Volume 2 (June 2022)

Journal of Biobased Chemicals

Department of Chemical Engineering
Universitas Jember

PREFACE

We would like to present the 2nd volume and edition of our journal, Journal of Biobased Chemicals, published by the Department of Chemical Engineering, University of Jember, Indonesia. This volume is expected to enhance the findings and research about natural product and their derivatives, mostly in energy, chemicals, and materials. We present articles related to the products, processes, and management of biobased chemicals.

This new journal was envisioned and founded to represent the growing needs of biobased chemicals research as an emerging and increasingly vital field, now widely recognized as an ideal substitution for fossil-based chemicals. The journal has an objective to deliver and provide notable and standardized research and findings through journal reporting. The journal is intended as a window or a library for practitioners and researchers to share their works, identify new issues, and organize further research, while industrial users could apply the invention for scale-up, problem-solving, and application.

Hopefully, this edition will contribute valuable thoughts for the readers and enhance future research related to biobased chemical products. Finally, we send gratitude to all participants, including authors, reviewers, and editors, for their contributions.

June 2022

Boy A. Fachri

EDITORIAL BOARD
Journal of Biobased Chemicals

Journal of Biobased Chemicals implements a regular system in terms of upload, review, and acceptance of the journal. Moreover, the journal is supported by an expert team in its fieldto maintain the quality of the publication.

EDITOR IN CHIEF

Boy Arief Fachri, S.T., M.T., Ph.D.
Department of Chemical Engineering, Universitas Jember, IndonesiaEmail: chemeng.teknik@unej.ac.id

EDITOR BOARD

TABLE OF CONTENTS

RESEARCH ARTICLE

JOURNAL OF BIOBASED CHEMICALS

Volume 2, Issue 1, 2022, pp. 1 – 9

Journal homepage: http://journal.unej.ac.id/JOBC

Hydrolysis of Mixed Sugarcane Bagasse and Rice Husk Using Cellulase Enzyme for Reducing Sugar Production

Melyta Rizky Pratami, Rizki Fitria Darmayanti*, Nanda Febia Nuraini, Faizzatul Munawaroh

Department of Chemical Engineering, Universitas Jember, Indonesia 68121

(Submitted: 10 January 2022; Revised: 12 March 2022; Accepted: 3 July 2022)

Abstract. Reducing sugar can be produced from lignocellulosic raw materials. The content of polysaccharides such as cellulose, hemicellulose, and starch will be broken down into simpler carbohydrates. This study used a mixture of sugarcane bagasse and rice husks as lignocellulosic raw materials. The lignin content in the raw material must be removed through delignification or pretreatment so that enzymes can access cellulose and hemicellulose. This study used a physicochemical pretreatment method, in which lignocellulosic material was soaked in 3% NaOH, then heated with microwave and boiling water. The following process is enzymatic hydrolysis with variations of cellulase enzyme activity 0.434, 0.871, 2.61, and 3.49 FPU/g mixture of bagasse and rice husks. The cellulase enzyme used in this study was also derived from the fungus *Trichoderma viride*. Analysis of the sugar concentration resulting from hydrolysis used the DNS method with the 3.5-dinitrosalicylic acid reagent. The concentration of sugar from hydrolysis using a variety of enzymes with microwave heating pretreatment and boiling water pretreatment obtained the highest results, which were the same at the addition of enzyme activity 3.49 FPU/g substrate at 24 hours, namely 4.077 g/L and 15.18 g/L. The optimum time for enzymatic hydrolysis is 12 hours, and the optimum enzyme activity is the addition of 2.61 FPU/g. The average concentration of sugar hydrolyzed by the addition of *Trichoderma viride* solution in pretreatment using microwave heating was 0.7611 g/L, with a yield of 21.01 mg sugar/g substrate, and with pretreatment in boiling water, it was 0.8679 g/L, with a yield of 23.95 mg sugar/g substrate.

Keywords: *sugarcane bagasse, rice husk, enzymatic hydrolysis, lignocellulose, reducing sugar, and Trichoderma viride*

1. Introduction

Until now, many studies have used biomass waste as a raw material to produce reduced sugar. Reducing sugar can be made from the hydrolysis of lignocellulosic materials because the lignocellulosic structure can be converted into reducing sugars and has the potential to be

* corresponding author: r.f.darmayanti@unej.ac.id

further processed for the manufacture of butanol, acetone, ethanol, and other products with higher economic value [1]. Examples of reducing sugars are all monosaccharides (*glucose*, *fructose*, *galactose*), disaccharides (*lactose*, *maltose*) except sucrose, and starch (*polysaccharides*) [2]. The content of cellulose and hemicellulose in lignocellulosic materials has the potential to be a source of reducing sugar production. Polysaccharides will be broken down into simple sugar monomers, such as reducing sugars [1]. Enzymatic hydrolysis can be chosen as a more environmentally friendly method than hydrolysis using acid to produce high concentrations of reducing sugars [1].

Biomass raw materials are abundant and not used as food, so their use as alternative fuels or other economically valuable materials does not interfere with food availability. Biomass can be produced from plants and agricultural and industrial waste [3]. Agrarian waste in Indonesia reaches 19.5 megatons per year for the primary commodities: rice husks, cassava peels, sugar cane bagasse, coffee grounds, and cocoa husks (BPS Indonesia, 2018). This study uses mixed biomass from rice husks and bagasse agricultural waste because there is still no research that uses mixed raw materials of agricultural waste. In the manufacture of sugar reduction, raw materials are processed through several steps, namely pretreatment, hydrolysis, and fermentation, to produce reducing sugar through 2 steps, namely pretreatment and hydrolysis [4].

