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Characterization of melon (var *Sky Rocket*) peel pectin using microwave-assisted extraction at different powers and extraction times

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Abstract. *Aini N, Herdawan IS, Sustriawan B, Setyawati R, Kurniawan REK, Suliman NM, Arsyistawa HS, Indarto. 2024. Characterization of melon (var* Sky Rocket*) peel pectin using microwave-assisted extraction at different powers and extraction times. Biodiversitas 25: 1528-1535.* Pectin is a heteropolysaccharide molecule that can be used as a thickening agent due to its ability to bind large amounts of water. Pectin can be obtained from fruit peels containing pectic compounds, one of which is melon. A modern extraction technique such as Microwave-Assisted Extraction (MAE) is appropriate because it requires a relatively short time and lower costs. The objective of the research was to determine the effect of power and time on the pectin extraction from melon peel using microwave-assisted extraction. Sample preparation was done by drying the melon peel and then crushing and sieving it to produce melon peel powder. The powder was extracted using combinations of various microwave power of 180 (D1), 270 (D2), and 360 (D3) watts and extraction time variations of 3 (W1), 5 (W2), and 7 (W3) minutes. The results showed that the best treatment combination was extraction using microwave power of 270 watts for 3 minutes, which produced melon peel pectin with a yield of 6.4%, moisture content of 8.85%, ash content of 7.73%, equivalent weight of 1,810.07 mg, methoxyl content of 2.46%, galacturonic acid content of 95.74%, and degree of esterification of 22.02%. Melon peel, usually considered waste, can be used more optimally as a source of pectin.

Keywords: Extraction, melon peel, microwave, pectin

Abbreviations: MAE: Microwave Assist Extraction

INTRODUCTION

Pectin is a heteropolysaccharide molecule in plant tissue's middle lamellae and main cell walls, particularly in the spaces between cellulose and hemicellulose (Su et al. 2019). Most of the food plants naturally contain a chemical called pectin. Pectin is a thickening agent because it binds a large amount of water and includes polysaccharide acids. Pectin is used in many different industries, including the food industry, to modify the functional properties of products, such as viscosity, emulsion properties, and gel formation. In the pharmaceutical industry, it is used as an additive to health products. It also lowers cholesterol and treats diarrhea (Cai et al. 2022).

The need for pectin is increasing along with the widespread use of pectin in various industrial fields. Indonesia imported about 69,097 kg of pectin in 2019. Pectin can be obtained from fruit peels, which contain pectic compounds. Pectin compounds in fruit peel can be extracted using an acid solvent. One type of fruit that has the potential to be a source of pectin is melon. Increasing melon production will result in a large amount of melon peel waste and melon dregs being underutilized. Melon peels are usually used as animal feed and plant fertilizer, so they become waste that causes environmental problems. Commercial production of pectin extraction uses orange and apple peel waste (Perina et al. 2007).

Several conventional extraction methods, namely maceration, soxhlet, and hydro distillation, need a large volume of solvents, specific temperature, and stirring. However, these extraction techniques require a lot of time and large volumes of solvent, and the pectin yields are low (Susanti et al. 2017). Another method, namely pectin extraction assisted by microwaves (microwave-assisted extraction), uses ultrasonics as a heating source. Modern extraction techniques require a relatively short time and lower costs. A previous study by Koh et al. (2014) showed that pectin extraction from jackfruit peel using Microwave-Assisted Extraction (MAE) requires less time; it contains less water and ash, so the pectin quality is better than that of the conventional method. The factors influencing pectin extraction are raw materials, extraction time, extraction

temperature, solvent concentration, type of solvent used, solid solvent ratio, surface area of raw materials, solvent pH, and stirring treatment (Perina et al. 2007). Susanti et al. (2017) performed microwave-assisted durian albedo pectin extraction using various power, i.e., 10%, 30%, and 50% of maximum power (399 watts) with an extraction time of 5 minutes. The result of Susanti et al. (2017) showed that the optimum yield was obtained at 30% of the maximum power (399 watts), which was 0.65 g, and the lowest at 10% of the maximum power (399 watts), was 0.58 g. Therefore, time and power influence the rate of the extraction process.

