin have been increasing. To date, Indonesia still imports pectin, with a recorded 455,035 tons of pectin imported into Indonesia at a cost of US$6,635,609. Other types of food materials as sources of pectin need to be continuously studied [3,4].

Extraction of pectin from plant cell walls can be done through various extraction methods, and the choice of method will affect the quality and quantity of the results obtained. The most common extraction method is the conventional method. The conventional extraction process is considered to have various weaknesses, including the need for a long time to produce optimal pectin. During the long extraction process, continuous stirring is also needed so that debranching or a decrease in the quality of pectin does not occur. Conventional techniques that use mineral acids are also considered less environmentally friendly. Also, this technique is often associated with increased costs [5]. Conventional extraction is carried out using mineral acids, such as nitrate, sulfate, phosphate, and hydrochloride at a temperature range of 60°C to 100°C for approximately one hour [6]. Mineral acids can cause toxicity and harmful effects on the environment.

Microwave-assisted extraction (MAE) is an extraction technique where electromagnetic radiation in the microwave range is used to induce heating within the sample and extraction solvent. Previous studies have compared the results of MAE with conventional methods for extracting pectin from dragon fruit peel [7], orange peel [8], and grape peel [9].The heat generated plays a major role in the extraction process because higher temperatures can increase the diffusion rate, resulting in increased extraction yields. In addition, the dielectric characteristics of the sample and solvent also have an impact on the extraction rate [10].

The objective of this research is to determine the optimal microwave power, extraction time, and feed-to-solvent (f/s) ratio using the Microwave-Assisted Extraction (MAE) method.

2. Materials and Methods

2.1. Tools

Analytical balance with 0.0001-gram accuracy (Sartorius),

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80-mesh sieve (Kitchensink LSM West Jakarta), cabinet dryer, microwave (Sharp R-725DA-BK), hot plate, food dehydrator, centrifuge (12 slot Corona), centrifuge tubes, filter cloth, aluminum foil, plastic wrap, petri dish, and commonly used glassware from Phoenix Surabaya.

2.2. Materials

Binjai rambutan from Porong market, Sidoarjo, aquadest, technical-grade citric acid ($C_6H_8O_7$) from Bohr Chemical, ethanol 96% from Sumber Ilmiah Persada Surabaya, and food-grade silica gel.

2.3. Methods

2.3.1. Production of rambutan peel powder

The rambutan peel, separated from the fruit, is cleaned to remove any dirt. The rambutan peel is then cut into smaller pieces. The cut rambutan peel is placed in a food dehydrator at a temperature of 70°C for approximately 6-7 hours or until completely dry. The dried rambutan peel is then chopped and ground using a grinder and an 80-mesh sieve. The rambutan peel powder can be stored in a zip-lock plastic bag equipped with silica gel [11].

2.3.2. Proximate analysis of rambutan peel powder

The AOAC method was applied to determine the moisture content and ash content [12].

2.3.3. Pectin microwave-assisted extraction

Ten grams of rambutan peel powder were placed in an Erlenmeyer flask containing an extraction solvent (citric acid) in a ratio ranging from 1:20 to 1:40. The flask was covered and heated in a microwave using varying power levels (180-630 Watts) for different durations (2-20 minutes). After the extraction process was completed, the Erlenmeyer flask was cooled to room temperature then the pectin extract was filtered and centrifuged at 4500 rpm for 20 minutes. After that, 96% ethanol was added in a 1:1 ratio to precipitate the pectin for 24 hours. The coagulated pectin precipitate was filtered again using filter paper and washed again with 96% ethanol to remove residual acid. The wet pectin was then dried in an oven at 55°C for 3-4 hours. The resulting pectin extract was then be analyzed for yield and other attributes [8].

