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Extraction of Polyphenols from Horn Banana Peel (*Musa Paradisiaca var. Typica*) Using the Ultrasound-Assisted Extraction Method

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Abstract. Banana peel contains starch, protein, fat, total fiber, unsaturated fatty acids, pectin, amino acids, polyphenols, and micronutrients. Horn banana peel has many benefits, namely, it can be processed into a natural antioxidant material that can minimize banana skin waste. The banana peel extraction method used is Ultrasound Assisted Extraction. Ultrasound-assisted extraction at optimal conditions produces good levels of total polyphenols with a short extraction time. In the use of ultrasonic no additional chemicals or other materials are needed. This study aims to determine the effect of extraction time (10, 20, 30 minutes), extraction temperature (20, 30, 40 °C), and solvent ratio (gr/mL) (1:25, 1:30, 1:35) on polyphenols. The Design Expert V13 program with Response Surface Methodology (RSM) Box-Behnken Design (BBD) was used to determine the combination of extraction parameters that lead to optimal results for total polyphenol content. Based on the research that has been done, it can be stated that the extraction parameters affect the total polyphenol content. The highest total polyphenol content was 61,007 mg GAE/g sample with the extraction conditions at an extraction temperature of 30°C, an extraction time of 30 minutes, and a ratio of banana peel powder to a dissolution of 1:30 g/mL.

Keywords: *Banana Peel, Polyphenols, and Ultrasound-Assisted Extraction*

1. Introduction

Bananas are a fruit that contributes around 30% of fruit production in Indonesia [1]. Based on the Central Statistics Agency and the Directorate General of Horticulture in 2021, it was reported that the amount of banana production in East Java reached 2.116.974 tons with the highest number of banana producers in Indonesia [2]. Until now, the banana plant that is often used is still limited to the fruit part, while other parts of the banana plant are considered

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waste and there is little further processing of some of these parts [3]. The peel of the horned banana (Musa Paradisiaca var. Typica) is one of the by-products of using bananas [4]. Horned banana peels are not widely used by the public, banana peels can be processed into fertilizer, purifying water, and heavy metals, lead (Pb) and copper (Cu) [5–7]. However, banana peel processing in Indonesia has not been utilized optimally compared to the amount of banana production in Indonesia [8]. Banana peel contains starch (3%), protein (6-9%), fat (3.8% - 11%), total fiber (43.2% - 49.7%), and unsaturated fatty acids, pectin, amino acids, and micronutrients [9]. Based on research conducted by Idah (2017) on banana peel extraction, shows that the total polyphenol content is 3.50104 w/v or 35.0104 mg GAE/g extract.

Antioxidant behavior is related to anthocyanins and the constituents of antioxidants are anthocyanins [10]. Anthocyanins are polyphenolic derivative compounds contained in various types of plants and have many important physiological functions in every living organism. Anthocyanins in plants are widely used in the food, health, and cosmetic industries because they do not have harmful effects. Currently, there are ±700 types of anthocyanins isolated from various types of plants and they have been identified, including pelargonidin, cyanidin, peonidin, delphinidin, petunidin, malvidin, and anthocyanidin glycosides Banana peels are rich in several antioxidants [11]. Banana peels also contain active compounds, namely tannins, saponins, flavonoids, and phenols [12]. Phenolic compounds are bioactive secondary metabolites that are channeled by cicamic acid, pentose phosphate, and the phenylpropanoid pathway [13]. Phenolic compounds are divided into subgroups of phenolic acids, flavonoids, tannins, and stilbenes based on the number of attached phenolic hydroxyl groups and the structure that links the benzene ring [14]. Phenolic compounds are known to be able to prevent and treat several diseases such as arteriosclerosis, brain dysfunction, cancer, and diabetes [15].

Several extraction methods can be used to extract polyphenols from banana peels, one of which is UAE (Ultrasound-Assisted Extraction) [16]. The UAE method under optimal conditions produces a good amount of phenolic when compared with the heat reflux method [17]. The maceration method requires a long extraction time and produces a smaller yield compared to the UAE method [18]. When using ultrasonics, no additional chemicals or other ingredients are needed [19]. The UAE method also doesn't cost too much [20]. Extraction using the UAE method also produces high yields [21]. The use of ultrasonics in the process of extracting organic compounds in plants and grains with organic solvents occurs quickly [22 – 26]. The cell walls of the material can be broken down with ultrasonic vibrations so that the

contents can be released easily [27]. The use of conventional methods for banana peel extraction can be seen in Table 1.

Table 1. Research on Various Types of Ultrasound-Assisted Extraction Methods

Raw Material	Method	Solvent	Extraction condition	Target Compound	Yield
Cratoxylum cromossum ssp. Formosum [28]	*Ultrasonic Assisted Extraction* (UAE)	Ethanol	Temperature 30, 45, 60, 75 °C, Time 10, 20, 30, 40, 50 minutes, Ratio 1:10, 1:20, 1:30, 1:40, 1:50 and Ethanol concentration 0, 25, 50, 75, 100%	Polyphenol	40.00±1.00 mg/100 g gallic acid
Pumpkin and peach [29]	*Ultrasonic Assisted Extraction* (UAE)	Methanol	Temperature 30, 40, 50°C, Time 10, 20, 30 minutes, and Power 30, 50, 70%	Polyphenol	44.09±1.09 mg/100 g gallic acid
Dayak Onion [30]	*Ultrasonic Assisted Extraction* (UAE)	Aquadest	Temperature 30°C, Frequency 40 kHz, Power 100%, Time 30, 45, 60, 75 minutes, solvent volume 200, 240, 280, and 320 mL	Polyphenol	2.20 mg GAE/gram Dayak onion
Kaffir Lime [31]	*Ultrasonic Assisted Extraction* (UAE)	Ethanol	Temperature 10, 20, 30°C and preeliminary treatment of kaffir lime peel consisting of dried orange peel and fresh orange peel	Essential oil	11.730%
Mangosteen Skin [32]	*Ultrasonic Assisted Extraction* (UAE)	Ethanol 96%	Time 15, 30, 45 minutes, and ultrasonic amplitudes 35, 50, 65%	Antioxidant	6.71%
Red Dragon Fruit Skin [33]	*Ultrasonic Assisted Extraction* (UAE)	Aquadest and Citric Acid	Time 15, 30, 45 minutes and Amplitudes 65% and 95%	Anthocyanin	24.074 ppm
Cocoa Shell [34]	*Ultrasonic Assisted Extraction* (UAE)	Aquadest and Ethanol	Temperature 50 – 60°C which was carried out for 3 hours	Antioxidant	Without treatment (88.38%), aquadest solvent (90.61%), ethanol solvent (92.78%)
Cocoa Shell [35]	*Ultrasonic Assisted Extraction* (UAE)	Ethanol 80%	Ethanol solvent 80% with ratio 1:10, frequency 40 kHz, 296 W, 55°C for 45 minutes	Antibacterial	107.8±27.0 µm
Cocoa Shell [36]	*Ultrasonic Assisted Extraction* (UAE)	Ethanol 96%	Operation Time 2×30 minutes	Antibacterial	2%
Pomegranate Peel [37]	*Microwave Assisted Extraction* (MAE)	Aquadest, Ethanol 50 and 70%. Methanol 50 and 70%	Aquadest, Ethanol 50 and 70%. Methanol 50 and 70%. Ratio 60/1 mL/g. Power 600 W	Polyphenol	199.4 mg GAE/g dry skin