A study by (Parasu et al. 2021) on melon peel pectin extraction by the reflux extraction method showed that 90 minutes of extraction had a 6.86% yield, while 60 minutes produced a 2.29% yield. The microwave-assisted method in the melon peel extraction process is expected to speed up the extraction. The research aims to determine the effect of the interaction between the power of pectin extraction and time on the characteristics of the pectin produced.

MATERIALS AND METHODS

Materials

The research was conducted at the Agricultural Technology Laboratory of Jenderal Soedirman University. The main ingredient used in this study was the melon peel of the Sky Rocket variant obtained from Cherry Fresh Fruit Market, Purwokerto, Indonesia. The equipment was a microwave of Sharp type R650.

Sample preparation

The melon peel powder was prepared based on (Azis et al. 2020). The melon peel is separated from the flesh and dried in a cabinet dryer at 55°C for 16 hours. The dried melon peel was crushed and sieved with an 80 mesh sieve.

Pectin extraction

The extraction of pectin from melon peel is referred to the method of Sulihono et al. (2012) and Golbargi et al. (2021). 30 g of melon peel powder was placed into an Erlenmeyer flask and added with 600 mL of 2 N sulfuric acid. The solution was then heated in a microwave with varying power (180, 270, and 360 watts) and time (3, 5, and 7 minutes). After extraction, the solution is filtered using a thick cloth to separate the filtrate from the pulp. The filtrate was placed in a beaker, added with 96% ethanol, as much as 1.5 times the volume, and allowed to settle for 24 hours. The precipitate was separated from the solution using filter paper and washed with 96% ethanol to remove the remaining acid. It is repeated until the pectin is neutral, as indicated by the pectin not turning red when the indicator Phenolphthalein (PP) is added. The wet pectin is dried in a cabinet dryer at 55°C for 24 hours. The dried pectin is ground into powder.

Experimental design

This research uses a factorial Completely Randomized Design (CRD) with 2 factors: power and extraction time. The power consisted of 3 levels, namely 180 watts (D1), 270 watts (D2), and 360 watts (D3), while the extraction time consisted of 3 levels, namely 3 minutes (W1), 5 minutes (W2), and 7 minutes (W3). The experiment has three replications.

Variables

The variables were yield, equivalent weight, moisture content, ash content, methoxyl content, galacturonic acid content, and degree of esterification.

Yield

The calculation of pectin yield refers to the method of Silsia et al. (2021). The dry pectin was weighed to calculate the yield, using Equation (1).

$$Yield\ (\%) = \frac{dry\ pectin\ weight\ (g)}{dry\ matter\ weight\ (g)}\ x\ 100\% \quad (1)$$

Equivalent weight

Equivalent weight analysis refers to the method of (Sulihono et al. 2012) 0.5 g pectin was placed in an Erlenmeyer flask, and 2 mL of 96% ethanol was added. Then, it is dissolved in 40 mL of distilled water and 5 drops of Phenolphthalein (PP) indicator. Next, the solution was titrated slowly with standard 0.1 N NaOH until the solution changed color. Then, the equivalent weight is calculated by Equation (2).

$$Equivalent\ weight\ = \frac{pectin\ mass\ after\ drying\ (mg)}{mL\ NaOH\ x\ N\ NaOH} \quad (2)$$

Moisture content

Moisture content analysis refers to the (AOAC 2005) method. The porcelain cup was dried in an oven at 105°C for 1 hour and then cooled in a desiccator for 15 minutes. The dried porcelain cup was weighed. 0.25 g was put into the cup and placed in an oven at 102-105°C for 30 minutes. Then, the cup was put into a desiccator and cooled for 30 minutes. Drying and weighing were carried out every 1 hour until a constant weight was obtained (<0.0003 g from the initial weight). The moisture content was calculated using equation (3).

$$Moisture\ content\ (\%) = \frac{weight\ of\ water\ lost\ (g)}{sample\ weight\ (g)}\ x\ 100\% \quad (3)$$

Ash content

Ash content analysis refers to the method of Silsia et al. (2021). 0.25 g of pectin was put into a porcelain cup that had been weighed, and its constant weight was known. The sample cup was covered, weighed, and placed into a furnace at 60°C for 6 hours, cooled in a desiccator to room temperature, and weighed to determine its weight. The ash content is calculated in Equation (4).

$$Ash\ content\ (\%) = \frac{initial\ weight\ (g)}{final\ weight\ (g)}\ x\ 100\% \quad (4)$$