Pretreatment is classified into several methods: physical, physicochemical, chemical, and biological pretreatment [5]. Some of the standard pretreatment methods can be combined. Microwave heating is generally used with other pretreatment methods, especially chemical treatments [6]. Pretreatment with boiling water heating is suggested as one of the leading pretreatment methods [5]. In this study, before pretreatment using a microwave and heating with boiling water, raw materials were soaked in NaOH 3%. The pretreatment methods with microwave heating and boiling water heating are more often recommended for use and are suitable for laboratory scale; therefore, the two pretreatment methods are compared with the effect of sugar concentration resulting from hydrolysis in this study.

Hydrolysis can be done chemically, biologically, and enzymatically. Enzymatic hydrolysis has several advantages compared to acid hydrolysis, which provides high sugar results and relatively low maintenance costs because there are no corrosive materials [7]. Acid hydrolysis has the disadvantage that it is not environmentally friendly. The hydrolysis method assisted by microorganisms can be compared with enzymatic hydrolysis in this study. From this

study, it is expected that the hydrolysis results will yield high sugar concentrations and an optimum time for enzymatic hydrolysis.

2. Materials and Methods

2.1 Materials

The materials used in this study were bagasse taken from a sugar factory in Semboro, Jember, and rice husks taken from rice processing in Wirolegi, Jember; cellulase enzymes, *Trichoderma viride* culture was obtained from the microbiology laboratory, FMIPA Universitas Jember; sodium citrate, citric acid, sodium hydroxide (NaOH), aquadest, dinitrosalicylic acid (DNS), potassium sodium tartrate ($KNaC_4H_4O_6.4H_2O$), and sodium metabisulfite ($Na_2S_2O_5$).

2.2 Pretreatment

Twenty-five grams of bagasse and rice husks were each soaked in 250 ml of 3% NaOH solution for 30 minutes. Raw materials that have been washed can be heated in the microwave for 4 minutes or heated with boiling water for 15 minutes.

2.3 Hydrolysis

Enzymatic hydrolysis with the addition of cellulase enzyme activity, 5 grams of delignified sample was added to a flask, then 50 ml of citrate buffer solution, pH 4.8, was added. The cellulase enzyme used was *Viscozyme cassava* CL with an enzyme activity of 709 EGU/g. Each enzyme activity of 0.434, 0.871, 2.61, and 3.49 FPU/g was added in a flask, then hydrolyzed in an incubator shaker with a temperature of 50 ºC and a speed of 160 rpm for 24 hours. The sample was taken every 0, 6, 12, and 24 hours.

3. Result and Discussion

3.1 Enzymatic Hydrolysis with The Treatment of Variations in Cellulase Enzyme Activity

Cellulase enzymes are biocatalysts that help support hydrolysis reactions. Sugar from the hydrolysis of polysaccharide components can be calculated from the absorbance obtained after analysis using the DNS method: the higher the absorbance, the higher the sugar concentration obtained [8]. There is a component in the cellulase enzyme that can break the bonds in cellulose, namely endoglucanase (*endo*-β-1.4-D-*glucan*-4-*glucanohydrolase*), which breaks down β-1.4-glucanohydrolase bonds in the cellulose chain at random, exoglucanase (β-1.4-D-*glucancellobiohydrolase*), which breaks down cellobiose units from the end of the chain, and β-glucosidase, which breaks down cellobiose into glucose [9].

Table 1. Enzymatic hydrolysis of sugar concentration by microwave heating pretreatment

Time (h)	Concentration (g/L)			
	M_1	M_2	M_3	M_4
0	0.7789	0.8011	0.8056	0.8323
6	2.880	3.133	3.151	3.258
12	3.089	3.365	3.961	3.970
24	3.245	3.383	4.063	4.077

Description:
M_1 : Addition of enzyme activity 0.434 FPU/g
M_2 : Addition of enzyme activity 0.871 FPU/g
M_3 : Addition of enzyme activity 2.61 FPU/g
M_4 : Addition of enzyme activity 3.49 FPU/g

Based on Table 1, the sugar concentration increases with time. This is because the enzymes and raw materials collide and react more, so the conversion is higher. The higher the enzyme activity added, the higher the sugar concentration obtained. Higher enzyme activity will hydrolyze more cellulose into sugar; the higher the enzyme activity, the faster the reaction speed will increase [10]. The highest sugar concentration was obtained from adding enzyme activity 3.49 FPU/g (M_4) at 24 hours, namely 4.077 g/L. Most cellulase enzymes have optimum activity in the temperature range of 20 – 50 °C, and the optimum pH range for cellulase activity is 4.5 – 7.0 [11]. If the temperature conditions increase to the optimum temperature, the enzyme reaction rate will increase because the kinetic energy increases.

Table 2. Enzymatic hydrolysis of sugar concentration by hot liquid water pretreatment

Time (h)	Concentration (g/L)			
	G_1	G_2	G_3	G_4
0	3.925	3.957	4.077	4.424
6	8.011	8.145	8.367	9.969
12	8.278	8.768	12.55	14.15
24	8.590	9.124	13.13	15.18

Description:
G_1 : Addition of enzyme activity 0.434 FPU/g
G_2 : Addition of enzyme activity 0.871 FPU/g
G_3 : Addition of enzyme activity 2.61 FPU/g
G_4 : Addition of enzyme activity 3.49 FPU/g

Based on Table 2, the highest sugar concentration of 15.18 g/L resulted from adding the highest enzyme activity of 3.49 FPU/g, namely G_4, with a hydrolysis time of 24 hours. The speed of the reaction also depends on the concentration of the enzyme, where the reaction speed will increase as the concentration of the enzyme increases [8].