Raw Material	Method	Solvent	Extraction condition	Target Compound	Yield
Lime Peel [38]	*Ultrasonic Assisted Extraction* (UAE) and *Microwave Assisted Extraction* (MAE)	Ethanol 55%	MAE, ethanol 55%, Power 140 W for 45 seconds with 8 repetition of extraction steps. UAE, ethanol 55%, amplitudes 38%, and time 4 minutes	Polyphenol	54.4 mg GAE/g
Chayote [39]	Percolation	Ethanol	Time 2, 3, and 4 hours. Ratio 1:5, 1:10, and 1:15. Ethanol concentration 30, 50, 70%	Polyphenol	2.50 mg EAG/g
Cocoa Shell [40]	Maceration	Ethanol and Acetone:Water	Ethanol solvent 70% and acetone:water (7:3)	Phenol, Tannin, and Flavonoid	Ethanol 70% = 6.948%. Acetone:water (7:3) = 8.327%
Kepok Banana Peel [41]	Maceration	Alcohol 97%	Banana peel water concentration 20%, 40%, 60%, 80%, and 100%	Antioxidant	60.50 ppm
Green Tea [42]	Maceration	Aquadest	Stirring 110 and 200 rpm. Size 80 – 100 mesh, Temperature 80°C	Polyphenol	29.3%
Arabica and Robusta Coffee Skin [43]	Maceration	Ethanol	Temperature 75, 85, and 95°C. Ratio 1:100, 2:100, and 3:100. 2 types of coffee arabica and robusta	Polyphenol	8.089%

The solvent used in this research is 96% ethanol, ethanol is an organic solvent that contains polarity according to anthocyanin [33]. Choosing an extraction time that is too long to extract banana peel will require more energy and can damage the bioactive compounds being extracted [44]. The length of extraction time is also in line with the quantity of extract produced, this is because the length of contact between the material and the solvent is greater [45]. When the material reaches the saturation point, the increase in extract yield will stop or run out [46]. Too long sonication time can increase the temperature of the solution compared to the rate of temperature reduction by the extraction temperature controller so that it can degrade the extracted anthocyanin content [47]. An increase in temperature during the extraction process is too high along with a reduction in viscosity and surface tension can cause only a few bubbles to burst [48]. The temperature in the ultrasonic bath is controlled by the external circulation of the water bath thermostat and a predetermined frequency [49]. Temperature control is very necessary for maintaining consistency of extraction temperature with the heat exchanger

principle [50, 51].

This research aims to determine the effect of extraction temperature, extraction time, and solvent–material ratio on the extraction of polyphenolic compounds from horn banana peels. The ultrasonic-assisted extraction method was chosen as a conventional extraction method because it is cheap, simple, and efficient.

2. Material And Methods

2.1 Materials

Horn banana peel was obtained from Klakah Village, Klakah District, Lumajang Regency, East Java. Ethanol with a concentration of 96%, distilled water, Na_2CO_3 (p.a. Merck), folin ciocalteu reagent (p.a. Merck), and gallic acid (p.a. Merck). All reagents were analytical grade and were used without further purification.

2.2 Equipment

The tools used are Ultrasonic Batch (BAKU BK-1200 1.47L), oven (Envilife), UV-Vis Spectrophotometer 752AP, Analytical Balance (Pioneer), and Blender (Philips HR-2115), glass beaker, spatula, aluminum foil, and watch glass.

2.3 Methods

2.3.1 Determination of Extraction Parameters

The research formulation design and response analysis were carried out using the Design – Expert V13 program with Response Surface Methodology (RSM) Box – Behnken Design. In this study, the dependent variable was the concentration of extracted polyphenolic compounds. The independent variables are extraction time, ratio of horn banana peel powder to solvent, and temperature with limit values of 10 to 30 minutes, 0.285 to 0.4 gram/mL, and 30 to 50°C respectively. These values are introduced to the program to obtain the selected combination as in table 2.

Table 2. A combination of Extraction Parameters was Used in this Study

Run	Time Extraction (minutes)	Ratio Banana Peel with Solvent (g/mL)	Temperature (ºC)
1	20	1:30	40
2	20	1:30	40
3	20	1:30	40
4	20	1:35	30
5	10	1:30	30

Run	Time Extraction (minutes)	Ratio Banana Peel with Solvent (g/mL)	Temperature (ºC)
6	30	1:25	40
7	20	1:35	50
8	30	1:30	50
9	20	1:25	30
10	30	1:30	30
11	10	1:25	40
12	10	1:35	40
13	20	1:30	40
14	10	1:30	50
15	20	1:25	50
16	30	1:35	40
17	20	1:30	40

2.3.2 Extraction of Horned Banana Peel Waste

The banana peel is cut into small pieces and then dried using an oven at a temperature of 50°C [52]. The water content produced during this drying process is 8.4%. The dried fruit skin is mashed using a blender (1). The sample is then sieved to the desired particle size at 80 mesh [23]. Banana peel powder was dissolved in 96% ethanol with a predetermined ratio (Table 2). The mixture was put into an extraction container and subjected to ultrasonic treatment with varying times and temperatures (Table 2) according to the following scheme (Figure 1). The mixture was filtered with filter paper and the filtrate obtained was collected as an extract.

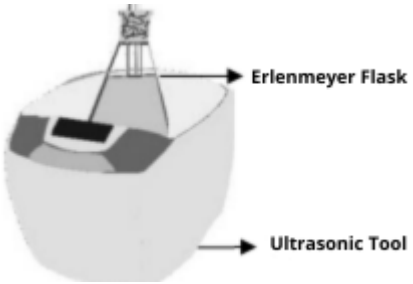


Figure 1. Schematic Representation of Ultrasonic Assisted Extraction of Horned Banana Peel Waste

2.3.3 Water Content Analysis

Determination of water content uses the drying method or thermogravimetric method, which is done by drying the material in an oven at a temperature of 105 – 110°C until a constant mass is obtained. Water content is defined as the mass ratio of the water phase to the solid phase, expressed as a percentage [53 – 55]. Calculation of the percentage of water content can be calculated using the formula:

$$\% \text{ Water content} = \frac{\text{Initial Mass} - \text{Final Mass (Constant)}}{\text{Initial Mass}} \text{ x } 100\ \% \qquad (1)$$

2.3.4 Determining Total Polyphenol Content

The total polyphenol content in each filtrate was determined using the Folin – Ciocalteu method of Norra *et al.* (2016) with slight modifications [60, 61]. This method is easy to perform, fast, and does not require expensive reagents [62]. The measurement begins by mixing 0.5 mL of 50% Folin – Ciocalteu reagent with 0,5 mL of sample filtrate. The mixture was stirred until homogeneous and left for 5 minutes, then 4 mL of 7.5% Na_2CO_3 and distilled water were added until the volume became 10 mL. samples were incubated for 30 minutes at room temperature. The absorbance of the filtrate was measured using a UV – Vis Spectrophotometer at a wavelength of 765 nm in triplicate [64, 64]. A Calibration curve for a standard solution of gallic acid with concentrations of 1, 2, 3, 4, and 5 ppm was created. Total polyphenol content was expressed as gallic acid equivalents in mg per gram dry weight of simplicial (mg GAE/g) [65]. Total polyphenol content can be determined using Equation 2 [66].

$$Total\ Polyphenol\ Content = \frac{Vs\ (ml) \times C\left(\frac{mg}{L}\right) \times Fp}{B} \qquad (2)$$

where Total polyphenol content in mg GAE/g, Vs is sample volume (mL), C is polyphenol concentration (mg/L), Fp is dilution factor, and B is mass of banana peel extract (g).