Methoxyl content

Determining methoxyl levels is referred to the method of Sulihono et al. (2012). The neutral solution from the equivalent weight was added with 25 mL of 0.2 N NaOH solution, stirred until smooth, and left for 30 minutes at room temperature in a closed condition. Then, 25 mL of 0.2 N HCl solution and 5 drops of phenolphthalein indicator were added. The equation (5) was used to calculate the methoxyl content.

$$Methoxyl\ (\%) = \frac{mL\ NaOH\ x\ 31\ x\ N\ NaOH}{sample\ weight\ (mg)}\ x\ 100\% \quad (5)$$

Galacturonic acid

The galacturonic acid analysis referred to the method of Latupeirissa et al. (2019). Galacturonic acid is obtained from the determination of the milliequivalent weight (mEq) of NaOH in Equivalent Weight (EW) and the milliequivalent weight (mEq) of NaOH in methoxyl. Then, equation (6) is used to calculate the galacturonic acid content.

$$Galacturonic\ acid\ (\%) = \frac{(mEq\ EW + mEq\ methoxyl)\ x\ 176\ x\ N\ NaOH}{sample\ weight\ (mg)}\ x\ 100\% \quad (6)$$

Esterification degree

The esterification degree is calculated from the methoxyl and galacturonic acid content referred to by Picauly and Tetelepta (2020).

$$Esterification\ degree\ (\%) = \frac{176\ \%\ metoxyl}{31\ x\ \%\ galacturonic\ acid}\ x\ 100\% \quad (7)$$

Data analysis

The quantitative data was statistically analyzed using Analysis of Variance (ANOVA), with a significant level at $p<0.05$. Significant treatment differences were analyzed using Duncan's Multiple Range Test (DMRT). The statistical analysis was carried out using IBM SPSS Statistics version 26.

RESULTS AND DISCUSSION

Yield

The pectin yields of melon peel using various powers and times are presented in Figure 1. They were significantly different from each other. The mean values of D1 (180 watts), D2 (270 watts), and D3 (360 watts) treatments were 4.9%, 5.67%, and 5.92%, respectively (Figure 1). The pectin yield increases with the increase in extraction power. It is in line with a study by Golbargi et al. (2021) that the extraction of melon peel pectin using the Microwave-Assisted Extraction (MAE) method showed that the higher the extraction power, the higher the pectin. The yield of pectin at various power of 300, 450, and 600 watts was 18.4, 21.7, and 23.1%, respectively (Golbargi et al. 2021). It is due to a microwave unit consisting of an electric and magnetic field that can vibrate molecules and conduct ionic molecules, producing rapid heat.

Pectin yield is the weight of pectin produced from melon peel extraction in each treatment combination per weight of melon peel powder used. At high microwave power, the temperature increases to control the energy supplied to the material to be converted into heat energy in the raw material (Pasandide et al. 2017). According to Erliyanti and Rosyidah (2017), the higher the power, the higher the temperature. The temperature increase during extraction is a result of the ability of the materials and solvent to absorb energy and microwaves. The higher the power, the higher the energy the material receives to be converted into heat, so the yield is higher quickly. The temperature and power of a microwave can accelerate the destruction of plant cells, causing the pectin to diffuse out and dissolve in the solvent, resulting in increased pectin yield. Therefore, the higher the microwave power, the higher the pectin yield (Chen et al. 2022).

Meanwhile, pectin extraction at various lengths produces significantly different pectin yields. The average pectin yield at W1 (3 minutes), W2 (5 minutes), and W3 (7 minutes) were 4.76%, 5.43%, and 6.3%, respectively (Figure 2

Figure 2). The pectin yield increases with the length of extraction. According to Tongkham et al. (2017), long irradiation times cause higher heat accumulation in the extraction solution, increasing pectin yield. It is in line with the statement of Silsia et al. (2021) that the longer the extraction, the higher the yield due to the longer the contact between the solvent and the material. This process continues until it is optimal at a specific time. However, the excessive extraction time could result in a decrease in yield because the solvent becomes saturated.