2.3.4. The analysis of pectin yield

Pectin yield extracted from Binjai rambutan peel can be calculated by using the Eq. (1) below (in the form of dry basis) [8].

$$Pectin\ yield\ (\%) = \frac{Weight\ of\ pectin\ extracted\ (g)}{Weight\ of\ rambutan\ peel\ used\ (g)} \times 100$$

2.3.5. Research design

This study was divided into three stages. The first stage determined the microwave power at 180–630 Watts, with the fixed variables being 3 minutes for extraction time and the f/s ratio of 1:30 w/v in citric acid. The second stage determined the extraction time at 5, 7, 9, 11, 13, and 15 minutes, with the fixed variables being the optimal microwave power from the previous stage (540 Watts) and the f/s ratio of 1:30 w/v in citric acid. The third stage determined the f/s ratio at 1:20, 1:30, and 1:40 w/v, with the fixed variables being the optimal microwave power from the first stage (540 Watts) and extraction time from the second stage (11 minutes).

3. Results and Discussion

3.1. Research results

As a preliminary analysis to ensure that the rambutan sample powder is suitable for extraction, a proximate test was carried out. The results of the proximate test, including water content and ash content, can be seen in Table 1.

Table 1. Proximate analysis results of rambutan peel powder

Analysis	Result	Literature
Moisture content	9.16%	10.5% [13]
Ash content	4.28%	2.74%[14]

The results of the analysis of pectin yield after extraction aimed at finding the best power, extraction time, and f/s ratio can be seen in Table 2.

Table 2. Pectin Yield Results

Extraction condition			Yield (%)
Power (W)	Time (min)	F/S ratio (w/v)	
180	3	1:30	3
270			5.525
360			6.51
450			6.855
540			7.535
630			4.42
540	5	1:30	2.84
	7		3.4
	9		5.115
	11		8.11
	13		5.615
	15		5.175
540	11	1:20	8.48
		1:30	5.435
		1:40	5.035

3.2. Discussion

3.2.1. Proximate composition of rambutan peel powder

Table 1 shows the proximate analysis of rambutan peel powder. The moisture content of rambutan peel powder was found to be 9.16% (w/w), lower than the findings by Khumaida et al [13] which was 10.5%. The ash content represent the total mineral content in the biomass which is used to determine total chemical composition of sample. The ash content was found to be 4.28% (w/w) higher from the findings by Faramayuda et al [14] which was 2.74%. The maximum ash content limit for a good-quality gel is 10% (w/w) [15].

3.2.2. Effect of microwave power on pectin yield

The effect of microwave power on pectin yield can be

seen in Figure 1. The highest pectin yield obtained was 7.53% (w/w) at the power of 540 Watt, followed by 450 Watt, 360 Watt, 270 Watt, 630 Watt, and 180 Watt with their respective pectin yields of 6.85%, 6.51%, 5.52%, 4.42%, and 3%.

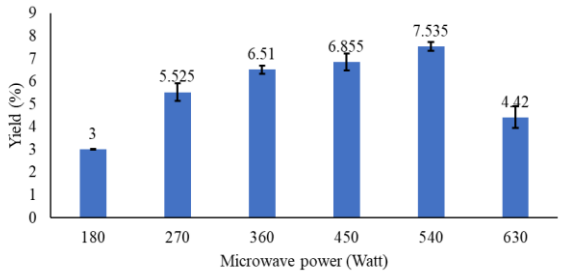

Fig. 1. Effect of microwave power on pectin yield

The pectin yield among all the samples shows a significant difference. Hence, microwave power is one of the factors that affects MAE significantly. The pectin yield was initially 3% (w/w) at 180 W microwave power, and increased to 5.25%, 6.51%, and 6.85% (w/w) as the microwave power was increased to 270 W, 360 W, and 450 W. The highest peak of pectin yield was 7.35% at 540 W microwave power. The pectin decreased dramatically to 4.42% (w/w) after 630 W of microwave power was applied. The irradiation of microwave energy enhances the solvent effectiveness to penetrate into the cell wall of plant. Rapid energy transfer to the solvent increases the temperature and internal pressure in sudden, causing the acceleration of cell rupture at the surface of sample and allowing the hydrolysis and exudation of pectin molecules into the solvent [16].