2.3.5 Data Analysis

This research used Design Expert 13 software and Response Surface Methodology (RSM) with Box Behnken type to determine the effect of parameters (extraction time, extraction temperature, and ratio between Horned powder and solvent) on total polyphenol content. A total of 17 combinations of extraction conditions will be applied to carry out an Analysis of Variance (ANOVA).

3. Results And Discussion

3.1 Extraction of Total Polyphenol Content from Horned Banana Peel

This research was carried out from November 2022 to March 2023 at the Basic and Process Laboratory, Chemical Engineering Study Program, Department of Mechanical Engineering, Faculty of Engineering, University of Jember. This research used Tanduk banana skin to be extracted and tested for total polyphenol content using the UAE extraction method. The water content value of the Banana Peel material is 8.4%. The total polyphenol content test in the extraction of horn banana peel

waste using the UAE method was carried out using the spectrophotometric method [67]. Spectrophotometric determination of polyphenol levels used Folin – Ciocalteu reagent. The hydroxyl group of the phenolic compound reacts with the Folin – Ciocalteu reagent to form a tungsten molybdenum complex blue which can be detected using a spectrophotometer. The addition of 7.5% Na_2CO_3 in the process of determining polyphenol levels aims to create alkaline solution conditions, this is because polyphenols and Folin – Ciocalteu can only react in alkaline conditions [68].

Determination of total polyphenol content using a standard solution, namely gallic acid (GAE). The use of gallic acid as a measurement standard is because gallic acid is a derivative of hydroxybenzoic acid which is a simple phenolic acid. The organic acid phenol content is pure and stable. The total polyphenol content is expressed in GAE (gallic acid equivalent), that is the equivalent number of milligrams of gallic acid in 1 gram sample [69]. Determination of total polyphenol levels in samples using the linear equation of the gallic acid standard curve, $y = 0.0863x + 0.0029$ ($R^2 = 0.9952$). An R-value that is close to 1 indicates the regression equation has approached linearity [70, 71]. The results of the analysis of the polyphenol content of Horned Banana Peel can be seen in Table 3

Table 3. Total Polyphenol Content in the Filtrate Resulting from the Extraction of Horned Banana Peels

Run	Extraction Time (minutes)	Ratio Banana Peel with Solvent (g/mL)	Temperature (ºC)	Polyphenol yield (mg GAE/g sample)
1	20	1:30	40	46.573
2	20	1:30	40	47.386
3	20	1:30	40	45.353
4	20	1:35	30	35.319
5	10	1:30	30	38.238
6	30	1:25	40	54.330
7	20	1:35	50	32.758
8	30	1:30	50	31.326
9	20	1:25	30	48.247
10	30	1:30	30	61.007
11	10	1:25	40	56.793
12	10	1:35	40	44.142
13	20	1:30	40	46.776
14	10	1:30	50	53.485
15	20	1:25	50	37.239
16	30	1:35	40	49.265
17	20	1:30	40	45.557

Based on the results of the research data in Table 3, it shows that the maximum total polyphenol content was obtained in the 10th running, 61.007 mg GAE/g sample, and the minimum total polyphenol content was obtained in the 8th running, that is 31.326 mg GAE/g sample. The 10th running obtained optimal results due to the maximum conditions in extracting polyphenols from horn banana peel waste, under the conditions of extraction time of 30 minutes, extraction temperature of 30°C, and the ratio of banana peel powder to solvent of 1:30. Phenolic compounds are the compounds most commonly extracted from horn banana peels. The total polyphenol content obtained from this research was greater when compared to research conducted by Ida (2018), the total polyphenol content of plantain peel extract had an average total phenolic content of 35 mg GAE/g [52]. In research conducted by Yulis (2020), the phenolic content of Muli banana peel extract was 100.016 mg GAE/g and Kepok banana extract was 32.176 mg GAE/g [12]. The difference in total levels of polyphenols produced is due to differences in extraction conditions and other factors that influence the extraction process, one of which is the type of banana peel extracted [72, 72].

3.2 Statistical Analysis

The results of research on polyphenol extraction from horned banana peel waste using the UAE method were analyzed by a Design Expert. Response surface analysis using Design Expert aims to determine appropriate data processing analysis. Data processing carried out included response analysis of total polyphenol content, Analysis of Variance (ANOVA) and also determining optimum extraction conditions [74]. Data on total polyphenol levels were then analyzed using Analysis of Variance (ANOVA) to prove that the parameters used in the extraction process could influence total polyphenol levels. ANOVA results are presented in Table 4.

Table 4. The Results of *Analysis of Variance* (ANOVA)

Source	Sum of Square	Df	Mean Square	F-Value	p-Value	
Model	1123.99	9	124.89	245.86	<0.0001	Significant
A-Temperature	98.02	1	98.02	192.97	<0.0001	
B-Times	1.34	1	1.34	2.63	0.1488	
C-Rasio d/p	154.22	1	154.22	303.60	<0.0001	
AB	504.63	1	504.63	993.43	<0.0001	
AC	17.84	1	17.84	35.12	0.0006	
BC	14.39	1	14.39	28.32	0.0011	
A^2	179.45	1	179.45	353.27	<0.0001	
B^2	162.55	1	162.55	320.00	<0.0001	

Source	Sum of Square	Df	Mean Square	F-Value	p-Value	
C^2	8.37	1	8.37	16.48	0.0048	
Residual	3.56	7	0.5080			
Lack of Fit	0.6306	3	0.2102	0.2874	0.8331	No significant
Pure Error	2.93	4	0.7313			
Cor Total	1127.54	16				

Based on the table above which was obtained using Design Expert software. The F Model value of 245.86 implies that the model is significant. There is only a 0.01% chance that an F value of this size could occur due to noise. The P – P-value of the model is <0.0001, this indicates that the model is significant. A significant model shows that the model has a real influence on the response to total polyphenol levels [75]. A model p-value of less than 0.05 indicates that the model is significant, while a model that isn't significant can be indicated by a p-value greater than 0,1. Variables said to be appropriate can be seen from the p-value. The results of the ANOVA data show that the temperature variable (A) and the ratio of banana peel powder to solvent (C) have significant values. This shows that the temperature variable and the ratio of banana peel powder to solvent have a real influence on the response of total polyphenol levels in the extraction process. Meanwhile, the time variable (B) has an insignificant value, this shows that the time variable doesn't have a real influence on the response of total polyphenol levels in the extraction process, this insignificant time variable is caused by the time range being too low compared to the optimum time.

The F-value of lack of fit is 0.2874, indicating that lack of fit isn't significant for pure error, the possibility of noise occurring from this value is 83.31. This shows that the model used to adjust the response variable is good at implying the relationship between the response value and the independent variable. Lack of fit which is not significant indicates that the model selection is appropriate because the appropriate model is lack of fit which is inversely proportional to the p-value [76]. Meanwhile, the value of the Sum of Square (SS) model is 1123.99. The sum of squares is a measure of the deviation of experimental data based on the average value of the data. This value is obtained from the deviation between the group average value and the overall average value. The SS value is used to calculate the Meam Square (MS) value. The MS value is obtained by dividing the SS value by df. The MS model value in the table above is 124,89 [77, 78].