A study by Silsia et al. (2021) showed that the extraction by the ultrasonic method of dragon fruit peel pectin using various lengths of extraction (15, 30, 60, and 90 minutes) increased pectin yield as the lengths of extraction increased. However, it would decrease at the excessive time of extraction. The yield of pectin produced by the ultrasonic method at varying times of 15, 30, 60, and 90 minutes was 5.66%, 10.58%, 13.57%, and 3.66%, respectively. This study proved that with an extraction time of up to 7 minutes, the solvent was not yet saturated and could produce a higher yield than 3 and 5 minutes.

Equivalent weight

Figure 3 shows that the weight of melon peel pectin equivalent is significantly different between D1 (180 watts) with D2 (270 watts) and D3 (360 watts), but D2 (270 watts) and D3 (360 watts) are not significantly different. However, the higher the power used, the equivalent weight decreases. According to Hosseini et al. (2019), increasing depolymerization or de-esterification of pectin indicates that pectic acid increases. Equivalent weight suggests the presence of free (non-esterified) galacturonic acid groups present in the pectin molecular chain. According to Latupeirissa et al. (2019), the equivalent weight of pectin decreases with increasing electrical power and extraction time (Ponmurugan et al. 2017; Latupeirissa et al. 2019).

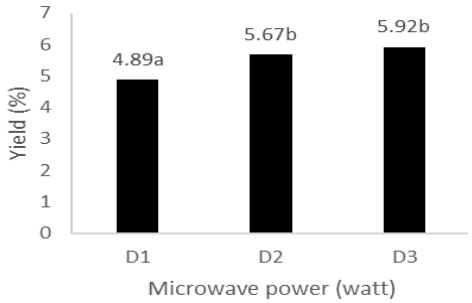

Figure 1. Yield of pectin from melon peel using MAE at varying microwave power

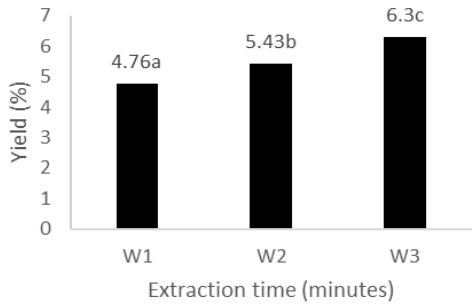

Figure 2. Yield of pectin of melon peel using MAE at varying lengths of extraction

In short extraction time, the pectin of melon peel still contains a lot of low-group protopectin. The lower the acid group, the higher the equivalent weight. Using higher power causes the extraction temperature to increase, resulting in the de-esterification process of pectin becoming pectic acid (Hosseini et al. 2016; Golbargi et al. 2021). The de-esterification process will increase the number of free acid groups. Increasing the number of free acid groups will reduce the equivalent weight.

Based on IPPA standards, the equivalent weight of pectin is 600-800 mg (Muñoz-Almagro et al. 2021). The equivalent weight of melon peel pectin produced in this study was more than 800 mg, so it did not meet IPPA standards. This equivalent weight is still higher than the standard, which is influenced by the quality of the pectin used. Several factors affect the equivalent weight value, i.e., the titration process and the nature of the extracted pectin, the quality of the raw materials, the extraction method, and the treatment in the extraction process.

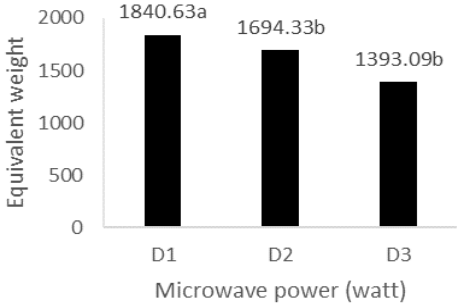

Figure 3. Equivalent weight of pectin from melon peel using MAE at varying microwave power

Moisture content

The moisture content of melon peel pectin using various microwave powers significantly differed among treatments. The average values of pectin moisture content produced in D1 (180 watts), D2 (270 watts), and D3 (360 watts) were 10.2%, 7.95%, and 6.17%, respectively (Figure 4). The moisture content of pectin decreases as the microwave power increases. According to Ozcelik et al. (2020), High microwave power increases the extraction temperature, which causes pectin hydrolyzation, so the molecular chains become shorter. The shorter the chain of pectin polymer, the easier it is to dry due to less moisture trapped in it (Su et al. 2019). It is in line with the research results of Djaeni et al. (2017), where the amount of water in pectin is inversely proportional to the power used.