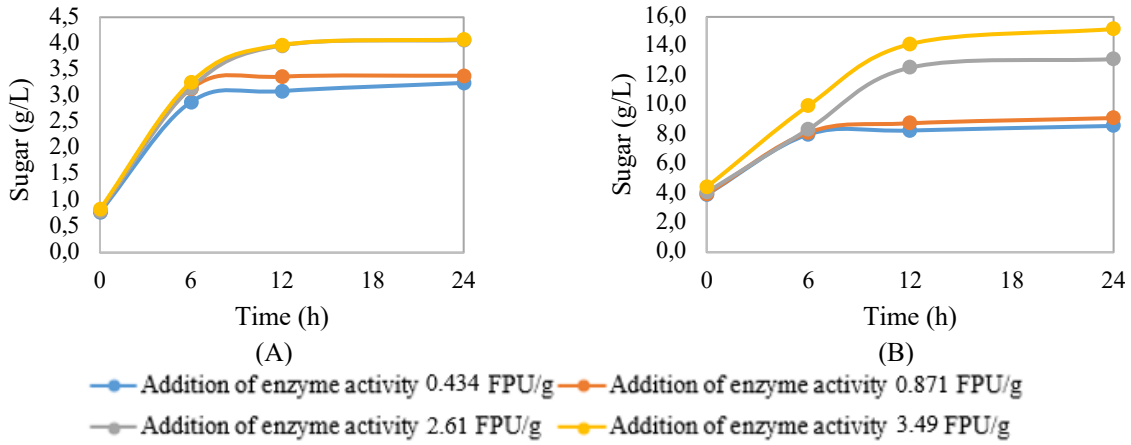


Figure 1. Graph of sugar concentration with cellulase enzyme variation treatment (A) microwave heating pretreatment (B) boiling water heating pretreatment

From Figure 1, it can be seen that the sugar concentration increased with each enzyme variation treatment. After hydrolysis for 24 hours, the lowest sugar concentration was obtained from adding the slightest variation of the enzyme, namely 0.434 FPU/g with 3.245 g/L for pretreatment using microwave heating and 8.590 g/L for pretreatment using boiling water heating. The highest concentration from the enzyme addition was 3.49 FPU/g with 4.077 g/L for pretreatment using microwave heating and 15.18 g/L for pretreatment using boiling water heating. From this statement, the addition of enzyme activity 2.61 FPU/g is quite an optimum enzyme activity, because the results of the sugar concentration are not much different from the treatment with the addition of enzyme activity 3.49 FPU/g.

Based on Figure 1, it can be concluded that the greater the enzyme concentration, the higher the sugar concentration obtained, which can increase the hydrolysis rate to a specific concentration limit [12]. The increase in sugar concentration from the 12 - 24 hours of each enzyme variation treatment was not very significant or relatively constant. If it exceeded the optimum time, sugar inhibitors would form so that the sugar concentration produced was lower or relatively constant [13]. It can be concluded that the optimum time for hydrolysis is 12 hours. The results of substrate hydrolysis will be continuous with increasing enzyme concentration because the addition of enzymes is no longer effective [10].

3.2 Enzymatic Hydrolysis with the Addition of Trichoderma Viride

The hydrolysate sampling time was carried out on the 7th day of hydrolysis. The optimum operating temperature conditions for the growth of *Trichoderma viride* are at 20 ºC – 36 ºC [14]. The operating temperature condition used in this study is 28 ºC, which is still

included in the optimal temperature range so that the enzyme can work optimally in hydrolyzing cellulose to produce sugar concentrations. Cellulase enzymes produced from *Trichoderma viride* break the complex bonds of cellulose into simpler bonds, namely sugar.

Table 3. Sugar concentration and yield of hydrolysis, addition of solution *Trichoderma viride* with microwave heating pretreatment

Repetition	Sugar concentration (g/L)	*Yield* (mg sugar/g substrate)
1	0.9480	26.16
2	0.4273	11.79
3	0.9079	25.06

Based on Table 3, it can be seen that the average sugar concentration is 0.7611 g/L with an average yield of 21.01 mg sugar/g substrate for raw materials that are treated with microwave heating. One of the microbes that can produce cellulase enzymes is *Trichoderma sp*. *T. viride* can produce cellulase enzymes consisting of endoglucanase, exoglucanase, and β-glucosidase [14].

Table 4. Sugar concentration and yield of hydrolysis, addition of solution *Trichoderma viride* with boiling water heating pretreatment

Repetition	Sugar concentration (g/L)	*Yield* (mg sugar/g substrate)
1	0.8412	23.22
2	0.8545	23.58
3	0.9079	25.06

Table 4 shows that the average sugar concentration obtained is 0.8679 g/L with a yield of 23.95 mg sugar/g substrate. Hydrolysis results with pretreatment heated in boiling water obtained a higher concentration than hydrolysis with pretreatment using microwave heating. This can be interpreted as a reduction in lignin content, so there is a lot of decomposition of the polysaccharide component by the cellulase enzyme from *Trichoderma viride* with pretreatment heated in boiling water.

There are 10 types of cellulosic enzymes produced by *Trichoderma viride* that work together to break down cellulose material [7]. Amorphous cellulose can be hydrolyzed by endoglucanase, which is randomly soluble, and crystalline cellulose can be degraded by cellobiohydrolase to produce cellobiose. These two enzymes combine to degrade cellulose into

cellobiose and other short cellooligosaccharides. β-glucosidase enzyme to hydrolyze cellobiose and other cellooligosaccharides produced by cellulase into glucose [7].

3.3 Effect of Pretreatment for Enzymatic Hydrolysis

Hydrolysis by pretreatment heated in boiling water obtained a higher sugar concentration every hour based on Table 2 also received a higher sugar concentration based on Table 4 compared with the results of sugar concentration in Tables 1 and 3, namely hydrolysis where the raw material was pretreated with microwave heating. The pretreatment process with longer heating will damage most of the lignin structure, so enzymes can more easily access cellulose and hemicellulose, so that the hydrolysis process runs more easily and a higher sugar concentration is obtained [15].