Table 5. *Model Summary*

	R^2 *adjusted*	R^2 *predicted*
0.9968	0.9928	0.9870

Model analysis using design expert software shows that the model is appropriate. The criteria for a suitable model are shown by the difference between R^2 *adjusted* and R^2 *predicted.* Based on the table 5, the predicted R^2 of 0.987 is accordance with the adjusted R^2 of 0.9928. This is as expected because the corresponding difference value is less than 0.2. The research results can be declared according to the model if the resulting R^2 value exceeds 0.75 or is close to 1 [75, 79, 80]. The ANOVA results produce an R value of 0.9968, which indicates that the model is following the research results. The resulting R^2 *adjusted* value of 0.9928 shows that there is a strong relationship between the parameters of extraction time, extraction temperature of Horned Banana Peel powder, and the ratio of Horned Banana Peel powder to solvent on the response to total polyphenol levels [75]. Total polyphenol content in response to extraction parameters was modeled using Equation 3:

$$Total\ Polyphenol\ Content = 46.33 - 3.50A + 0.4088B + 4.39C - 11.23AB - 2.11AC - 1.90BC - 6.53A^2 + 6.21B^2 - 1.41\ C^2 \quad (3)$$

where,

A = temperature

B = time

C = ratio of banana peel powder to solvent

The values A, B, and C are respectively the parameters of extraction temperature, extraction time, and the ratio of Horn Banana Peel powder to solvent. If the parameter coefficient is negative then there is a decrease in the value of the total polyphenol content, and the opposite applies [75]. When the temperature decreases, the total polyphenol content also decreases, indicated by the temperature parameter (A) being negative. Meanwhile, when time and the ratio of horn banana peel powder to solvent increase, the total polyphenol content also increases as indicated by the time parameter (B) and the ratio of horn banana peel powder to solvent (C) is positive. Based on Equation 3, all extraction parameters statistically influence the total polyphenol content. The relationship between experimental data and model data is presented in Figure 2.

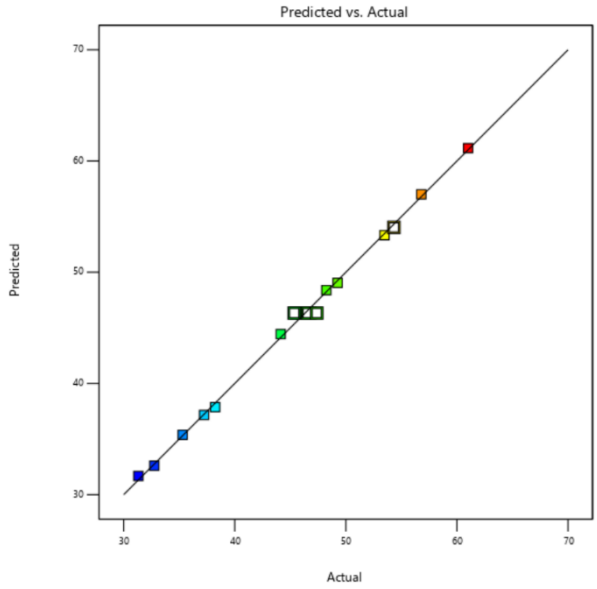
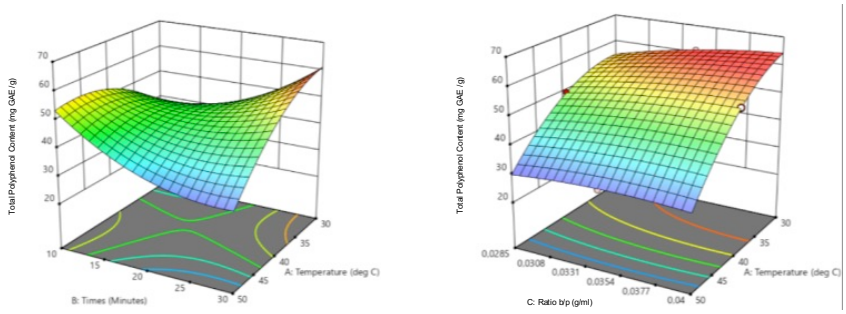


Figure 2. Graph of experimental data vs model data

Figure 2 shows that the graph of experimental data with model prediction data is very accurate, there is a strong correlation between experimental data and model data. The distance between the data and the trendline shows the accuracy of the data. The closer of the data is to the line, the more accurate the data will be [81]. Based on this research, the data plot touches a line which shows that the experimental data is close to the model data, supported by a R^2 value of 0.9968.

3.3 3D Surface Analysis of the Effect of Extraction Parameters on Total Polyphenol Content

a) b)



c)

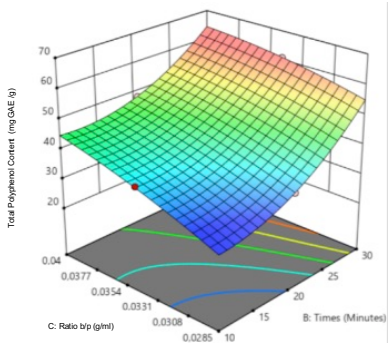


Figure 3. Respon Surface Analysis of Total Polypehenol Content as a Function of a) Extraction temperature and time, b) Extraction temperature and solvent ratio, and c) Extraction time and solvent ratio.

Figure 3 is a graph showing the effect of each extraction parameter (extraction time, extraction temperature, and ratio of Horned Banana Peel powder to solvent) on total polyphenol content. The figure shows that there is a combination of parameters that influence the response value through color differences. The optimum total polyphenol content resulting from this research was 61.007 mg GAE/g sample. Based on the total polyphenols obtained, it is estimated that the maximum total polyohenol extraction can be achieved when the combination of extraction temperature and extraction time is 30 °C and 30 minutes respectively.

The factor that influences extraction is extraction temperature. The increases temperature in the extraction process needs to be considered because high temperatures with long extraction times and exceeding the optimum limit can result in the loss of compound in the solution due to the evaporation process, and conversely if the extraction temperature is too low, it will result in not all active compounds being extracted from the material so that the results is low [86, 92]. Temperature conditions that are too high can thermally damage the target compound [84]. This is also in line with what was stated by Anal (2014), that at high

temperatures and longer extraction times, some phenolic compounds are likely to be oxidized and experience a decrease in extract yield [85]. Bioactive components such as polyphenols are not resistant to temperatures above 50°C, so they can changes in structure, physiochemical properties and the resulting extract is small, high heat results in the evaporation of some phenolic compounds resulting the decomposition of lycopenene, vitamins C and A [91]. Changes in the structure of polyphenols are characterized by not being detected when polyphenols are tested using a spectrophotometer. Low temperatures and fast extraction time also produce extracts that are not optimal so that the polyphenol extract obtained is low [87]. The higher extraction temperature ca result in greater solubility of phenol compounds in the ethanol solvent and also the higher temperature will result in the cell wall network of solid particles becoming softer, making it easier for teh solute to move into the solvent, but temperatures above 45°C will result in damage to the material being processed extract and undergo structural changes resulting in a decrease in total phenol [88, 89].