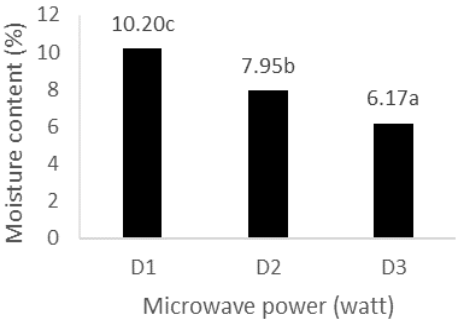

Figure 4. The moisture content of pectin from melon peel using MAE at varying microwave power

It is shown in Figure 5 that the average value of pectin moisture content produced at W1 (3 minutes), W2 (5 minutes), and W3 (7 minutes) were 8.76%, 8.04%, and 7.48%, respectively. The moisture content of pectin decreased as the extraction time increased. It is in line with Nuh (2017) that extracting *kepok* banana peel pectin with various lengths of times (1.5 hours, 2 hours, 2.5 hours, and 3 hours) produces pectin moisture content which decreases as the extraction time increases. The moisture content of pectin produced by the ultrasonic method at 1.5, 2, 2.5, and 3 hours was 10.82, 10.7, 10.62, and 10.3%.

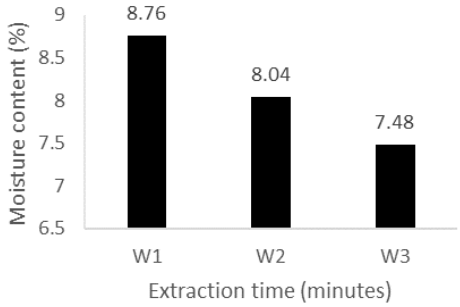

Figure 5. The moisture content of pectin from melon peel using MAE at varying extraction times

Chandel et al. (2022) stated that the longer the extraction time, the lower the pectin moisture content. High extraction temperatures and times will hydrolyze the pectin polymer into shorter chains, making drying easier. The higher the electrical power and the longer the extraction time, the more water vapor evaporates, so the moisture content in the pectin decreases. Based on IPPA standards, the maximum moisture content in pectin is 12%. The moisture content of the melon peel pectin in this study in all treatments was less than 12%, which meets the IPPA standards.

Ash content

The average ash content of pectin in D1 (180 watts), D2 (270 watts), and D3 (360 watts) were 6%, 8.53%, and 10.98%, respectively (Figure 6). The ash content of pectin increases with increasing microwave power. Increasing microwave power increases temperature, which results in protopectin hydrolysis. The higher the microwave power, the higher the intensity of microwave radiation, so more electromagnetic energy is converted into heat energy, which is indicated by an increase in temperature. High temperatures help the diffusion of solvents into plant tissue and increase solvent activity in hydrolyzing pectin, which is generally found in primary plant cells. Hydrolysis of protopectin causes an increase in calcium and magnesium content. According to Su et al. (2019), in the hydrolysis process of protopectin into pectin, there is a change in the state of calcium and magnesium ions by hydrogen ions originating from sulfuric acid to become calcium sulfate and magnesium sulfate under acidic conditions. A previous study by Koh et al. (2014) showed that the extraction of pectin from jackfruit peel using the Microwave Assisted Extraction (MAE) method at various powers (400, 600, and 800 watts) produced pectin with increasing ash content by increasing extraction power.

The ash content of melon peel pectin with various extraction times significantly differed between treatments. The average ash content of pectin produced in W1 (3 minutes), W2 (5 minutes), and W3 (7 minutes) were 7.82%, 8.49%, and 9.2%, respectively (Figure 7). The ash content of melon peel pectin increased with the increasing extraction time. A study by Dong et al. (2021) showed that the ash content of orange peel pectin obtained from the microwave assisted extraction method increased as the extraction time increased. The ash content indicates the inorganic components in the pectin. These inorganic components are calcium and magnesium, which are hydrolyzed together with protopectin. The ash content influences the level of pectin purity; i.e., the lower the ash content, the better the pectin purity.