In the enzymatic hydrolysis process using lignocellulosic materials, pretreatment is crucial to increase the accessibility of cellulose-degrading enzymes [16]. The conversion of lignocellulosic biomass materials into sugars is done through pretreatment to open the biomass structure, release sugar groups from cellulose and hemicellulose, and increase the material's porosity [17]. Microwave heating is generally used in combination with other pretreatment methods. Microwave heating with a combination of pretreatment using an alkali has been widely studied, mainly because the results obtained by alkaline solvents are better and recommended, and have been shown to produce high sugar yields and higher lignin removal compared to acidic solvents [6]. Boiling water heating pretreatment is suggested as one of the leading methods [5].

Several advantages of using a microwave as a pretreatment method are faster heating rate, shorter reaction time, and high energy efficiency. The main drawback of microwave heating is the non-uniform heat profile [6]. When lignocellulosic biomass is heated by microwave, selective heating of polar molecules is observed due to the effect of dipolar polarization. This selective heating also decreases the crystallinity of cellulose. In the presence of polar solvents, hot spots can cause rupture or explosion of some lignocellulosic structures [6]. The advantages of boiling water heating are that there is no need to reduce the particle size of the substrate, it is effective and cost-efficient because there is no addition of other chemicals, and it is not corrosive. The purpose of boiling water heating is to trigger changes in the structure of lignocellulose to make cellulose more accessible to enzymes. Hemicellulose, on heating, is maintained in the form of oligomers, and the formation of monomers is minimized [5].

Based on Table 2, with the highest sugar concentration of 15.18 g/L, and Table 4, with an average sugar concentration of 0.8679 g/L, the highest sugar concentration was obtained from pretreatment of raw materials using boiling water heating for 15 minutes. This is because when soaking with 3% NaOH for 30 minutes, the NaOH solution damaged the lignin structure, the crystalline and amorphous parts, and the solution also separated some of the lignin and hemicellulose. It caused swelling of the cellulose [18]. Several studies have been conducted on the superiority of NaOH as a pretreatment solution for lignocellulosic materials. The strongest alkali catalyst that is effective in increasing the rate of enzymatic hydrolysis is NaOH solution compared to other alkali solvents [19]. The cellulose content after pretreatment increased. In addition to the NaOH solution, heating can damage the lignin structure. The longer the delignification process uses heat, the more lignin is degraded.

4. Conclusion

Enzymatic hydrolysis with adding variations in enzyme activity obtained a higher sugar concentration than hydrolysis with adding *Trichoderma viride*. The optimum time for enzymatic hydrolysis was 12 hours, with the optimum variety of enzyme activity 2.61 FPU/g. Pretreatment by heating in boiling water, combined with 3% NaOH immersion, obtained a higher sugar concentration because a lot of lignin was degraded, thereby increasing the accessibility of cellulose-degrading enzymes.

ACKNOWLEDGMENTS

PG supported and facilitated the study. Jember, Jember Wirolegi Rice Processing, Microbiology Laboratory, Faculty of Mathematics and Natural Sciences (FMIPA), and Chemical Engineering Department of Universitas Jember.

REFERENCES

[1] Hanifa, A. S. Degradasi komponen selulosa, hemiselulosa, dan pati tepung kulit ubi kayu menjadi gula pereduksi oleh *Aspergillus niger, Trichoderma viride, dan Acremonium sp.* IMI 383068 (2018).

[2] Afriza, R., & Ismanilda. Analisis perbedaan kadar gula pereduksi dengan metode lane eynon dan luff schrool pada buah naga merah (*Hylocereus Polyrhizus*). Jurnal Teknologi dan Manajemen Pengelolaan Laboratorium (Temapela) (2019).

[3] Fajariah, H. D. Pemanfaatan serbuk gergaji menjadi biobutanol dengan hidrolisis selulase dan fermentasi bakteri *Clostridium acetobutylicum*. Department Environmental Engineering, Faculty of Civil Engineering and Planning Sepuluh Nopember Institute of Technology (2012).

