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# Exploring the Impact of Temperature and Solvent Ratio on Phenol and Flavonoid Levels in *Alpinia galangal* L. Extract Using Evaporative Vacuum Cooling

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**ABSTRACT**

*The objective of this research is to determine the impact of temperature gradients and solvent ratios in the evaporative vacuum cooling method on the yield of phenol and flavonoid content in galangal extract; ascertain the impact of these factors on the yield generated by galangal extract; and ascertain the mass balance analysis of materials are the objectives of this study. Throughout the extraction of galangal. The study's findings demonstrated that the evaporative vacuum cooling technique, conducted at 49 ºC and with a 1:1 solvent ratio of 1.4432±0.7317 mg GAE/g, produced the highest total phenol concentration. The three differences in the temperature of the evaporative vacuum produced the total phenol content cooling. The overall phenol content obtained decreases with increasing solvent ratio addition. Although the evaporative vacuum cooling treatment at 45 °C yielded the highest total flavonoid content (1.2418±0.2365 mg QE/g) at a 1:2 solvent ratio, the total flavonoid content varied between the three evaporative vacuum cooling temperature variations. The yield of total phenolic and flavonoid compounds was not significantly affected by temperature gradient adjustments or the ratio of galangal extract to solvent (Sig. > 0.05) in any of the data samples pertaining to phenolic and flavonoid compounds.*

## 1. INTRODUCTION

Galanga (*Alpinia galanga*) is spice plants known as *lengkuas* or *kelawas*. This plant is adaptable to both highland and lowland environments. It is typically used in traditional medicinal mixtures with spices. White and red galangal are the two types of galangal that are distinguished by the color, shape, and size of the rhizome. Red galangal is typically used as medication, whilst white galangal is typically used as a spice for other cuisines. Galangal has long been used as an anti-itch, anti-fungal, anti-inflammatory, anti-allergic, and anti-hypoglycemic medication (Darmawan, 2013). Traditional medicine makes extensive use of red galangal (*Alpinia purpurata* K. Schum) (Vankar *et al*., 2006). Galangal flowers are bell-shaped compound flowers with a pleasant scent. They are greenish-white or yellowish-white in color and come in bunches. The handle of the flower is long (10-30 cm), slender and stands upright at the top of the stem (Setyaningsih, 2013). This plant has alternating, spherical, hard fruit that is green when young and reddish-black when older. The leaves are small, green, and have short stalks (Fauzi, 2019).

About 1% of greenish-yellow essential oil is found in galangal, mostly in the form of 48% methyl-cinnamate, 20%–30% cineol, eugenol, 1% camphor, sesquiterpenes, δ-pinene, and galangin (Tjitrosoepomo, 1994). Phenols and flavonoids are the primary constituents of galangal. The crystalline material known as phenol is colorless and has a distinct smell. One hazardous and caustic substance is phenol (Qadeer & Rehan, 1998). Phenol molecules can oxidize, which allows them to function as reducing agents (Hoffman *et al*., 1997). Most green plants have phenolic chemicals called flavonoids, which are often found in seeds, fruits, fruit peels, bark, leaves, and flowers (Miller, 1996). Strong antioxidant activity and superior hydrogen donor properties are possessed by flavonoids (Prakash & Gupta, 2009). In nature, flavonols, flavones, isoflavones, flavanones, anthocyanidins, and proanthocyanidins are the most prevalent types of flavonoid chemicals (Bravo, 1998). Galanin, a semi-polar molecule formed from flavonoid derivatives, is the active element in galangal rhizome that has been researched and may help relieve fatigue (Sumodiningrat, 1999).

The new method that is currently starting to develop is using evaporative vacuum cooling technology. Evaporative vacuum cooling is a technology that utilizes a solution thickening process by boiling or evaporating part of the solvents, without involving any chemicals at all using the vacuum principle. The principle of cooling galangal with vacuum cooling is to use low temperatures and pressure below atmospheric, namely -73 cmHg to evaporate the remaining free water in the galangal so that the cooling process can be carried out in a relatively short time (Cahyani, 2021). An evaporation method is necessary to prevent or reduce damage and loss of compound content in galangal. High temperatures are typically used in the evaporation process to cause harm to the chemical substances it contains. Therefore, in this research, the content of phenolic and flavonoid compounds from galangal juice will be carried out using the pre-treatment evaporative vacuum cooling method. The new method that is currently starting to develop is using evaporative vacuum cooling technology. Evaporative vacuum cooling is a technology that utilizes a solution thickening process by boiling or evaporating part of the solvents, without involving any chemicals at all using the vacuum principle.

Thus, it is necessary to conduct research on the application of evaporative vacuum cooling to the phenol and flavonoid content of galangal juice to determine the effect of the evaporation temperature gradient and the ratio of the amount of solvents to the phenol and flavonoid content. This research was continued by optimizing the results using the Response Surface Methodology (RSM) method with Design Expert software, to know the optimum values for the variables that have been determined.

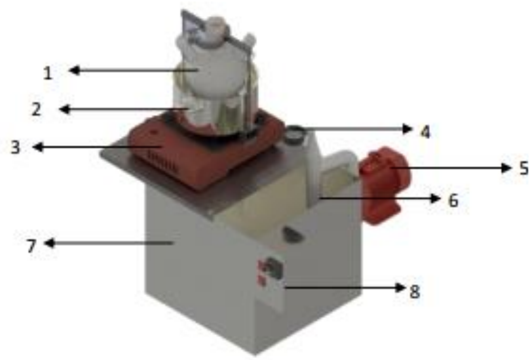
## 2. RESEARCH METHOD

This research was conducted at the Lastrindo Engineering Science and Technology Laboratory (STLE) located at Jalan Rajekwesi No. 11, Gading Kasri, Klojen District, Malang City, East Java Province. The tools used are evaporator vacuum cooling, beaker glass, quartz cuvette, digital scales, measuring pipette, dropping pipette, stir bar, visible spectrophotometer 721, moisture analyzer, container, measuring flask, measuring cup, Erlenmeyer, test tube, tube rack, bulbs, glass bowls, spatulas, refrigerators, cutting boards, watch glasses, blenders, glass bottles, jars, glass cups, and tongs. While the materials used are galangal, distilled water, ice cubes, aluminum foil, label paper, filter paper, latex gloves, tissue, and plastic bags.