Patience et al. (2021) showed that the longer the extraction time, acid treatment, and contact between the material and the solvent, the more protopectin hydrolyzed. It results in more mineral components being released and higher ash content. According to Su et al. (2019), the stronger the acid used in pectin extraction, the more the protopectin hydrolysis and the Ca and Mg components in the extract solution increased. This study used a strong sulfuric acid as a solvent, resulting in a high ash content.

The maximum ash content in pectin is 10% based on IPPA standards. This study showed that the ash content of melon peel pectin was less than 10%, so they met the IPPA standards.

Methoxyl content

Melon peel pectin extracted with various microwave powers had significantly differed methoxyl content. The methoxyl contents in D1 (180 watts), D2 (270 watts), and D3 (360 watts) were 2.16%, 2.61%, and 3.12%, respectively (Figure 8). As the microwave power and time increase, the methoxyl pectin content increases. A previous study by Koh et al. (2014) showed that the extraction of jackfruit peel pectin using the Microwave-Assisted Extraction (MAE) method increases the methoxyl content as the power increases, with the methoxyl content at 300 watts and 400 watts were 7% and 7.1%, respectively.

Methoxyl content is the amount of methanol in pectin and the number of esterified carboxyl groups (Costa et al. 2022). The methoxyl content in pectin is influenced by the heating temperature, the solvent's pH, and the heating time (Ponmurugan et al. 2017). Power and extraction temperature are interrelated, i.e., the power increases, so the temperature increases. A study by Tambunan et al. (2022) showed that high temperatures and concentrations accelerate the hydrolysis of protopectin from orange peel, increasing the methoxyl levels. The higher the temperature, the faster the esterification reaction of carboxylic acid by methyl ester (Ahmed and Sikder 2019). Increasing esterified carboxylic acids or methoxyl groups will increase the methoxyl content of pectin.

The mean values of methoxyl content in the treatment of W1 (3 minutes), W2 (5 minutes), and W3 (7 minutes) were 2.46%, 2.63%, and 2,8% (Figure 9). Methoxyl pectin levels increased with increasing extraction time. The longer the protopectin hydrolysis, the longer the polygalacturonate chain, and the higher the esterification level (the number of carboxyl groups that undergo the methylation process). The increase in methoxyl due to carboxyl groups in pectin can undergo esterification with alcohol to increase the pectin's methoxyl content (Chandel et al. 2022).

The methoxyl in pectin plays a role in determining the pectin solution's functional properties and influences the pectin gel's structure and texture (Muñoz-Almagro et al. 2021). The pectin in this study is categorized as low methoxyl pectin because it has a methoxyl content value of less than 7%. Low methoxyl pectin cannot form gels in the presence of sugar and acid but can form gels in the presence of bivalent cations (Roque et al. 2022). Low methoxyl pectin does not require high sugar levels for gel formation, so it can be used as a thickener in making low-calorie drinks, jelly for diabetes, and other healthy foods (Liu et al. 2022).

Galacturonic acid

The average value of galacturonic acid content of pectin from extraction with various microwave powers is significantly different among treatments. The average values of galacturonic acid at the treatment of D1 (180 watt), D2 (270 watts), and D3 (360 watts) were 17.39%, 20.37%, and

24.31%, respectively (Figure 10). As the power increased, the galacturonic acid also increased. Muñoz-Almagro et al. (2019) reported that the level of galacturonic acid produced from cocoa pod husk pectin using the Microwave Assisted Extraction (MAE) method increases with increasing extraction power. According to Ahmed and Sikder (2019), the hydrolysis of protopectin rises as the power used increases, causing more and more bonds between the galacturonate pectin component and other compounds, i.e., cellulose, to be broken. It increased the production of pectin galacturonic acid.

The average galacturonic acid content of pectin from various extraction times significantly differs between treatments. The galacturonic acid content in the treatment of W1 (3 minutes), W2 (5 minutes), and W3 (7 minutes) extraction times were 19.49%, 20.78%, and 21.90%, respectively (Figure 11). Galacturonic acid levels increase with increasing extraction time due to the increasing hydrolysis of protopectin into pectin. Fibrianto et al. (2020) showed that galacturonic acid levels of banana peel pectin using the Microwave-Assisted Extraction (MAE) method increase with the length of extraction time. Long extraction times result in the hydrolysis of pectin into galacturonic acid. Under acidic conditions, the glycosidic bonds of the methyl ester groups of pectin tend to be hydrolyzed to produce galacturonic acid.