[4] Menon, V., & Rao, M. Trends in bioconversion of lignocellulose: biofuels, platform chemicals & biorefinery concept. Progress in Energy and Combustion Science 38(4) (2012) 522–550.
[5] Karimi, K. Biofuel and biorefinery technologies volume 1: lignocellulose-based bioproducts. Springer International Publishing AG Switzerland.2015.
[6] Muley, P. D., & Boldor, D. Advances in biomass pretreatment and cellulosic bioethanol production using microwave heating. SEEP2017.
[7] Faiqoh, H. Efisiensi hidrolisis tepung kulit ubi kayu menggunakan H_2SO_4, *Trichoderma viride* dan *Aspergillus niger*. Digital Repository Universitas Jember.2017.
[8] Rismawati, Y., Bahri, S., & Prismawiryanti. Produksi glukosa dari jerami padi *(Oryza Sativa)* menggunakan jamur *Trichoderma sp*. KOVALEN2016.
[9] Sitasari, C. I., & Prasetyo, Y. I. Produksi gula reduksi dari bagasse tebu melalui hidrolisis enzimatik menggunakan crude enzyme selulase dan xilanase. Department Chemical Engineering, Sepuluh Nopember Institute of Technology.2014.
[10] Permanasari, A. R., Yulistiani, F., Tsaqila, M. A., Alami, D., & Wibowo, A. Pengaruh konsentrasi substrat dan enzim terhadap produk gula reduksi pada pembuatan gula cair dari tepung sorgum merah secara hidrolisis enzimatis.2018.
[11] Kusumaningrum, A., Gunam, I. B. W., & Wijaya, I. M. M. Optimasi suhu dan ph terhadap aktivitas enzim endoglukanase menggunakan Response Surface Methodology (RSM). Jurnal Rekayasa dan Manajemen Agroindustri (2019).
[12] Sitompul, H., Putra, D. R., Kimia, J. T., Teknik, F., & Lampung, U. Proses hidrolisis tandan kosong kelapa. Analit: Analytical and Environmental Chemistry.2016.
[13] Utami, R. S., & Sari, E. P. Pati kentang dengan katalis asam. E K U I L I B R I U M2014.
[14] Juwaied, A. A., Al-amiery, A. A. H., & Abdumuniem, Z. Optimization of cellulase production by aspergillus niger and trichoderma viride using sugar cane waste. Journal of Yeast and Fungal Research 2(2) (2011).
[15] Asgher, M., Ahmad, Z., Muhammad, H., & Iqbal, N. Alkali and enzymatic delignification of sugarcane bagasse to expose cellulose polymers for saccharification and bio-ethanol production. Industrial Crops & Products 44 (2013) 488–495.
[16] Oktavia, F. I., Argo, B. D., Lutfi, M., & Korespondensi, P. Hidrolisis Enzimatik Ampas Tebu (Bagasse) Memanfaatkan Enzim Selulase dari Mikrofungi *Trichoderma reseei* dan *Aspergillus niger* Sebagai Katalisator dengan Pretreatment Microwave. Jurnal Keteknikan Pertanian Tropis dan Biosistem (2014).
[17] Dharmaraja, J., Shobana, S., Pugazhendhi, A., & Kumar, G. Biobutanol from lignocellulosic biomass : bioprocess strategies in Lignocellulosic Biomass to Liquid Biofuels. INC. 2020.
[18] Gunam, I. B. W., Buda, K., & Guna, I. M. Y. S. Pengaruh Perlakuan Delignifikasi Dengan Larutan Naoh Dan Konsentrasi Substrat Jerami Padi Terhadap Produksi Enzim Selulase dari *Aspergillus niger*. Jurnal Biologi XIV (1) (2010).
[19] Kim, S. J., Lee, Y. Y., & Hyun, T. Bioresource Technology A review on alkaline pretreatment technology for bioconversion of lignocellulosic biomass. Bioresource Technology (2015).

RESEARCH ARTICLE

JOURNAL OF BIOBASED CHEMICALS

Volume 2, Issue 1, 2022, pp. 10 – 30

Journal homepage: http://journal.unej.ac.id/JOBC

Comparison of Pegagan (*Centella asiatica* (L.)) Extraction with Ultrasound-Assisted Extraction and Microwave-Assisted Extraction Methods Using Response Surface Methodology

Ayu Ulum Rahmawati[1], Atiqa Rahmawati[2,*]

[1]Department of Chemical Engineering, Universitas Jember, Indonesia 68121

[2]Department of Leather Engineering and Skin Preservation, Politeknik ATK Yogyakarta, Indonesia 55188

(Submitted: 17 January 2022; Revised: 15 March 2022; Accepted: 10 July 2022

Abstract. Pegagan (*Centella asiatica* (L.)) is an herbaceous plant that grows and flowers throughout the year. Pegagan has been used for hundreds of years, especially in the dermatology and cosmetology industries. Pegagan (*Centella asiatica* (L.)) has distinctive bioactive components, namely triterpene ester glycoside compounds in the form of asiaticoside and madecoside, as well as triterpene group compounds in the form of asiatic acid and madecasic acid. There are various extraction methods to produce the following compounds, namely, conventional extraction methods and modern extraction methods. The two methods have differences in the results obtained. Therefore, the difference in the extraction method will determine the outcome of the difference in the levels of a compound. So that this research was carried out on the effect of Pegagan (*Centella asiatica* (L.)) extraction using a comparison of the Microwave-Assisted Extraction (MAE), and Ultrasound-Assisted Extraction (UAE) methods on the total phenol content in the Pegagan (*Centella asiatica* (L.)) extracted. The extracted bioactive content was analyzed by analyzing the total phenol content using the Folin-Ciocalteau reagent method and analyzing the data through the Analysis of Response Surface Design expert 11 to see the significance of the research variables. The results obtained from the study compare the optimal conditions for the total phenol content, namely, the comparison between the UAE and MAE methods for *Centella asiatica* (L.). Extracted with ethanol solvent, which is more optimal using the MAE method, because it can produce 1130,7882 mg quickly.

Keywords: *Ultrasound-Assisted Extraction, Microwave-Assisted Extraction, Centella asiatica* (L.)*, Phenolic Test.*

1. Introduction

Many new modern medicines are on the market; there is a global tendency to return to nature (back to nature). Some of the factors that encourage people to utilize natural medicines, among others, are the high prices of modern/synthetic medication and the many side effects

associated with these drugs. Therefore, natural medicines are now increasingly popular among the public, and their use is increasing in developing countries such as Indonesia and developed countries such as Germany and the United States. One of the plants that has medicinal properties is Pegagan (*Centella asiatica* (L.)) [1].

Pegagan (*Centella asiatica* (L.)) is an herbaceous plant that grows and flowers throughout the year. Pegagan is often found in rice fields, between grasses, on slightly moist soil, and in the low and highlands. This plant grows in tropical Asia and various countries such as the Philippines, China, India, Sri Lanka, Madagascar, and Indonesia [2]. Pegagan is a plant that people in Asian countries widely use. It contains various beneficial compounds that can be used as medicines, natural fungicides, and antimicrobials [3]. The Pegagan herb treats abdominal pain, cough, bloody cough, wound healing, dysentery, inflammation, aches, pains, asthma, hemorrhoids, tuberculosis, leprosy, fever, diabetes, and appetite enhancer [1]. Several researchers have tested the content of Pegagan compounds, such as Pegagan extract, which contains compounds that are antimicrobial and anti-fungal [4], as an antioxidant [5] and anticancer [6].