This study used a randomized block design (RBD) using 2 factors. The first factor is the value of the evaporation temperature gradient, namely temperature 41°C, temperature 45°C, and temperature 49°C. While the second factor is the ratio of the amount of galangal extract solvent, namely 1:1, 1:2, and 1:3. Each treatment combination of the two factors was repeated three times to obtain a total of 27 samples plus nine samples as control treatments. The control treatment in this study used evaporative galangal extract without vacuum cooling at 100 °C. According to (Retno & Priantinah, 2012), control variables are variables that are controlled or kept constant. The design of the vacuum cooling evaporator used in this study can be seen in Figure 1. Furthermore, analysis was carried out using Design Expert software with the Response Surface Methodology (RSM) method in Central Composite Design (CCD). The research stages were presented in Figure 2.

### 2.1. Galangal Preparation

Galangal preparation according to Manurung (2016) namely wet sorting, washing, chopping, and milling. The first step is called wet sorting, during which any dirt or other materials that may have adhered to the gathered galangal rhizomes are removed. After giving the galangal, a quick wash under running water and rinsing it off, thin it out with a knife that is between 5 and 7 mm thick. In addition, a blender is used to grind the galangal.




1. Chamber capacity 1 liter
2. Pan
3. Stove
4. Manometer
5. Motorcycle
6. Vacuum jet pump
7. Water tub
8. Control panels

Figure 1. Design series of evaporator vacuum cooling (Cahyani, 2021).

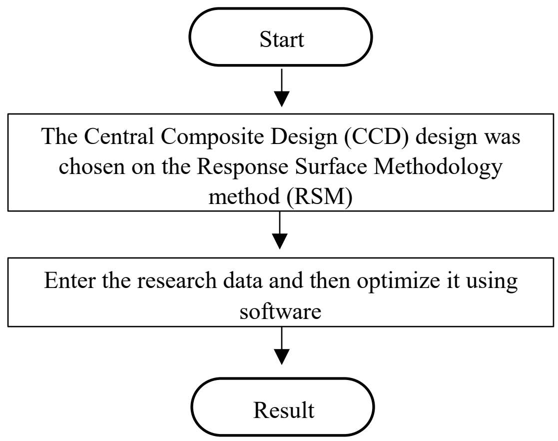



Figure 2. Optimization flowchart using the Central Composite Design (CCD) method

### 2.2. Galangal Evaporation

A maximum of 50 grams of galangal was weighed and then added to distilled water in different solvent ratios (1:1, 1:2, and 1:3). Moreover, a filter cloth is used to filter the solvent that has been combined with fine galangal in a tray. Subsequently, the filtrate was transferred into a plastic bottle, refrigerated at ±4°C, and evaporated using a vacuum cooling evaporator. Convection is the method by which molecular heat and water vapor mass transfer happen (Waziroh *et al.*, 2017).

### 2.3. Testing of Phenol and Flavonoid Compounds

A spectrophotometer was used to test for phenolic and flavonoid chemicals while incorporating several reference solutions. Gallic acid was utilized as a reference solution for phenolic component testing, while quercetin was used for flavonoid testing. Establishing the maximum wavelength, creating a standard gallic acid calibration curve, and calculating the total phenol concentration were the procedures used to analyze total phenol (Singleton *et al.*, 1999). Finding the maximum wavelength, creating a standard quercetin calibration curve, and calculating the total flavonoid content were the procedures used to analyze the total flavonoids (Chang *et al.*, 2002).

## 3. RESULTS AND DISCUSSION

### 3.1. Test Results for Total Phenol Levels in Galangal Extract

Based on the standard curve absorbance test for gallic acid with a concentration series of 10, 20, 30, 40, and 50 ppm at a maximum wavelength of 740 nm, the linear regression equation $y = 0.0091x + 0.073$ with a coefficient of determination of $R^2 = 0.965$ was obtained. Based on the resulting $R^2$ value, shows that the concentration of gallic acid has an effect of 96.5% on the resulting absorbance value. Meanwhile, the results from other factors not studied were 3.5%, so the gallic acid standard curve obtained had a good level of accuracy. The linear regression equation obtained will be used to measure the total phenolic content of galangal juice using absorbance data.

Based on oxidation-reduction reactions, the Folin-Ciocalteau principle was used in this investigation to determine the total phenol concentration in galangal extract. Figure 4 displays the total phenol content test findings.