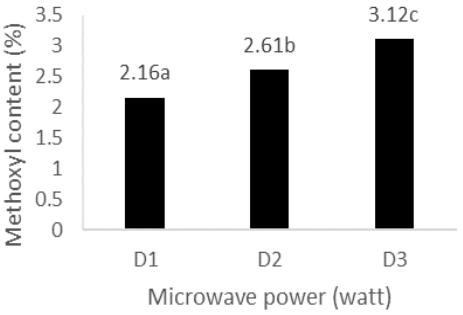

Figure 8. The methoxyl content of pectin from melon peel using MAE at varying microwave powers

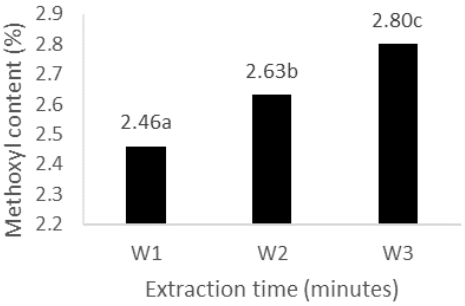

Figure 9. The methoxyl content of pectin from melon peel using MAE at varying extraction times

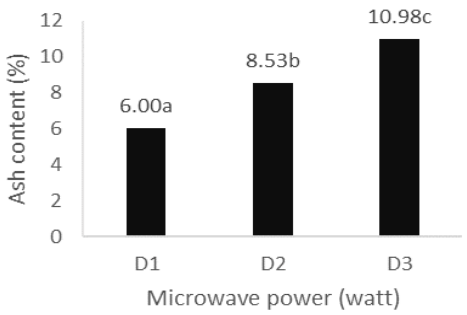

Figure 6. The ash content of pectin from melon peel using MAE at varying microwave power

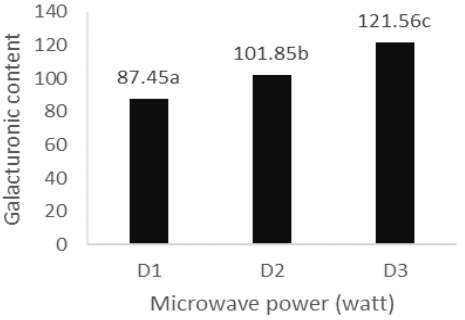

Figure 10. The galacturonic acid content of pectin from melon peel using MAE at varying microwave power

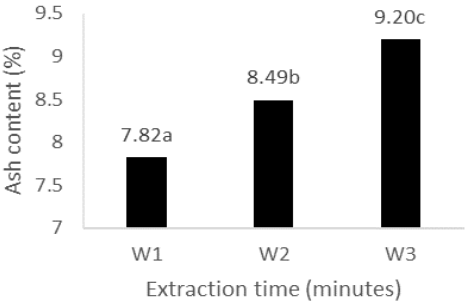

Figure 7. The ash content of pectin from melon peel using MAE at varying extraction times

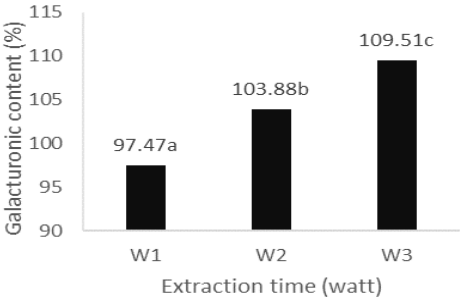

Figure 11. The galacturonic acid content of pectin from melon peel using MAE at varying extraction times

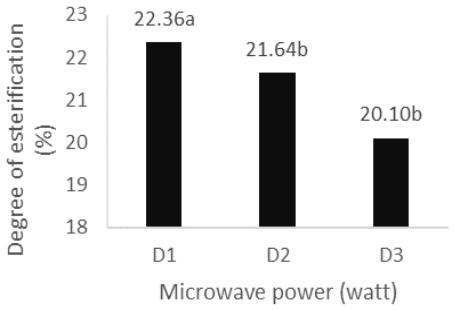

Figure 12. Esterification degree of pectin from melon peel using MAE at varying microwave power

Galacturonic acid is the basic framework of pectin compounds describing pectin's purity. Galacturonate content and pectin molecular charge function determine pectin's functional properties. Galacturonate levels can affect the structure and texture of pectin gel (Gawkowska et al. 2018). The higher the galacturonic acid content, the higher the purity of the pectin due to the lower organic content such as arabinose, galactose, rhamnose, and other types of sugar. The large amount of galacturonic acid content also influences the gel formation. The more galacturonic acid content, the stronger the three-dimensional network is formed to trap all the liquid, resulting in a firmer gel.