Winanta (2015) [90] explained that the longer the extraction time, the greater the quantity of material extracted due to the greater chance of contact between the material and the solvent, so that the resulting extract will increase to the saturation point of the solution [90]. Long extraction time produces a greater quantity of extract, this is because the contact time between the material and the solvent is longer [45]. However, when the material reaches the saturation point, the increase in extract yield will stop or run out [46]. Increasing the sonication time initially has a positive effect, but afterward the results tend to decrease over time [95]. In research conducted by Yilmaz and Tavman (2017), extraction time needs to be paid attention to in order to avoid the effects, because it can reduce yield due to decreased mass transfer due to cavitation bubbles [81, 94]. This condition caused by the maximum mass transfer that has been achieved and the degradation effect is caused by cavitaton which results in degradation of the solute [95, 96]. Cavitation is the formation of bubbles in a fluid flow due to a decrease in pressure in the fluid to below the saturated vapor pressure. Cavitation bubbles in the material are created from ultrasonic bubbles. When the bubble burst close to the cell wall, it results in the formation of a shock wave and liquid jets which cause the cell wall to rupture. This rupture of the cell wall causes components inside the cell to mix with the solution [93]. Extraction times that are too long result in the extract being hydrolyzed, while short extraction times result in not all active compounds being extracted from the material [33].

The ratio of ingredients to solvent is crucial because the amount of solvent used must be sufficient to dissolve the desired compound [97]. According to Figure 3, the ratio parameters of Horned Banana Peel powder to solvent show that the higher the ratio of horned banana peel powder to solvent, the higher the total level of polyphenols produced. These results are in accordance with the research conducted by Bancha *et al.* (2014) which stated that there was an increase in total polyphenol levels when using a ratio of ingredients to solvent from 1:30 to 1:50 g/mL [82]. This is also supported by the statement of Aulia & Wijanarko (2018), that the increase in total polyphenols increases as the solvent ratio increases [98]. However, according to Zhang *et al.* (2018) using a ratio of ingredients to solvent that is too high will cause a long extraction time [84]. Low total polyphenol yields from the extraction process can also caused by the presence of undesirable components [81]. The greater the liquid – solid ratio, the higher the mass transfer in the solvent due to the favorable concentration gradient during diffusion and the lower viscosity of the system increasing the cavitation effect [95].

4. Conclusions

Based on the research results, it can be concluded that the extraction parameters (extraction time, extraction temperature, and ratio of horned banana peel powder to solvent) influence the total polyphenol content. The optimum total polyphenol content from the results of this study was 61.007 mg GAE/g which was obtained under extraction conditions with an extraction temperature of 30°C, extraction time of 30 minutes, and a ratio of horned banana peel powder to solvent of 1:30 g/mL.

REFERENCES

[1] Rizka Mukhlisa, L. P. (2018). Uji Fitokimia Ekstrak Infusa Kulit Pisang (Musa acuminata x Musa Balbisiana). 1-7.
[2] Hortikultura, B. P. (2019). Produksi Pisang Menurut Provinsi, Tahun 2015-2019.
[3] Pane, E. R. (2013). Uji Aktivitas Senyawa Antioksidan dari Ekstrak Metanol Kulit Pisang Raja (Musa paradisiaca var. sapientum). (2), 1978-8193.
[4] Mihai Babota, O. F. (2022). Optimized ultrasound-assisted extraction of phenolic compounds from Thymus comosus Heuff. ex Griseb. et Schenk (wild thyme) and their bioactive potential. 1350-4177.
[5] Wiwik Purwati W, S. M. (2017). Analisis Pemanfaatan Limbah Kulit Pisang Sebagai Energi Alternatif Pada Baterai. *Teknik Energi*, Vol 13 No. 2; 61-67.
[6] Wa Ode Ermawati, S. W. (2016). Kajian Pemanfaatan Limbah Kulit Pisang Raja (Musa paradisiaca var Raja) Dalam Pembuatan Es Krim. *Sains dan Teknologi Pangan*, Vol. 1, No. 1, p. 67-72.
[7] Edi Suryanto, L. I. (2011). Potensi Senyawa Polifenol Antioksidan Dari Pisang Goroho (Musa sapien sp.). *AGRITECH*, Vol. 31, No. 4.

[8] Deli Wakano, E. S. (2016). Pemanfaatan Limbah Kulit Pisang Sebagai Bahan Olahan Kripik Dan Kue Donat Di Desa Batu Merah Kota Ambon. *Biology Science & Education*, vol 5 no 2 Page 152-156.

[9] Hadisoewignyo, L. F. (2017). Isolation and Characterization of Agung Banana Peel Starch from East Java Indonesia. *International Food Research*, 24(3):1324.

[10] Buanasari, Y. F. (2019). Potensi Metode Ultrasonic-Assisted Extraction (UAE) Dalam Mengekstrak Senyawa Aktif Dari Bahan Alam. *Farmasi & Sains Indonesia*, Vol. 2 No. 1.

[11] Singh, J. K. (2016). In vitro antioxidant and antimicrobial properties of jambolan (Syzygium cumini) fruit polyphenols. *LWT*, 65: 1025-1030.

[12] Putri Ade Rahma Yulis, Y. S. (2020). Aktivitas Antioksidan dari Limbah Kulit Pisang Muli (Musa acuminata Linn) dan Kulit Pisang Kepok (Musa paradisiaca formatypica). *Al-Kimia*, 189 - 200.

[13] Andi Nursanti, I. H. (2018). Uji Aktivitas Antibakteri Limbah Kulit Pisang Kepok (Musa Acuminata x Balbisiana), Kulit Pisang Uli (Musa Paradisiaca Sapientum), Dan Kulit Pisang Nangka (Musa Sp L). *Al-Kimia*, 6(2):129–34.

[14] Lee, N. D.-H. (2020). Komposisi Senyawa Fenol Dan Potensi Antioksidan Dari Kacang-Kacangan: Review. *Agroteknologi*, Vol. 14 No. 01.

[15] Singh, B. S. (2017). Phenolic composition and antioxidant potential of grain legume seeds: A review. *Food Research International*, 101 : 1-16.

[16] Syifa Fadilah, R. R. (2015). Pembuatan Biomaterial dari Limbah Kulit Pisang (Musa Paradisiaca). *Prosiding Simposium Nasional Inovasi dan Pembelajaran Sains*.

[17] Garg, N. A.-A. (2016). Microbes in Food and Health. 42-45.

[18] Megawati, E. L. (2016). Ekstraksi Pektin dari Kulit Pisang Kepok (Musa paradisiaca) Menggunakan Pelarut HCl sebagai Edible Film. *Bahan Alam Terbarukan*, JBAT 5(1) 14-21.

[19] Pellegrini, M., Lucas-Gonzalez, R., Pakisndez-LHaipez, J., Ricci, A., Pérez lvarez, J., Sterzo, C., & Viuda-Martos. (2017). Bioaksesibilitas senyawa polifenol dari enam biji quinoa selama pencernaan gastrointestinal in vitro. *Fungsi Makanan*.

[20] Dewi IGAM, G. P. (2021). Karakteristik Ekstrak Kulit Biji Kakao (Theobroma cacao L.) sebagai Sumber Antioksidan pada Perlakuan Suhu dan Waktu Maserasi. *Rekayasa Dan Manajemen Agroindustri*, 9(1):1.