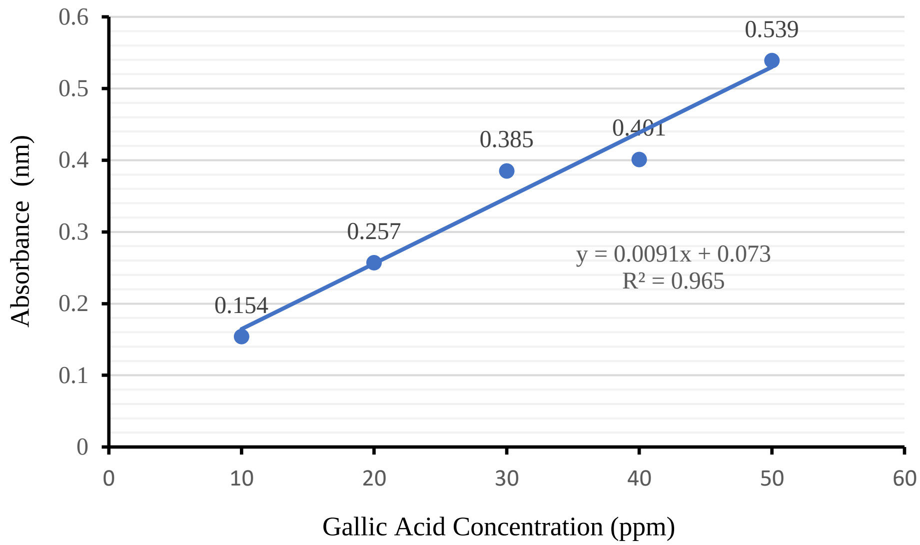



Figure 3. Gallic acid standard curve

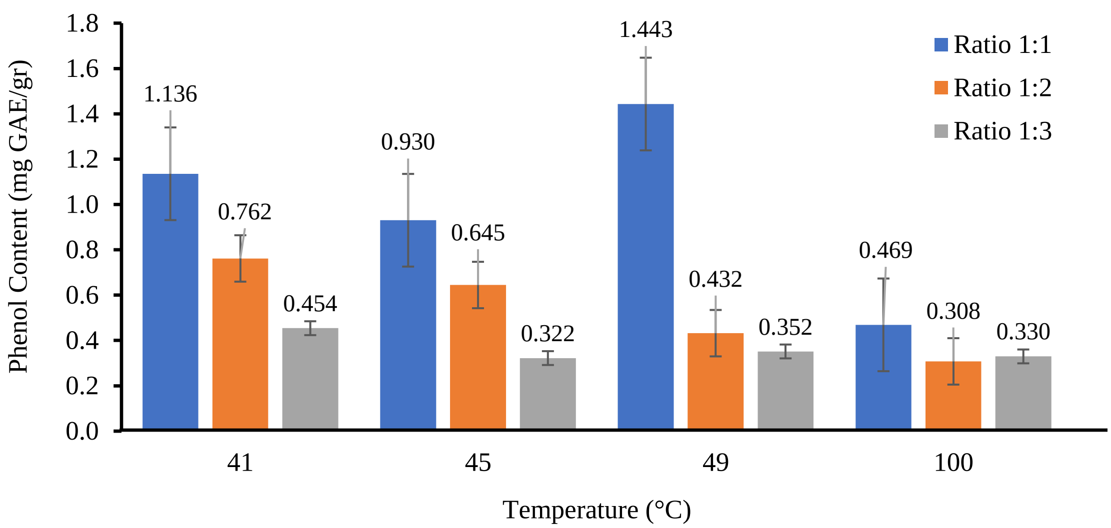



Figure 4. Graph of total phenol content of galangal extract with evaporation treatment

The total phenol content of a sample drops with each rise in the ratio of the amount of solvent, as demonstrated by Figure 2, which depicts the same trend for the three changes in vacuum cooling evaporation temperature. This investigation shown that the total phenol content produced decreased with increasing addition ratio of solvent. This results from the different ratios of the solvents utilized; the water content increases with the amount of water supplied to the material; the water examined to determine the water content includes both physically bound and free water present in the material (Weliana *et al.*, 2020). According to Mutiaran (2021), water will evaporate off the material's surface and inside the material as a result of the evaporation process, which uses vacuum cooling at low temperatures and pressures. The water content decreases as a result of latent heat evaporation and a decrease in the material's sensible heat. That being said, in this investigation. The yield of total phenolic compounds was not significantly impacted by the ratio of the solvent used in the galangal extract evaporation temperature gradient.

Based on Table 1 with F-value of 9.03, the model is statistically significant. It is quite unlikely (only 0.07%) that noise could have caused such a large F-value. P-values of less than 0.0500 are deemed significant for model terms. In this case, B is an important model word. If the result exceeds 0.1000, the model terms become irrelevant. A model that has a large number of superfluous terms (aside from those needed to preserve hierarchy) may benefit from model reduction in order to improve accuracy. The 1.46 F-value for Lack of Fit suggests that the statistical significance of the error is not visible when compared to the pure error. A strong F-value for lack of fit has a 23.10% chance of being noise. It is desirable if there is a non-significant lack of fit in the model.

As can be observed in Figure 5, which displays a linear outcome, the image lacks any peaks and no red color. Each corner and midway in the image above has five points. The temperature and amount of solvent used at the lower left corner of the figure resulted in 0.3297 mg GAE/g total phenol; the temperature and amount of solvent used at the right point, which was at 100 °C, produced 0.1758 mg GAE/g total phenol; and the temperature and amount of solvent used at the upper left corner, which was at 41°C and 100 mL, produced 0.8352 mg GAE/g total phenol, the temperature of 100 °C and 100 mL of solvent at the position on the upper right produced 0.967 mg of GAE/g of phenol, while the temperature of 70.5 °C and 66.65 mL of solvent at the point in the middle of the image created 0.7253 mg of GAE/g of phenol. In order to avoid having any peaks or red-colored points, the picture generates a linear model.

Table 1. ANOVA for total phenol

| Source | Sum of Squares | df | Mean square | F-value | p-value | Note |
|---|---|---|---|---|---|---|
| **Model** | 2.25 | 2 | 1.12 | 9.03 | 0.0007 | Significant |
| A-Temperature | 0.0229 | 1 | 0.0229 | 0.1845 | 0.6704 | Not significant |
| B-Solvent | 2.22 | 1 | 2.22 | 0.0002 | 0.0002 | Significant |
| **Residual** | 4.10 | 33 | 0.1244 | | | |
| Lack of Fit | 1.00 | 6 | 0.1671 | 1.46 | 0.2310 | Not significant |
| Pure Error | 3.10 | 27 | 0.1149 | 1.16 | 0.2900 | |
| **Cor Total** | 6.35 | 35 | 8.62 | | | |

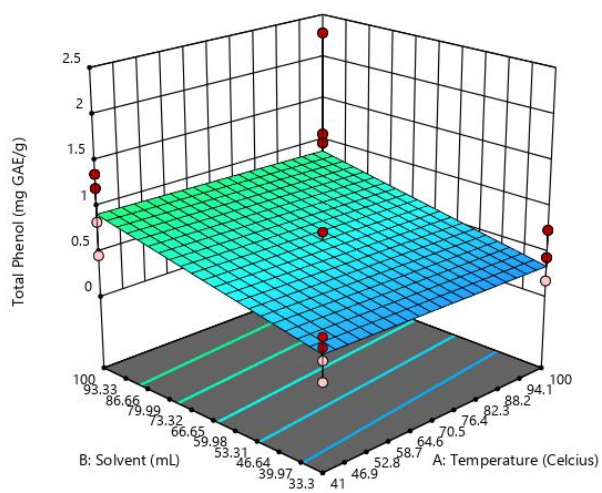



Figure 5. Contour Plots and Graphs Total Phenol

The phenol content test in this study used methanol as a solvent. This solvent can produce optimal active ingredients, where only small-scale impurities are included in the filter fluid. The research results show that the solvent has a real effect, but the temperature has no effect, so this is because solvents generally have a low boiling point and evaporate more easily, leaving the dissolved substance behind. By using a low temperature, the solvent can produce a more concentrated solution and has high concentration.

Perdani *et al.* (2019) states that the research data obtained indicates a tendency for the total phenolic extract to increase with higher concentrations. This is demonstrated by the total phenol results, which show different amounts of phenol for the same ratio of 30 ml/g at concentrations of 53.79%, 75%, and 96.21%, resulting in 289.70 mg GAE/g, 503.17 mg GAE/g, and 514.91 mg GAE/g, respectively. Meanwhile, the total phenol content in the evaporation control treatment without vacuum cooling at a temperature of 100 °C with a 1:1 solvent ratio was 0.4689 mg GAE/g but decreased at a 1:2 solvent ratio of 0.3077 mg GAE/g. then increased at a 1:3 ratio of 0.3297 mg GAE/g.