Galacturonic acid is affected by the raw material source, solvent, and extraction method used. Apart from galacturonic acid, pectin also contains other compounds, namely neutral sugars such as D-galactose, L-arabinose, L-rhamnose, and different types of sugar. These non-uranate compounds can be carried away during the pectin clumping process to affect the composition of pectin compounds. The extraction method can also influence the composition of pectin compounds, affecting the galacturonate levels (Christiaens et al. 2016). Based on IPPA standards, the galacturonic acid content in pectin is at least 35%. The galacturonic acid levels of melon peel pectin in this study were above 35%, so they met the IPPA standards.

Degree of esterification

It is shown in Figure12 that the average value of the degree of esterification of pectin in D1 (180 watts), D2 (270 watts), and D3 (360 watts) were 22.36%, 21.64%, and 20.10%, respectively (Figure 6). The higher the power and extraction time, the decrease in the degree of esterification of melon peel pectin. This aligns with the degree of esterification of pectin produced from the extraction of jackfruit peel and banana peel pectin using the microwave-assisted extraction method, which decreases as the power used increases.

The degree of esterification shows the amount of D-galacturonic acid residue in percent units where the carboxyl group is esterified by ethanol (Christiaens et al. 2016). The decrease in the degree of esterification at higher extraction temperatures is due to the higher extraction temperature increase in the esterification of pectin, so the value of pectin esterification is lower. During the extraction process, a de-esterification process always occurs. Golbargi et al. (2021) stated that microwave power causes the degradation of the methyl ester groups in pectin to carboxylic acid due to the presence of acid. Acids hydrolyze hydrogen bonds in the methyl ester groups of pectin to become galacturonic acid.

According to (Maran et al. 2015), the degree of esterification decreases with increasing temperature and extraction time. High temperatures and long extraction times caused degradation of the methyl ester groups in pectin to carboxylic acids due to the presence of acid (Latupeirissa et al. 2019). The methyl ester of pectin tends to be hydrolyzed to galacturonic acid. Prolonged extraction caused the pectin to turn into pectic acid, where the galacturonic acid is free from methyl ester groups. The number of methyl ester groups indicates the number of unesterified carboxyl groups (Latupeirissa et al. 2019). Based on IPPA standards, the degree of esterification in pectin should be less than 50%.

The research findings indicate that the microwave power in the extraction process significantly impacts the characteristics of pectin derived from the melon peel. Elevated microwave power corresponds to increased pectin yield, pectin ash content, methoxyl content, and galacturonic acid content. However, it simultaneously decreases pectin moisture content, equivalent weight, and pectin esterification degree. Furthermore, a prolonged extraction duration yields higher pectin yield, pectin ash content, methoxyl content, and galacturonic acid content while diminishing the moisture content of the extracted pectin. Notably, the combination of both factors does not exhibit any significant interaction effect between microwave power and extraction duration on the characteristics of the resulting pectin. However, the best treatment combination was extraction using microwave power of 270 watts for 3 minutes, which produced melon peel pectin with a yield of 6.4%, moisture content of 8.85%, ash content of 7.73%, equivalent weight of 1,810.07 mg, methoxyl content of 2.46%, galacturonic acid content of 95.74%, and degree of esterification of 22.02%. Based on the research results, it can provide implications, namely considering melon peel as cheaper and more environmentally friendly source of pectin raw materials. Knowing the effect of extraction power and time on the pectin quality can also provide information so that the extraction process can be optimized more efficiently to produce better-quality pectin.

On the other hand, the results of this research can be a reference for optimizing the use of melon peel as a source of pectin. Melon peel, usually considered waste, can be used more optimally as a source of pectin by considering the parameters produced in this research, such as optimal extraction power and time. Overall, the results of this research can provide practical and theoretical benefits in developing cheaper, environmentally friendly, and more sustainable sources of pectin raw materials.

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