The components of the compounds contained in Pegagan are triterpenoids, including pentacyclic triterpenic acids, and glycosides, which consist of: asiatic acid, asiaticoside, mandecassic acid, m, andecassoside, brahmoside, brahmic acid, brahminoside, thankuniside, isothankuniside, centalloside, madasiatic acid, centic acid. Pegagan also contains flavonoids such as quercetin, kaempferol, and astragalin. Hydrocotylin alkaloids, as well as phytosterols, stigmasterol, and sitosterol. Other compounds are tannins, amino acids, B vitamins, and resins [3]. There are various extraction methods to produce the following compounds, namely, conventional extraction methods and modern extraction methods.

Conventional extraction methods include maceration and reflux. Meanwhile, modern extraction methods include Microwave-Assisted Extraction (MAE) and Ultrasound-Assisted Extraction (UAE) according to [7]. Extraction using the MAE method on onion skin with a power of 800 watts for 6 minutes produces a flavonoid level of 17.18%. Extraction using the maceration method for 3 days at room temperature produces a flavonoid level of 14.92%. Another study on white tea leaves showed that the optimum time and temperature for the UAE method was 40 °C for 19.5152 minutes with a flavonoid content of 0.39% [7]. In addition, research on corn cobs showed that extraction using the reflux method with a temperature of 50

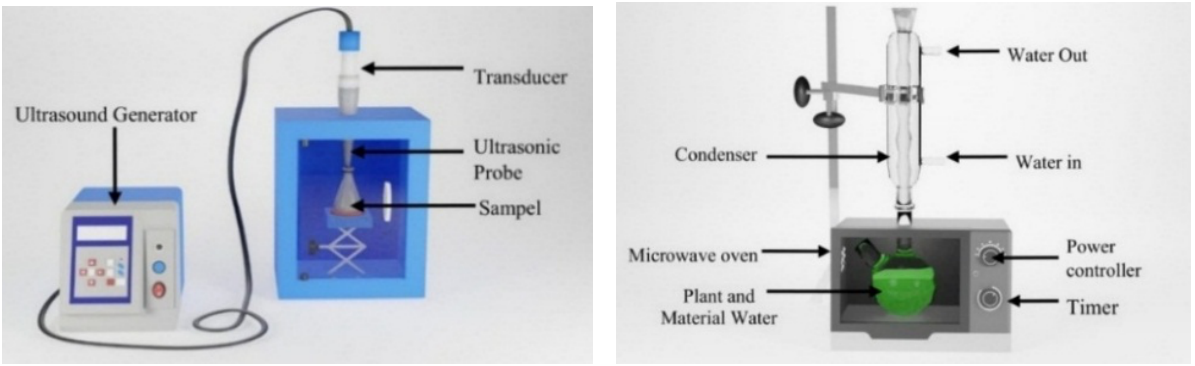
°C for 2 hours produced a phenolic content of 0.03% [8]. Therefore, the difference in the extraction method will determine the result of the difference in the levels of a compound.

Based on the problems and facts above, a study was conducted on the effect of Pegagan (*Centella asiatica* (L.)) extraction by using a comparison of the Microwave-Assisted Extraction (MAE) and Ultrasound-Assisted Extraction (UAE) methods on the total phenol content of the Pegagan (*Centella asiatica* (L.)) extracted. This research is expected to find the most optimum method to achieve optimal conditions by producing the highest total phenol content in the Pegagan (*Centella asiatica* (L.)) extract.

2. Materials and Methods

2.1 Materials

Pegagan leaves (*Centella asiatica* (L.)) were obtained from the Sumberarum area, Songgon District, Banyuwangi. The Pegagan leaves are dried in the sun for 2 days, the dried Pegagan leaves are crushed using a blender until they become powder, the Pegagan powder is sifted using a 40-mesh sieve, and data processing is done using expert design.



(a) (b)

Figure 1. Tool Schematic (a) Ultrasound-Assisted Extraction (b)

In Figure 1 (a), this *Ultrasound-Assisted Extraction* method uses a probe-type Sonicator. In contrast, Figure 1 (b) shows *Microwave-Assisted Extraction, which* uses a microwave oven type Electrolux model EMM2308X, 23 liters, max temperature 250, dimensions 292.5 x 485 x 370 mm. Uses 800 W of power.

The research procedure was carried out through 3 stages: (1) sample preparation, extraction using the method *Ultrasound-Assisted Extraction* and *Microwave-Assisted Extraction*, (3) Analysis of research results. Pegagan leaves were dried in the sun for 2 days with the determination of physical drying, then mashed with a size of 40 mesh with a mass of 1 gram. Furthermore, the extraction was carried out with several variables, including the UAE

concentration method (25%, 50%, 75%, time variables of 20 minutes, 40 minutes, and 60 minutes, and power variables of 30 watts, 150 watts, and 270 watts. As for the MAE method, the variables are concentration variables of 25%, 50%, and 75%, time variables are 5 minutes, 10 minutes, and 15 minutes, and variable power of 150 watts, 300 watts, and 450 watts. The extraction results were stored in an 8 ml vial at a temperature of 4 ℃.

2.2 Preparation of a Standard Solution of Gallic Acid at 100 Ppm

Weighed 0.01 grams of gallic acid, then added 1 ml of ethanol and one distilled water until the volume became 100 ml.