### 3.2. Test Results for Total Flavonoid Content of Galangal Extract

Based on the absorbance test of the quercetin standard curve with a concentration series of 10, 20, 30, 40, and 50 ppm at a maximum wavelength of 440 nm, a linear regression equation y = 0.0083x + 0.0158 was obtained with a coefficient of determination of $R^2 = 0.9812$. Based on the resulting $R^2$ value, it shows that the quercetin concentration has an effect of 98.12% on the resulting absorbance value. Meanwhile, the results from other factors not studied were 1.88%, so the quercetin standard curve obtained had a good level of accuracy. The linear regression equation obtained will be used to measure the total flavonoid content of galangal juice using absorbance data.

In determining the total levels of flavonoids in galangal extract, this study used the AlCl3 principle, namely the formation of stable complexes with C-4 keto groups, as well as C-3 or C-5 hydroxyl groups from flavones and flavonoids. The results of testing the total levels of flavonoids in galangal extract can be made as a graph of the average galangal extract flavonoids in the evaporation treatment as shown in Figure 7. It illustrates how the three differences in the vacuum cooling evaporation temperature have resulted in both increases and decreases in the overall levels of flavonoids. The number of solvents in the 1:2 ratio increased among the three versions, but the 1:3 ratio declined once more. The maximum value of total flavonoid content is obtained for each modification of vacuum cooling temperature evaporation when the ratio of solvents is 1: 2. This may occur as a result of the stove's potential for temperature fluctuations. Variations in vapor pressure, air temperature, wind, water quality, and evaporation surface area all have a significant impact on the evaporation process (Aldrian, 2008). However, with each increase in

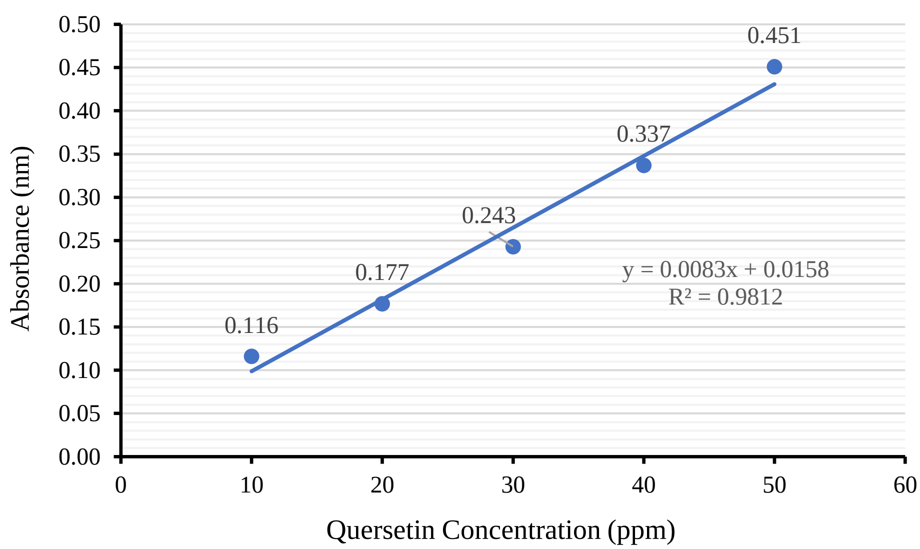



Figure 6. Quercetin standard curve

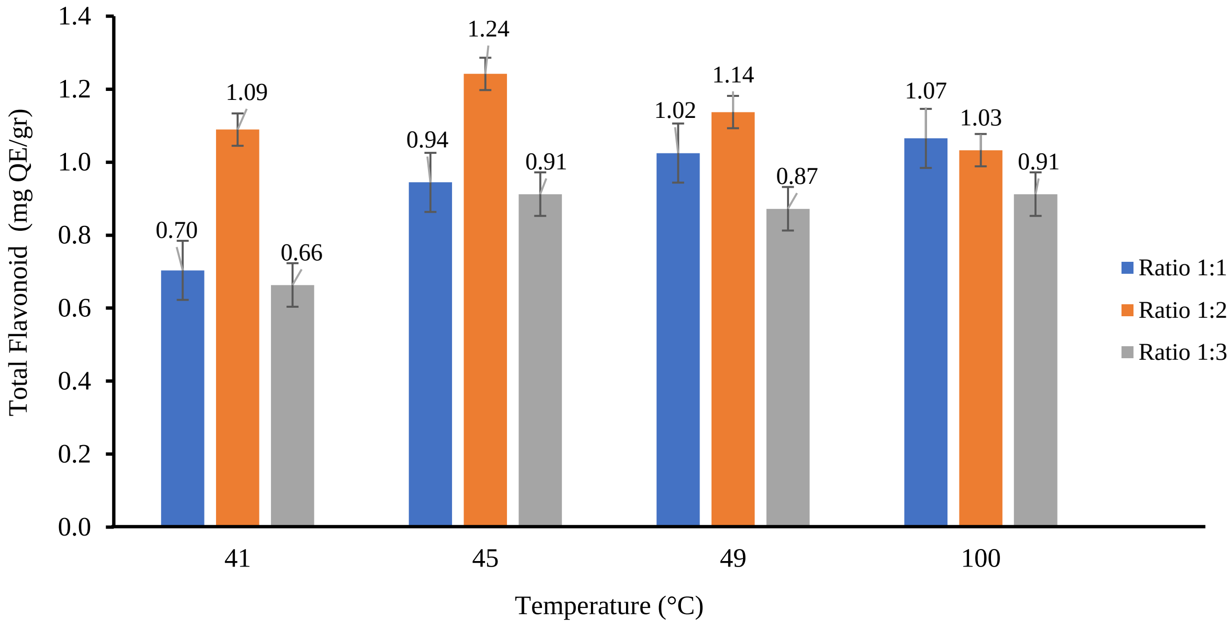



Figure 7. Total flavonoid content of galangal extract with evaporation treatment

the total solvent ratio, the total levels of flavonoids in the evaporation control treatment without vacuum cooling at 100 °C with a ratio of 1:1, 1:2, and 1:3 solvents dropped. As stated by Zainol in (Hradaya & Husni, 2021), an increase in temperature may also result in a drop in total flavonoid compounds because high temperatures can harm the material cell structure, causing the present components to migrate more readily and be more vulnerable to various chemical processes involving light and oxygen. The yield of total flavonoid components in this study was not significantly impacted by the solvent ratio of galangal extract with the evaporation temperature gradient.