[21] Uji Aktivitas Senyawa Antioksidan dari Ekstrak Metanol Kulit Pisang Raja (Musa paradisiaca Sapientum). (2013). Valensi Vol. 3 No. 2, (75-80).

[22] I Wayan Rai Widarta, I. W. (2015). Ekstraksi Komponen Bioaktif Daun Alpukat Dengan Bantuan Ultrasonik Pada Berbagai Jenis Dan Konsentrasi Pelarut. *Seminar Nasional Sains dan Teknologi (Senastek)*.

[23] Dwikora, A. S. (2016). Serbuk Kulit Pisang Tanduk (Musa)"Horn" Ijuk Enau Dan Serbuk Sabut Kelapa Sebagai Bioadsorben Logam Berat Cd (Ii) Dan Penjernih Air. *Kartika-Jurnal Ilmiah Farmasi*, 4(1), 37-41.

[24] Baihaqi, I. W. (2018). Peningkatan Efektivitas Ekstraksi Oleoresin Pala Menggunakan Metode Ultrasonik. *Jurnal Keteknikan Pertanian (JTEP)*, Vol. 6, No. 3.

[25] Jing Wang, B. S. (2008). Optimisation of ultrasound-assisted extraction of phenolic compounds from wheat bran. *Food Chemistry*, 106 : 804–810.

[26] Dannisa Fathiya Rachma, A. W. (2021). Ekstraksi Oleoresin dari Kulit Mangga Kuweni (Mangifera Odorata. Griff) dengan Ultrasound Assisted Extraction (UAE) Bertingkat. *Keteknikan Pertanian Tropis dan Biosistem*, 9(1).

[27] Meysi Andriani, I. D. (2019). Pengaruh Suhu Dan Waktu Ekstraksi Daun Belimbing Wuluh (Averrhoa bilimbi L.) Terhadap Aktivitas Antioksidan Dengan Metode Ultrasonic Assisted Extraction (UAE). *Ilmu dan Teknologi Pangan*, Vol. 8, No. 3, 330-340.

[28] Bancha Yingngam, M. M. (2014). Ultrasound-assisted extraction of phenolic compounds from Cratoxylum formosum ssp. formosum leaves using central composite design and evaluation of its protective ability against H_2O_2-induced cell death. *Asian Pacific Journal of Tropical Medicine*, 7 (Suppl 1): S497-S505.

[29] Ammar Altemimi, D. G. (2016). Ultrasound Assisted Extraction of Phenolic Compounds from Peaches and Pumpkins. *PLoS ONE*, 11(2): e0148758.

[30] Ashadi Sasongko, R. W. (2017). Penentuan Total Fenol Ekstrak Umbi Bawang Dayak Hasil Ekstraksi Dengan MetodeUltrasoundAssisted Extraction (UAE) dan Ultrasonic-Microwave Assisted Extraction (UMAE). *Jurnal Sains Terapan*, Vol. 3 No. 2.

[31] Bambang Susilo, S. H. (2016). Pengaruh Pretreatment dan Lama Waktu Ekstraksi terhadap Karakteristik Ekstrak Kulit Jeruk Purut (Citrus hystrix D.C) Menggunakan Ultrasonic Assisted Extraction (UAE). *Keteknikan Pertanian Tropis dan Biosistem*, Vol. 4 No. 3, 230-241.

[32] Mar'atus Sholihah, U. A. (2017). Aplikasi Gelombang Ultrasonik untuk Meningkatkan Rendemen Ekstraksi dan Efektivitas Antioksi dan Kulit Manggis. *Jurnal Keteknikan Pertanian (JTEP)*, Vol. 5, No. 2, p 161-168.

[33] Asri Widyasanti, N. N. (2018). Karakteristik Fisikokimia Antosianin Ekstrak Kulit Buah Naga Merah Menggunakan Metode UAE. *Ilmiah Rekayasa Pertanian dan Biosistem.* Vol.6, No.1.

[34] Palente I, S. E. (2021). Karakterisasi Serat Pangan Dan Aktivitas Antioksidan Dari Tepung Kulit Kakao (Theobroma cacao L.). *Chem Prog.*, 14(1):70–80.

[35] Khairana K, P. Z. (2022). Pengaruh Metode Maserasi dan Ultrasonik terhadap Ukuran Partikel Ekstrak Kulit Buah Kakao (Theobroma cacao) metode maserasi dan ultrasonik. 4(1):4–6.

[36] Maajid MN, S. R. (2021). Antibacterial Activity of Fermented and Non-Fermented Edel Cacao Bean Extract (Theobroma Cacao L.) Against Porphyromonas gingivalis. *Humanistic Network for Science and Technology Health*, 5(8):289–94.

[37] Kyriakos Kaderides, L. P. (2019). Microwave-assisted extraction of phenolics from pomegranate peels: Optimization, kinetics, and comparison with ultrasounds extraction. *Chemical Engineering & Processing: Process Intensification*, 137: 1–11.

[38] Sothornvit, P. R. (2019). Extraction of phenolic compounds from lime peel waste using ultrasonic-assisted and microwave-assisted extractions. *Food Bioscience*, 28:66–73.

[39] Idah Rosidah, Z. R. (2017). Optimasi Kondisi Ekstraksi Senyawa Total Fenolik Buah Labu Siam (Sechium edule (Jacq.) Sw.) Menggunakan Response Surface Methodology. *Media Litbangkes*, Vol. 27 No. 2, 79–88.

[40] Pagarra H, d. A. (2022). Identifikasi Senyawa Kulit Buah Kakao Sulawesi (Theobroma cacao L .) Menggunakan Etanol dan Aseton . XI(I):68–77.

[41] Anggi Pantria Saputri, I. A. (2020). Uji Aktivitas Antioksidan Ekstrak Air Kulit Pisang Kepok (Musa acuminate x Musa balbisiana (ABB cv)) Dengan Metode ABTS (2,2 azinobis (3-etilbenzotiazolin)-6-asam sulfonat) Pada Berbagai Tingkat Kematangan. *Kedokteran*, Vol . 8 No.1.

[42] Rudi Firyanto, M. S. (2019). Pengambilan Polifenol Dari Teh Hijau (Camellia sinensis) Dengan Cara Ekstraksi Menggunakan Aquadest Sebagai Pelarut. *Prosiding SNST*.