2.3 Determination of the Maximum Wavelength of Gallic Acid

Take 1 ml of 100 ppm gallic acid mother liquor, put it in a test tube, and add 1 ml of Folin's reagent. Then the solution mixture was shaken until homogeneous and allowed to stand at room temperature for 4-8 minutes. 4 ml of 10% Na_2CO_3 solution was added to a test tube, shaken until homogeneous, and allowed to stand for 15 minutes at room temperature. Analyzed using a UV-vis spectrophotometer with a wavelength range of 700 – 800 nm [9].

2.4 Preparation of Gallic Acid Calibration Curve with Folin-Ciocalteu Reagent

Take 100 ppm gallic acid mother liquor, 1 ml each, 3 ml, 5 ml, and 7 ml. Then diluted with distilled water to a final volume of 10 ml, a solution with a concentration of 10 ppm, 30 ppm, 50 ppm, and 70 ppm will be obtained. 0.2 ml of each solution was taken, put into a test tube, and 1 ml of Folin Ciocalteu reagent was added, shaken until homogeneous, and allowed to stand for 8 minutes. Then 3 ml of 10% Na_2CO_3 was added, shaken until homogeneous, and allowed to stand for 30 minutes at room temperature. Measure the absorption using the maximum wavelength that has been obtained previously. Then a calibration curve is made with the regression equation $y = ax + b$ [9].

2.5 Determination of Total Phenol Content using The Folin-Ciocalteu Method

Take 0.1 ml of the extract, add 9.9 ml of distilled water (dilution 100 times), add 1 ml of Folin-Ciocalteu reagent, then shake until homogeneous, and let stand for 8 minutes. Then add 3 ml of 10% Na_2CO_3 to the mixture, shake until homogeneous, and leave the solution for 1 hour at room temperature. Measure the absorption with a UV-vis spectrophotometer at its maximum wavelength. The content analysis was repeated 3 times so that the phenol content obtained was expressed as mg gallic acid equivalent/gram of fresh sample. Repeat 3 times so

that the total phenol level is described as equivalent gallic acid (Acid Equivalent Gallic/AGE) [9].

3. Result and Discussion

3.1 The Gallic Acid Standard Curve

Determination of total phenol content begins with determining the standard gallic acid curve. The aim is to choose a linear regression equation, which is then used to determine the sample's total phenol content. The standard gallic acid curve was obtained by measuring the absorbance of a series of standard solutions of gallic acid with several concentrations of gallic acid, namely 10 ppm, 30 ppm, 50 ppm, and 70 ppm, and the results from the measurement of the maximum wavelength of 765 nm. Based on the results of making a standard curve using a UV-vis spectrophotometer, the absorbance measurement of the standard solution of gallic acid from several concentrations was measured based on the maximum wavelength obtained, namely 765 nm. The following are the results of the standard gallic acid curve, and the straight-line equation that will be used to determine the total phenol concentration.

Based on the curve in Figure 2, the equation of a straight line is obtained, namely, y = 0.0078x + 0.2144. With the value of the correlation coefficient (R^2) = 0.9949. The correlation coefficient value shows the strength of the relationship between two variables. The strength and weakness of the relationship between the two variables, measured on an interval scale of 0-1. If the correlation coefficient value is close to 1, then the two variables have a firm relationship [10].

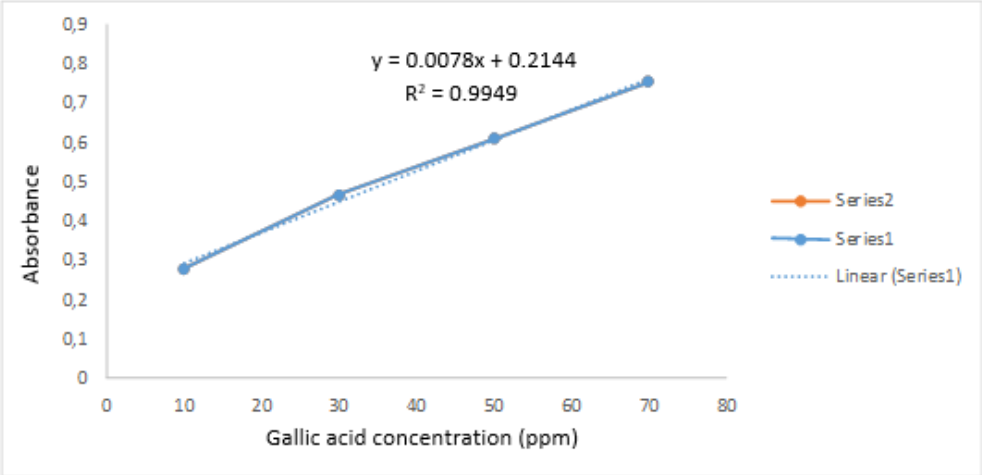


Figure 2. Gallic acid calibration curve *at 765nm wavelength.*

3.2 Extraction Results of Pegagan (*Centella asiatica* (L.)) using the UAE Method

The results of the absorbance and total phenol results from the research can be seen in Table 1 below.

Table 1. Total Phenol Content in Pegagan Plant Extract (*Centella asiatica* (L.)) in *the* UAE

No	Solvent Concentration (%)	Time (Min)	Power (Watts)	Absorbance (Average)	Total Phenol (mg.AGE/g)
1	50	40	150	0.675	589.87
2	50	40	150	0.704	627.05
3	50	40	150	0.656	566.15
4	75	20	150	0.507	357.13
5	75	40	270	0.621	521.28
6	50	40	150	0.682	598.85
7	75	40	30	0.432	278.97
8	25	40	30	0.442	291.79
9	25	60	150	0.531	405.90
10	50	20	270	0.732	662.95
11	50	60	270	0.867	836.67
12	25	40	270	0.662	573.21
13	50	40	150	0.707	631.54
14	50	60	30	0.561	443.72
15	75	60	150	0.563	446.92
16	25	20	150	0.544	422.56
17	50	20	30	0.603	498.21

It can be seen from the Table above that the highest total phenol content was 836.67 mg. The AGE/g of the sample in the UAE variable has a power of 270 watts, with a concentration of 50% for 60 minutes.