The solvent affects the total yield of flavonoids, making simplicia more soluble and more diffuse into the extraction solvent. Research using the Response Surface Methodology (RSM) Box-Behnken design provides a second-order polynomial regression model with a correlation value of $R^2 = 0.9426$ which shows that the quadratic polynomial model can be used to optimize flavonoid levels (Sari *et al*., 2020). In the research, the value of $R^2 = 0.9812$ means that the quadratic polynomial model can be used for optimization. Below is Table 2, which presents the ANOVA (Analysis of Variance) results for total flavonoids, a model is considered significant if the p-value is < 5%. Considering Table 2, F-value of the model is 1.71, implying that it is not significant given the noise. There is a 16.21% chance that noise is the cause of a big F-value. When P-values less than 0.0500, model terms are deemed significant. In this case, B2 is an important model term. If the value exceeds 0.1000, the model terms become in significant. If the

Table 2. ANOVA for total flavonoid

| Source | Sum of Squares | df | Mean square | F-value | p-value | Mark |
|---|---|---|---|---|---|---|
| **Model** | 0.4052 | 5 | 0.0810 | 1.71 | 0.1621 | Not significant |
| **A-Temperature** | 0.0544 | 1 | 0.0544 | 1.15 | 0.2921 | Not significant |
| **B-Solvent** | 0.0430 | 1 | 0.0430 | 0.9079 | 0.3483 | Not significant |
| **A×B** | 0.0192 | 1 | 0.0192 | 0.4057 | 0.5290 | Not significant |
| **$A^2$** | 0.1064 | 1 | 0.1064 | 2.25 | 0.1441 | Not significant |
| **$B^2$** | 0.2882 | 1 | 0.2882 | 6.09 | 0.0195 | Significant |
| **Residual** | 1.42 | 30 | 0.0473 | | | |
| **Lack of Fit** | 0.3680 | 3 | 0.1227 | 3.15 | 0.0412 | Significant |
| **Pure Error** | 1.05 | 27 | 0.0390 | | | |
| **Cor Total** | 1.82 | 35 | | | | |

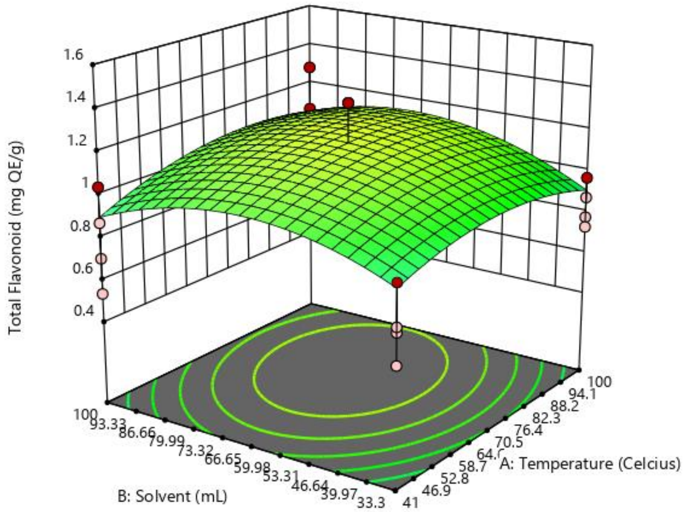



Figure 8. Contour plots and graphs total flavonoid

model contains a lot of unnecessary terms (beyond those required to preserve hierarchy), model reduction may be able to improve it. The considerable lack of fit is indicated by the F-value of 3.15 for the absence of fit. The risk of noise causing a substantial lack of fit F-value is 4.12%. The research need the model to fit, then a significant departure from fit is not desired.

Figure 8 shows a surface contour map contrasted with the answer. An optimal point, or quadratic, is seen in the image above. There are five points at the midway and each corner of the image above. The points in the lower left corner of the image, which were at 41 °C and produced a yield of 0.9205 mg QE/g, were followed by the points on the right, which were at 100°C and produced a yield of 0.9687 mg QE/g, and the points in the upper left corner, which were at 41 °C and produced a yield of 0.8723 mg QE/g, a temperature of 100°C and 100 mL of solvent gave a yield of 1.0651 mg QE/g at the spot in the top right corner of the image. A temperature of 70.5 °C and 66.65 mL of solvent produced a yield of 1.3783 mg QE/g at the center of the image.

### 3.3. Results of Testing the Moisture Content of Galangal Extract

The amount of water in the substance helps to define how fresh and how long it will last on the shelf. A high-water content will facilitate the growth of bacteria, mold, and yeast, which could damage or alter the product. The evaporation process is required to lower the water content in galangal extract. Figure 9 displays the data regarding the outcomes of measuring the water content in galangal extract.

Based on Figure 9, which illustrates how the ratio of the amount of solvent has caused an increase or reduction in the average value of water content for each modification in the ratio. The range of data fluctuation is indicated by a higher standard deviation value, but a lower standard deviation value suggests that the data are approaching the average. The water examined to determine the water content is free water contained in the material, including physically bound water. The more water added to the substance, the more water it will contain (Weliana *et al.,* 2019). The temperature increase controls the rate at which water evaporation occurs in heating materials. In this investigation, a high temperature of 100 °C is used for evaporation without vacuum cooling. Heat transfers into the substance more quickly the bigger the temperature differential between the heater and the material (Mujumdar, 2004).

The low water content will protect the product from damage for a relatively long period of time. In addition, a decrease in water content will cause the total dissolved solids value to increase. Temperature and solvent ratio influence the water content. The higher the temperature, the lower the water content (Maliaentika *et al*., 2016).