[43] Enny Sholichah, R. A. (2019). Produk Samping Kulit Kopi Arabika Dan Robusta Sebagai Sumber Polifenol Untuk Antioksidan Dan Antibakteri.
[44] Lisan Mella Rujiyanti, B. K. (n.d.). Pengaruh Lama Ekstraksi Kulit Melinjo Merah (Gnetum gnemon L.) Berbantu Gelombang Ultrasonik Terhadap Yield, Fenolik, Flavonoid, Tanin dan Aktivitas Antioksidan.
[45] Arumsari, N. N. (2021). Studi Literatur Metode Ekstraksi Pektin dari Beberapa Sumber Limbah Kulit Buah. *Riset Farmasi*, Volume 1, No. 1, Hal : 55-63.
[46] Diah Dhianawaty, d. R. (2015). Kandungan Total Polifenol dan Aktivitas Antioksidan dari Ekstrak Metanol Akar Imperata cylindrica (L) Beauv. (Alang-alang). Volume 47 No. 1.
[47] Estrella Espada-Bellido, M. F.-G. (2016). Optimization of the ultrasound-assisted extraction of anthocyanins and total phenolic compounds in mulberry (Morus nigra) pulp. *Food Chemistry*.
[48] Melini, V. M. (2021). Modelling and Optimization of Ultrasound-Assisted Extraction of Phenolic Compounds from Black Quinoa by Response Surface Methodology. *Molekules*, 26, 3616.
[49] Pratiwi, N. N. (2017). Kandungan Fenolik, Flavonoid dan Aktivitas Antioksidan Ekstrak Daun Paku Laut (Acrostichum aureum L.) Fertil dan Steril. *Journal of Tropical Biodiversity and Biotechnology*, Vol. 2, 51—56.
[50] Susilo, D. N. (2017). Analisis Fitokimia Ekstrak Kulit Pisang Agung Semeru Dan Mas Kirana. *Biologi dan Pembelajaran Biologi*, Volume 2 Nomor 2.
[51] Rafael G. Araujo, R. M.-J.-S. (2020). Process optimization of microwave-assisted extraction of bioactive molecules from avocado seeds. *Industrial Crops & Products*, 154: 112623.
[52] Ida Adhayanti, T. A. (2018). Uji Kandungan Total Polifenol Dan Flavonoid Ekstrak Etil Asetat Kulit Pisang Raja (Musa paradisiaca var. sapientum). *Media Farmasi*, Vol. XIV. No. 1.
[53] Daud A, S. N. (2019). Kajian Penerapan Faktor yang Mempengaruhi Akurasi Penentuan Kadar Air Metode Thermogravimetri. *Lutjanus*, 24(2):11–6.
[54] R, H. U. (2017). Perbandingan Warna Tepung Suweg Fase Dorman dan Vegetatif Secara Instrumental dan Sensoris. *Agrisaintifika Ilmu-Ilmu Pertanian*, 1(1):64.
[55] Kelly, B. (2014). An Water Content Determinations for Peat and Other Organic Soils Using the Oven Drying Method. *An Int J*, 32:1–31.
[56] Adhiksana, A. (2017). Perbandingan Metode Konvensional Ekstraksi Pektin dari Kulit Buah Pisang dengan Metode Ultrasonik. *Journal of Research and Technology*, Vol. 3 No. 2.
[57] Tri Saptari H, T. B. (2019). Kadar Fenolik dan Aktivitas Antioksidan Ekstrak Etanol Rumput Laut Coklat (*Padina australis*). *Fitomarka*, Vol.9, No.1.
[58] Melania Priska, N.P. (2018). Review: Pemanfaatan Antosianin dan Pemanfaatannya. *Cakra Kimia*, Volume 6 Nomor 2.
[59] Barba-Espin, G., Glied, S., Crocoll, C., Dzhanfezova, T., Joernsgaard, B., Okkels, F., Lutken, H., & Muller, R. (2017). Foliar-Applied Ethephon Enhances the Content of Anthocyaninof Black Carrot Roots (Daucus carota ssp. sativus var. atrorubens Alef.). BMC Plant Biology 17 (70): 1-11. DOI: 10.1186/s12870-017-1021-7
[60] M. Ramdani, O. Elasri, N. Saidi, N. Elkhiati, F.A. Taybi, M. Mostareh, O. Zaraali, B. Haloui, M. Ramdani. (2017). Evaluation of antioxidant activity and total phenol content

of Gracilaria bursa-pastoris harvested in Nador lagoon for an enhanced economic valorization, Chem. Biol. Technol. Agric. 4 1–7

[61] I. Norra, A. Aminah, R. Suri. (2016). Effects of drying methods, solvent extraction and particle size of Malaysian brown seaweed, Sargassum sp. on the total phenolic and free radical scavenging activity, Int. Food Res. J. 23 1558–1563

[62] M. Musci, S. Yao. (2017). Optimization and validation of Folin–Ciocalteu method for the determination of total polyphenol content of Pu-erh tea, Int. J. Food Sci. Nutr.

[63] I. Safitri, W. Warsidah, M.S.J. Sofiana, A.A. Kushadiwijayanto, T.N. Sumarni. (2021). Total phenolic content, antioxidant and antibacterial activities of Sargassum polycystum of ethanol extract from waters of Kabung Island, Berk, Berk. Sainstek. 9 139

[64] S. Sedjati, E. Supriyantini, A. Ridlo, N. Soenardjo, V.Y. Santi. (2018). Kandungan pigmen, total fenolik dan aktivitas antioksidan Sargassum sp., J. Kelaut. Trop. 21-137.

[65] K. Korzeniowska, B. Łęska, P.P. Wieczorek. (2020). Isolation and determination of phenolic compounds from freshwater Cladophora glomerata, Algal Res. 48

[66] A.A. Samin, N. Bialangi, Y.K. Salimi. (2013). Penentuan kandungan fenolik total dan aktivitas antioksida dari rambut jagung *Zea mays L*. yang tumbuh di daerah Gorontalo, J. Sainstek. 7 247–259.

[67] Andriani, M., Permana, I. D. G. M., & Widarta, I. W. R. (2019). Pengaruh Suhu dan Waktu Ekstraksi Daun Belimbing Wuluh (*Averrhoa bilimbi L*.) Terhadap Aktivitas Antioksidan Dengan Metode *Ultrasonic Assisted Extraction* (UAE). Jurnal Ilmu Dan Teknologi Pangan, 8(3), 330–340.

[68] Rizky Amelia, F. (2015). Penentuan Jenis Tanin Dan Penetapan Kadar Tanin Dari Buah Bungur Muda (*Lagerstroemia Speciosa Pers*.) Secara Spektrofotometri Dan Permanganometri. Jurnal Ilmiah Mahasiswa Universitas Surabaya, 4(2), 1.

[69] Jin HwanLee, Ki HunPark, Myoung-HeeLeec Hyun-TaeKimcWoo DuckSeocJun YoungKimcIn-YoulBaekcDae SikJangdTae JoungHa. (2013). "Identification, Characterisation, and Quantification of Phenolic Compounds in the Antioxidant Activity-Containing Fraction from the Seeds of Korean Perilla (*Perilla Frutescens*) Cultivars." Food Chemistry 136(2):843–52.

[70] T.S. Haryani, Tria. (2019). Kadar fenolik dan aktivitas antioksidan ekstrak etanol rumput laut coklat (*Padina australis*), Carbohydr. Polym. 6 5–10.

[71] M.R. Marjoni, Afrinaldi, A.D. Novita. (2015). Kandungan Total Fenol Dan Aktivitas Antioksidan Ekstrak Air Daun Kersen (Muntingia calabura L.), Yars. Med. J. 23 187–1962.

[72] I. Kadek Widhiana Putra, G. Ganda Putra, L. Putu Wrasiati. (2020). Perbandingan bahan dengan pelarut dan waktu maserasi terhadap ekstrak kulit biji kakao (*Theobroma cacao L.*) sebagai sumber antioksidan, J. Rekayasa Dan Manaj. Agroindustri. 8 167–176.

[73] N. Milicevic, P. Kojic, C. Perussello, V. Banjac, M. Poji, B. Tiwari. (2021). Ultrasonics Sonochemistry Kinetic modelling of ultrasound-assisted extraction of phenolics from cereal brans, 79.