However, when higher irradiation power of 630 W was applied, the molecular interaction was disturbed due to the superfluous energy in the solvent and matrix, thus resulting in the thermal degradation of polysaccharides, which decreases the pectin yield [17,18].

3.2.2. Effect of extraction time on pectin yield

The effect of extraction time on pectin yield can be seen in Figure 2. The best extraction time with the highest yield was 11 minutes, which was 8.11%. Beyond 11 minutes, the yield tended to be unstable, and the values fluctuated. Figure 2 shows that the highest pectin yield obtained was 8.11% (w/w) at 11 minutes, followed by 13 minutes, 15 minutes, 9 minutes, 7 minutes, and 5 minutes with their respective pectin yields of 5.62%, 5.2%, 5.11%, 3.4%, and 2.84%.

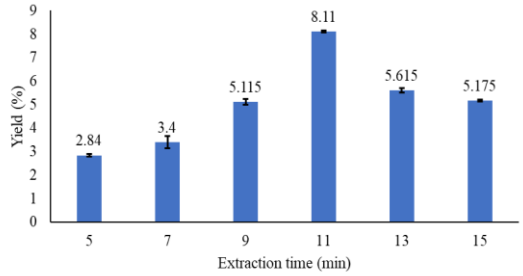

Fig. 2. Effect of extraction time on pectin yield

This is in accordance with the statement of Kanse et al. [19], that the pectin extraction factor is influenced by pH, temperature, solvent used, and extraction time. In general, longer extraction time produces higher pectin yield, but only up to a certain limit. It is stated that extreme extraction times can reduce pectin yield and reduce it from its maximum level due to pectin degradation. In line with the research of Beghreian et al. [9], molecular weight decreases with increasing heating time; moreover, the reduction in molecular weight is greater with increasing power.

The decrease in molecular weight with increasing heating time and microwave power (temperature) can be explained by this theory that continuous heating of pectin can cause disaggregation of the pectin network into its component parts (pectin degradation). When compared with the results of conventional rambutan skin pectin extraction carried out by Laiya et al. [20], under extraction conditions of 80°C for 120 minutes, the highest yield obtained was 8.02%. This shows that the MAE extraction time of 11 minutes can match the conventional extraction time of 120 minutes.

3.2.3 Effect of F/S ratio on pectin yield.

The effect of f/s ratio on pectin yield can be seen in Figure 3. The highest pectin yield obtained was 6.48% (w/w) at the ratio of 1:20 (w/v) followed by ratio of 1:30 and 1:40 (w/v) with their perspective pectin yield of 5.45% and 5.03%. This result may be attributed to the fact that the 1:20 ratio creates a more acidic solvent mixture (lower pH) compared to the others. This is because a larger f/s ratio (such as 1:40) dilutes the citric acid concentration in the same volume of solvent [21].

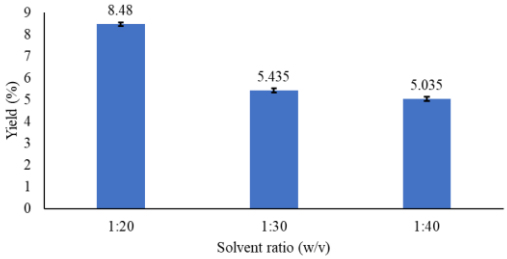

Fig. 3. Effect of f/s ratio on pectin yield

The 1:20 ratio also produced a higher yield because it was combined with the optimal microwave power (540 Watts). In this case, a more concentrated acid facilitates better penetration into the plant material. However, this also increases the risk of degradation. A higher acid concentration, especially when paired with elevated temperatures, can accelerate demethylation. Prolonged exposure to concentrated acid and heat may lead to pectin degradation under certain conditions [22].

4. Conclusion

This study found that higher microwave power within a certain limit—longer extraction time, and lower pH levels (achieved through a lower f/s ratio) can increase pectin yield. The highest yield was obtained using 540 Watts of microwave power, 11 minutes of extraction time, and f/s ratio of 1:20 (w/v). However, certain limits of each factor should also be considered to avoid pectin degradation which can reduce its yield.

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