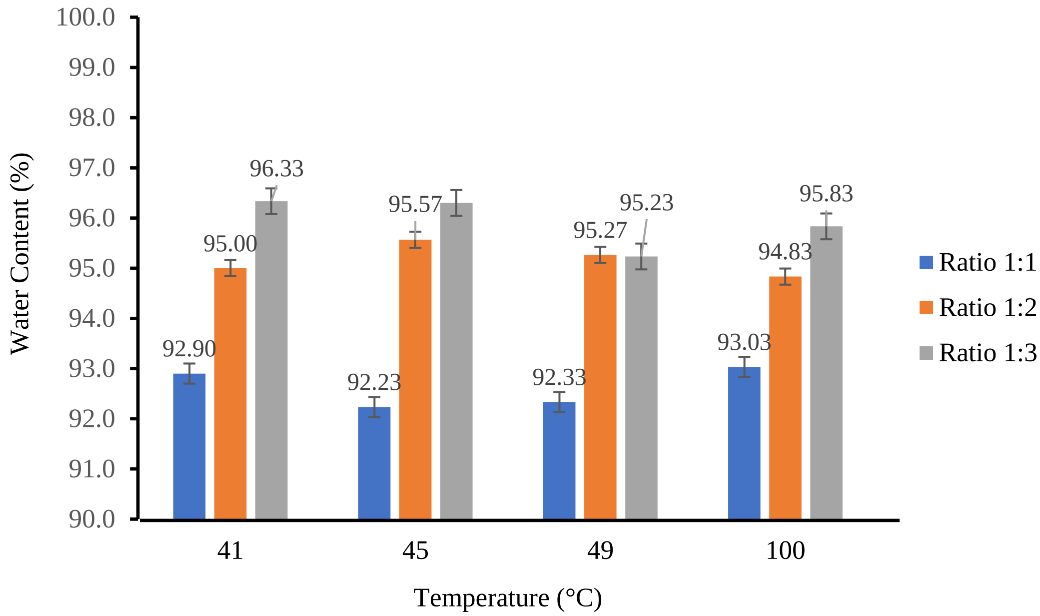



Figure 9. Graph of water content in galangal extract after evaporation

### 3.4. Galangal Extract Yield Test Results

The goal of the evaporative vacuum cooling method is to boil or partially evaporate the solvent in order to get a concentrated galangal extract. The evaporative process ran for ±30 minutes at a low temperature and pressure of -73 cmHg below the atmosphere. By comparing the mass of galangal juice utilized (starting mass) with the mass of extract mass generated (extract mass), the extract yield was determined. Figure 10 presents the yield results.

The average yield value derived from each adjustment in the ratio of the amount of solvent that has increased and decreased is depicted in Figure 10. According to Salamah & Widyasari (2015), a number of factors, including the extraction method, sample particle size, storage conditions, duration of extraction, ratio of sample count to solvent volume, and solvent type, may have an impact on the yield value generated. Variations in how each approach is treated, such as variations in temperature, may create this. According to Huda (2008), the proportion of material left behind will increase if the evaporation temperature is higher, whereas the opposite will occur if the evaporation temperature is lower since the evaporation rate will decrease and the percentage of material left behind will increase. The yield in this investigation was not considerably affected (nor was it significantly different) by the evaporation temperature and ratio. According to Rifai *et al*. (2018), the yield generated will increase with increasing solvent usage. According to Salamah & Widyasari (2015), the yield value generated can be influenced by various parameters, which include the extraction method employed, sample particle size, storage conditions and duration, duration of extraction, ratio of sample count to solvent volume, and kind of solvent utilized.

Optimization of avocado seed oil extraction produces variables that significantly influence the yield results. The time given for higher temperature variables is shorter in extraction because at higher temperatures the solvent has the ease of penetrating the cells in a material and extracting the desired components. Meanwhile, extraction that occurs at low temperatures and for a short time will speed up the contact time of the solvent with the material and it will be difficult for the solvent to penetrate the cells of the material so that the oil components in avocado seeds cannot be extracted completely. Very high temperatures with very long extraction times can cause damage to several components. The extraction temperature has a p-value of 0.0171, indicating that the extraction temperature model has a significant influence on the yield of avocado seed oil extract (Qodim *et al*., 2023).

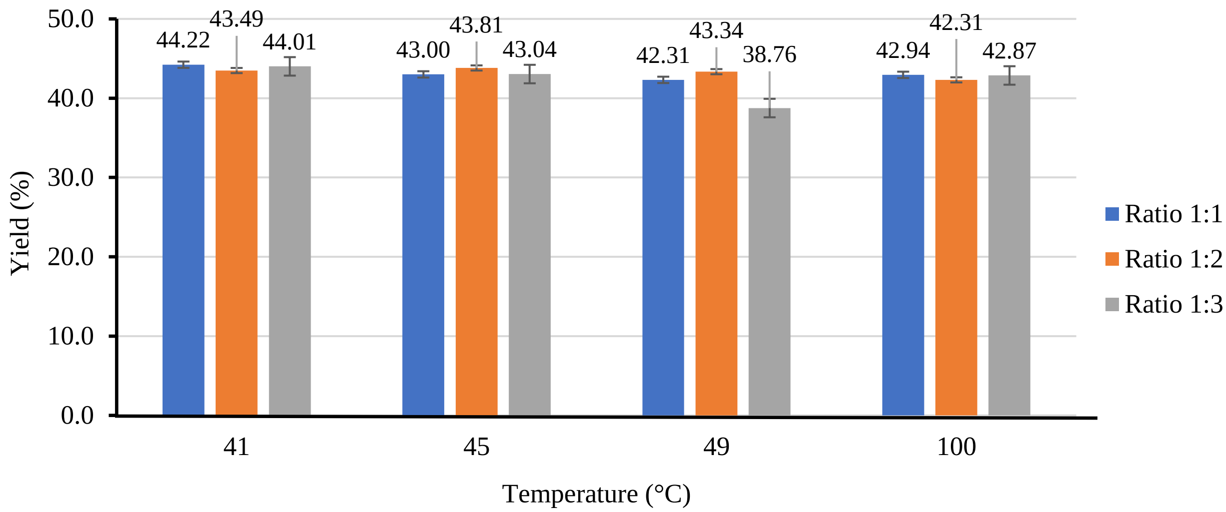



Figure 10. Graph of yield of galangal extract with evaporation treatment

This is different from the results of research on galangal juice extraction, namely the p-value at temperature was 0.3938, which means it is not significant. This can be influenced by factors that may occur and influence the resulting yield value, namely the extraction method used, sample particle size, storage conditions and time, length of extraction time, the ratio of the number of samples to the amount of solvent used, and the type of solvent used.