[74] Sabathani, A., Widjanarko, S. B., & Yuwono, S. S. (2018). OPTIMASI WAKTU EKSTRAKSI DAN RASIO BAHAN PER PELARUT EKSTRAK DAUN PEPAYA UNTUK UJI AKTIVITAS ANTIBAKTERI. *The Optimization of Extraction Time and*

Material Ratios per Solvent of Papaya Leaf Extract for Antibacterial Activity Test. 19(3), 193–206

[75] F.U. Rohmah, A. Rahmawati, M.F. Rizkiana, A. Susanti. (2022). Optimization of extraction of bioactive compound from pegagan leaves using ethanol solvent with microwave-assisted extraction method (MAE), J. Biobased Chem. 2 40–5

[76] B.L. Sari, T. Triastinurmiatiningsih, T.S. Haryani. (2020). Optimasi metode microwave-assisted extraction (MAE) untuk menentukan kadar flavonoid total alga coklat Padina australis, ALCHEMY J. Penelit. Kim. 16-38

[77] M.G. Pertiwi, J. Fajrin, I.W. Sugiartha. (2018). Aplikasi response surface methodology (RSM) untuk meningkatkan kuat tekan paving block dengan campuran abu ampas tebu, Artik. Ilm. 1–15.

[78] F. Rahmawaty, H.T. Sutanto. (2014). Penerapan metode permukaan respon untuk optimalisasi proses sealing pada pengemasan produk makanan jelly, J. Ilm. Mat. 3 1–6.

[79] B. Yingngam, A. Chiangsom, A. Brantner. (2020). Modeling and optimization of microwave-assisted extraction of pentacyclic triterpenes from Centella asiatica leaves using response surface methodology, Ind. Crops Prod. 147.

[80] B.A. Fachri, R.M. Abdilla, C.B. Rasrendra, H.J. Heeres. (2015). Experimental and modelling studies on the uncatalysed thermal conversion of inulin to 5-hydroxymethylfurfural and levulinic acid, Sustain. Chem. Process. 3 1–11. https://doi.org/10.1186/s40508-015-0035-4

[81] T. Yılmaz, S. Tavman. (2017). Modeling and optimization of ultrasound assisted extraction parameters using response surface methodology for water soluble polysaccharide extraction from hazelnut skin, J. Food Process. Preserv. 41.

[82] V.G.P. Putra, S. Mutiarahma, W. Chaniago, P. Rahmadi, D. Kurnianto, C. Hidayat, C. Carrera, M. Palma, W. Setyaningsih. (2022). An ultrasound-based technique for the analytical extraction of phenolic compounds in red algae, Arab. J. Chem. 15-103597

[83] Diky Ramdani, Iman Hernaman, An An Nurmeidiansyah, dan Denie Heryadi. (2016). "The Potential of Nutrients, Phenols, and Tannins in Local Banana Peels of Ambon at Different Ripe Stages for Sheep Feeding". (November):883–88.

[84] Fidrianny, I., Anggraeni, N. A. S., & Insanu, M. (2018). "Antioxidant Properties of Peels Extracts from Three Varieties of Banana (Musa Sp.) Grown in West Java-Indonesia." International Food Research Journal 25(1):57-64

[85] Anal, Anil Kumar, Sirorat Jaisanti, and Athapol Noomhorm. (2014). "Enhanced Yield of Phenolic Extracts from Banana Peels (*Musa Acuminata Colla AAA*) and Cinnamon Barks (*Cinnamomum Varum*) and Their Antioxidative Potentials in Fish Oil." Journal of Food Science and Technology 51(10):2632–39.

[86] Ibrahim, A.M., Yunita dan H.S. Feronika. (2015). Pengaruh suhu dan lama waktu ekstraksi terhadap sifat kimia dan fisik pada pembuatan minuman sari jahe merah dengan kombinasi penambahan madu sebagai pemanis. Jurnal Pangan dan Agroindustri. 3 (2):530-541.

[87] Yuliantari, N.W.A., I.W.R. Widarta dan I.D.G.M. Permana. (2017). Pengaruh suhu dan waktu ekstraksi terhadap kandungan flavonoid dan aktivitas antioksidan daun sirsak (*Annona muricata L.*) menggunakan ultrasonik. Scientific Journal of Food Technology. 4(1): 35-42

[88] Margaretta, S., S.D. Hanyani, N. Indraswati dan H. Hindarso. (2011). Ekstraksi senyawa phenolic Pandanus amaryllifolius Roxb sebagai antioksidan alami. Jurnal Widya Teknik. 10(1):21-30.

[89] Handayani, H., and F.H. Sriherfyna. (2016). Ekstraksi Antioksidan Daun Sirsak Metode Ultrasonik Bath (Kajian Rasio Bahan : Pelarut dan Lama Ekstraksi). Jurnal Pangan dan Agroindustri 4(1):262-272.

[90] Winata, E. dan Yunianta. 2015. Ekstraksi Antosianin ~Buah Murbei (*Morusalba L.*) Metode Ultrasonic Batch (Kajian Waktu dan Rasio Bahan : Pelarut). Jurnal Pangan dan Agroindustri. 3(2) 773-783.

[91] Yuanita, O. T. (2021). Efek Metode Pengolahan dan Penyimpanan Terhadap Kadar Senyawa Fenolik dan Aktivitas Ontioksidan. *UNESA Journal of Chemistry,* Vol. 10, No. 2.

[92] Ni Wayan Ayuk Yuliantari, I. W. (2017). Pengaruh Suhu dan Waktu Ekstraksi Terhadap Kandungan Flavonoid dan Aktivitas Antioksidan Daun Sirsak (*Annona muricata L.*) Menggunakan Ultrasonik. *Media Ilmiah Teknologi Pangan* (*Scientific Journal of Food Technology*), Vo. 4, No.1, 35-42.

[93] I Wayan Budiastra, S. S. (2020). Pengaruh Amplitudo Ultrasonik dan Waktu Ekstraksi Terhadap Rendemen dan Mutu Oleoresin Pala. *Jurnal Keteknikan Pertanian*, Vol. 8 No.2, p 45-52.

[94] Sandra Sekarsari, I. W. (2019). Pengaruh Suhu dan Waktu Ekstraksi dengan Gelombang Ultrasonik Terhadap Aktivitas Antioksidan Ekstrak Daun Jambu Biji (Psidium guajava L.). *Jurnal Ilmu dan Teknologi Pangan*, Vol. 8, No. 3, 267-277.

[95] Umar, K.; Srivastav, S.; Sharanagat, V.S. (2021). Ultrasound assisted extraction (UAE) of bioactive compounds from fruit and vegetable processing by-products: A review. Ultrason. *Sonochem*. 70, 105325.

[96] Kumcuoglu, S.; Yilmaz, T.; Tavman, S. (2014). Ultrasound assisted extraction of lycopene from tomato processing wastes. *J. Food Sci. Technol*, 51, 4102–4107.

[97] Silva, S., Costa, E. M., Calhau, C., Morais, R. M., & Pintado, M. E. (2017). Anthocyanin Extraction From Plant Tissues: A Review. Critical Reviews In Food Science And Nutrition, 57(14), 3072–3083.

[98] Aulia, L. P., & Widjanarko, S. B. (2018). Optimasi Proses Ekstraksi Daun Sirsak (Annona Muricata L) Metode Mae (Microwave Assisted Extraction) Dengan Respon Aktivitas Antioksidan Dan Total Fenol. Jurnal Agroindustri Halal, 4(April), 79–87.