In line with Table 3, the F-value of 0.63 reveals that the model is not significant with respect to noise. The likelihood that an F-value this large is the product of noise is 67.90%. P-values of less than 0.0500 are deemed significant for model terms. Notably, this example lacks any significant model terms. If the result exceeds 0.1000, the model terms become irrelevant. A model that has a large number of superfluous terms (aside from those needed to preserve hierarchy) may benefit from model reduction in order to improve accuracy. The F-value of 1.25 for the lack of fit suggests that there is no substantial difference between it and the pure error. 31.19% of substantial failure of fit F-values can be attributed to noise. A non-significant lack of fit in the model is what is desired.

Figure 11 clearly shows that the image lacks peaks and red color, indicating a linear outcome. There are five points located at the midway and each corner of the image. Specifically, a temperature of 41 °C and 33.3 mL of solvent produced a yield of 43.97% at the lower left corner; at temperature of 100 °C and 33.3 mL of solvent produced a yield of 42.67% at the right corner; a temperature of 41 °C and 100 mL of solvent produced a yield of 43.27% at the upper left corner; a yield of 43.07% was obtained at the upper right corner with a temperature of 100 °C and 100 mL of solvent; and a yield of 45.77% was produced at the midpoint of the image with a temperature of 70.5 °C and 66.65 mL of solvent. The absence of peaks or red-hued points in the image confirms that it represents a linear model.

Table 3. ANOVA for yield analysis

| Source | Sum of Squares | df | Mean square | F-value | p-value | Mark |
|---|---|---|---|---|---|---|
| **Model** | 27.11 | 5 | 5.42 | 0.6290 | 0.6790 | Not significant |
| **A-Temperature** | 6.45 | 1 | 6.45 | 0.7487 | 0.3938 | Not significant |
| **B-Solvent** | 1.34 | 1 | 1.34 | 0.1558 | 0.6959 | Not significant |
| **A×B** | 5.25 | 1 | 5.25 | 0.6089 | 0.4413 | Not significant |
| **$A^2$** | 12.73 | 1 | 12.73 | 1.48 | 0.2338 | Not significant |
| **$B^2$** | 10.00 | 1 | 10.00 | 1.16 | 0.2900 | Not significant |
| **Residual** | 258.61 | 30 | 8.62 | | | |
| **Lack of Fit** | 31.49 | 3 | 10.50 | 1.25 | 0.3119 | Not significant |
| **Pure Error** | 227.12 | 27 | 8.41 | | | |
| **Cor Total** | 285.72 | 35 | | | | |

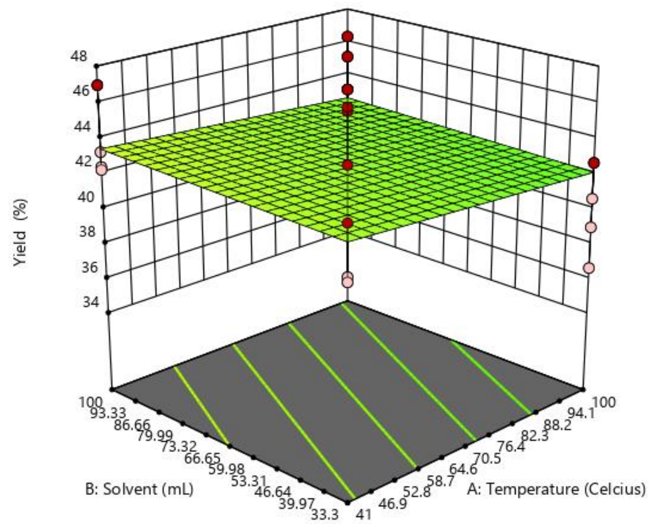



Figure 11. Contour plots and graphs yield

## 4. CONCLUSION

The results obtained during optimization using Design Expert software with the Response Surface Methodology (RSM) model, namely for total phenol, obtained a value that was not yet optimal, indicated by the linear F-value result of lack of suitability of 1.46, meaning that the lack of suitability was not significant compared to the pure error. There is a possibility of 23.10% due to noise. For total flavonoids, the optimal results were quadratic, with the p-value for lack of fit being significant at 0.0412, so the resulting p-value was <5%. Furthermore, the yield optimization has not found the optimum point because the p-value is not significant. The variety of the evaporation temperature gradient (41 °C, 45 °C, 49 °C), the ratio of the amount of solvent (1:1, 1:2, 1:3), and the interaction of the two variables in the method of evaporative vacuum cooling demonstrated that there was no significant effect on the yield of total phenolic compounds and flavonoids, according to the research findings. With a 1:1 solvent ratio of 1.4432±0.7317 mg GAE/g and an evaporative vacuum cooling treatment at 49 °C, the maximum total phenol content was achieved. Below that point, the total phenol content decreased. The evaporative vacuum cooling process at 45 °C yielded the highest quantities of total flavonoids, with a 1:2 solvent ratio of 1.2418±0.2365 mg QE/gr. The evaporative vacuum cooling method produced from galangal extract does not exhibit any significant effect (Sig. > 0.05) on the yield when the evaporation temperature gradient (41 °C, 45 °C, 49 °C) and the ratio of the amount of solvent (1:1, 1:2, 1:3) are varied. The maximum yield of galangal extract was achieved at an evaporation temperature of 41 °C under vacuum cooling and a solvent ratio of 1:1, or 44.222±2.413 %. All samples produced varied masses throughout the processing of galangal extract from evaporative vacuum cooling results; the greatest results were obtained at 41 °C evaporation temperature treatment with a 1:1 solvent ratio of 13.27 g of concentrated extract. This can occur due to the use of variations or inappropriate solvent to temperature ratios.

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## REFERENCES

Aldrian, E. (2008). *Meteorologi Laut Indonesia*. Jakarta: Badan Meteorologi dan Geofisika.

Bravo, L. (1998). Polyphenols: Chemistry, dietary sources, metabolism, and nutritional signifinance. *Nutrition Reviews*, ***56***(11), 317-333. https://doi.org/10.1111/j.1753-4887.1998.tb01670.x

Cahyani, S.A. (2021). Pengaplikasian vacuum cooling pasca pasteurisasi pada madu hutan riau terhadap aktivitas enzim diastase dan sifat fisik. [*Undergraduate thesis*]. Malang: Faculty of Agricultural Technology, Brawijaya University.

Chang, C.C., Yang, M.H., Wen, H.M., & Chern, J.C. (2002). Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *Journal of Food and Drug Analysis*, ***10***(3), 178-182. https://doi.org/10.38212/2224-6614.2748

Darmawan, D. (2013). *Metode Penelitian Kuantitatif*. Bandung: Remaja Rosdakarya.

Fauzi, A. (2019). *Aneka Tanaman Obat & Khasiatnya*. Yogyakarta: Media Pressindo.

Hoffman, R., Feltovich, P.J., & Ford, K. (1997). A general conceptual framework for conceiving of expertise and expert systems. In P.J. Feltovich, K.M. Ford, & R.R. Hoffman (Eds.), *Expertise in context* (1st ed.). AAAI/MIT Press.

Hradaya, K.P.T., & Husni, A. (2021). Pengaruh suhu ekstraksi terhadap aktivitas antioksidan ekstrak metanolik *Eucheuma spinosum*. *Jurnal Pengolahan Hasil Perikanan Indonesia*, ***24***(1), 1-10. https://doi.org/10.17844/jphpi.v24i1.34193

Huda, S. (2008). Analisa proses pengentalan susu evaporasi pada berbagai perlakuan suhu dengan menggunakan evaporator vakum tipe water jet. [*Undergraduate thesis*]. Malang: Faculty of Agricultural Technology, Brawijaya University.

Maliaentika, S., Yuwono, S.S., & Wijayanti, N. (2016). Optimasi penurunan kadar air madu metode adsorption drying dengan response surface methodology (RSM). *Jurnal Pangan dan Agroindustri*, ***4***(2), 505-514.

Manurung, E. (2016). Pengaruh waktu dan suhu pada ekstraksi fenol dari lengkuas merah (*Alpinia purpurata* K *schum*). [*Undergraduate Papers*]. North Sumatera: Faculty of Engineering, University of North Sumatera.

Miller, A.L. (1996). Antioxidant flavonoids: Structure, function, and clinical usage. *Alternative Medicine Review*, ***1***, 103-111.

Mujumdar, A.S. (2004). *Guide to Industrial Drying: Principles, Equipment and New Developments*. Mumbai, India: Colour Publications Pvt. Limited.

Mutiaran, N. (2021). Pembuatan produk sediaan tablet temulawak (*Curcuma zanthorrhiza Roxb*) melalui uji senyawa total fenol dan flavonoid dengan metode evaporasi vacuum. [*Undergraduate thesis*]. Malang: Faculty of Agricultural Technology, Brawijaya University.

Perdani, C.G., Pranowo, D., & Qonitatilah. (2019). Total phenols content of green coffee (*Coffea arabica* and *Coffea canephora*) in East Java. *IOP Converence Series: Earth and Environmental Science*, ***230***(1), 231.

Prakash, D., & Gupta, K.R. (2009). The antioxidant phytochemicals of nutraceutical importance. *The Open Nutraceuticals Journal*, ***2***, 20-35. http://dx.doi.org/10.2174/1876396000902010020

Qadeer, R., & Rehan, A.H. (1998). A study of the adsorption of phenol by activated carbon from aqueous solutions. *Turkish Journal of Chemistry*, ***26***(3), 357-361.

Qodim, A., Setyorini, D., Panjaitan, R., Variana, Y., & Ansori. (2023). Optimasi ekstraksi minyak biji alpukat dengan pelarut n-hexana. *Jurnal Teknologi Kimia Mineral [JTKM], **2***(1), 53–59. https://doi.org/10.61844/jtkm.v2i1.452

Rifai, G., Widarta, I.W.R., & Nocianitri, K.A. (2018). Pengaruh jenis pelarut dan rasio bahan dengan pelarut terhadap kandungan senyawa fenolik dan aktivitas antioksidan ekstrak biji alpukat (*Persea americana Mill.*). *Jurnal Ilmu dan Teknologi Pangan (ITEPA)*, ***7***(2), 22-32. https://doi.org/10.24843/itepa.2018.v07.i02.p03

Retno, R.D., & Priantinah, D. (2012). Pengaruh good corporate governance dan pengungkapan corporate social responsibility terhadap nilai perusahaan (Studi empiris pada perusahaan yang terdaftar di bursa efek Indonesia periode 2007-2010). Nominal: *Barometer Riset Akuntansi dan Manajemen*, ***1***(1), 84-103. http://dx.doi.org/10.21831/nominal.v1i2.1000

Salamah, N & Widyasari, E. (2015). Aktivitas antioksidan ekstrak metanol daun kelengkeng (*Euphoria longan* (L) *Steud.*) dengan metode penangkapan radikal 2,2'-Difenil-1-Pikrilhidrazil. *Pharmaciana Journal*, ***5***(1), 25-34. http://dx.doi.org/10.12928/pharmaciana.v5i1.2283

Sari, B.L., Triastinurmiatiningsih, & Haryani, T.S. (2020 Optimasi metode microwave-assisted extraction (MAE) untuk menentukan kadar flavonoid total alga coklat padina australis. *Alchemy: Jurnal Penelitian Kimia*, 16(1). https://doi.org/10.20961/alchemy.16.1.34186.38-49

Setyaningsih, T. (2013). Studi Aktivitas Antibakteri dan Identifikasi Fraksi Teraktif Rimpang Lengkuas (*Alpinia galanga* (L.) Swartz ). [Undergraduate Thesis]. Department of Chemistry, Universitas Sebelas Maret, Surakarta, Indonesia.

Singleton, V.L., Othofer, R., & Lamuela-Raventos, R.M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology*, ***299***(14), 152-178. https://doi.org/10.1016/S0076-6879(99)99017-1

Sumodiningrat, G. (1999). *Pemberdayaan Masyarakat dan Jaring Pengaman Sosial*. Jakarta: PT. Gramedia Pustaka Utama.

Tjitrosoepomo, G. (1994). *Morfologi Tumbuhan*. Yogyakarta: Gajah Mada University Press.

Vankar, P.S., Shanker, R., Srivastava, J., & Tiwari, A.V. (2006). Change in antioxidant activity of spices - turmeric and ginger on heat treatment. In: Purnomo, H., Jaya, F., & Widjanarko, S.B., eds., 2010. The effects of type and time of thermal processing on ginger (Zingiber officinale Roscoe) rhizome antioxidant co. *International Food Research Journal*, ***17***, 335-347.

Waziroh, E., Ali, D.Y., & Istianah, N. (2017). *Proses Termal pada Pengolahan Pangan*. Malang: Brawijaya University Press, Malang.

Weliana, Raharjo, D., & Hartanti, L. (2020). Singkong patient of formulation (*Manihot Utillisima*) and gelatin on physicocymic and oranoleptic properties of marshmallow. *Jurnal Sains Pertanian Equator*, ***9***(1), 1-12.