3.3 Analysis of Response Surface Design with ANOVA (*Analysis of Variance*)

Table 2 shows that the significance of the variables used is determined by the p-value, which is said to be significant if the p-value <0.05. The F-value of the model obtained from the calculation is 62.19. In the F distribution Table, the value of the F Table with the df model is 9, and the df error value is four at a probability of 0.05, the percentage point is 6.00, which means that the F-value is greater than the F Table. The hypothesis used in the F-value, namely, H_0, is the absence of a relationship between the independent and dependent variables. At the same time, H_1 is a relationship between the independent and dependent variables. H_1 is accepted if the F-value is greater than the F-Table, while H_0 is accepted if the F-value is smaller. So, based on the existing F-value, it shows that F-value > F-Table, which indicates a rejection of H_0, which means that H_1 is accepted. H_1 is a hypothesis that states a significant effect between the dependent and independent variables that has been tested and analyzed.

Table 2. Results of ANOVA Analysis on Pegagan Plant Extracted UAE Method

Source	Sum of Square	df	Mean Square	F-Value	P-Value	
Model	3.217E+05	9	35742.48	62.19	<0.0001	Significant
A-Concentration	632.97	1	632.97	1.10	0.3289	
B-Time	3800.18	1	3800.18	6.61	0.0369	
C-Power	1.426E+05	1	1.426E+05	254.35	<0.0001	
AB	1955.85	1	1955.85	3.40	0.1076	
air conditioning	382.40	1	382.40	0.6653	0.4415	
BC	13019.95	1	13019.95	22.65	0.0021	
A2	1.553E+05	1	1.553E+05	270.26	<0.0001	
B2	16.93	1	16.93	0.0295	0.8686	
C2	136.33	1	136.33	0.2372	0.6411	
Residual	4023.21	7	574.74			
Lack of Fit	1083.21	3	361.07	0.4912	0.7072	Not Significant
Pure Error	2940.00	4	735.00			
Total Cast	3.257E+05	16				

In addition, the F-value is inversely proportional to the value of the p-value, as shown in Table 2. The P-value is said to be significant if the P-value <0.05. The P's value is 0.0001, which means the meaning is smaller than the set probability of 5% or 0.05. *Centella asiatica* (L.) research model significantly affects the extract's total phenol content.

The analysis results in Table 2 also show that the UAE pore variable and extraction time significantly affect the total phenol content, with p-values of 0.0001 and 0.03695, respectively. For the interaction between variables on the response, the interaction of time on power has a real or significant effect on the total phenol content, with a p-value of 0.0021. However, the concentration variable has a p-value of 0.3289, which means that the p-value is greater than 0.005, so the concentration variable in the Pegagan extracted with the UAE method does not significantly affect the total phenol content. This is because the extraction power is too high, which can damage the material's compounds. This is by following per under research conducted by [11], the use of sonication in the extraction process can cause vibrations that have the potential to cause heat so that it can damage the extracted content which causes the acquisition of the total phenol content to below so that it can affect the significance of the model which means it has no real or insignificant effect on the total phenol content. The inaccuracy of the test or the lack of fit value means the deviation or inaccuracy of the model. Lack of Fit testing is required if there are repeated observations. The hypotheses used in the Lack of Fit test are:

H_0 = There is no Lack of Fit in the research model

H_1 = There is a lack of fit in the research model

The Lack of Fit test is carried out to determine whether the research model is appropriate [12]. In Table 2, based on the ANOVA Table, it is found that Lack of fit has a P-value of 0.7072 or more than 0.05, so that H_0 is acceptable, meaning there is no lack of fit in the research model. So, it can be interpreted that the research model used is suitable for predicting the total phenol content in the extraction process.

From the ANOVA analysis, the R-squared value of 0.9876 or 98.76% is more than 75%, indicating that the model fits the research results well. An adjusted R^2 value of 0.9718 indicates a significant relationship between ethanol concentration, extraction time, and UAE power on the response. The value of R-squared is declared according to the model if it is more than 75% [13]. So, the equation of the model can be used to predict the study's actual results. Based on the regression equation obtained, it can be concluded that the effect of concentration, time, and power variables can affect the total phenol concentration. The regression equation is as follows:

$$\text{Total Fenol} = 602.692 - 8.895\text{A} + 21.795\text{B} + 135.178\text{C} + 22.1125\text{AB} - 9.7775\text{AC} + 57.0525\text{BC} - 192.07\text{A}^2 + 2.00525\text{B}^2 + 5.69025\text{C}^2$$

The equation shows that the extraction time response will increase directly proportional to power, the interaction between concentration and time, the interaction between time and power, the interaction between time and power, and the interaction between power and power. A positive constant indicates this. The response of total phenol concentration will decrease with increasing concentration, as well as the interaction between concentration and power, and the interaction between concentrations. A negative constant indicates this.

3.4 Optimization of Total Phenol Content Using Response Surface Methodology with the UAE Method

The results of the extraction and testing of Pegagan (*Centella asiatica* (L.)) at various conditions of time, power, and concentration are presented in Table 4.1. The value of total phenol content of Pegagan extracted was the highest (836.67 mg.AGE/g sample). The results of the measurement data were analyzed statistically using the help of Design Expert ver.11 software (response of the contour plot, and surface response in each variable as well as the optimum condition of total phenol content of Pegagan (*Centella asiatica* (L.)). In this study, the variables used, among others, were solvent concentration, time, and power.

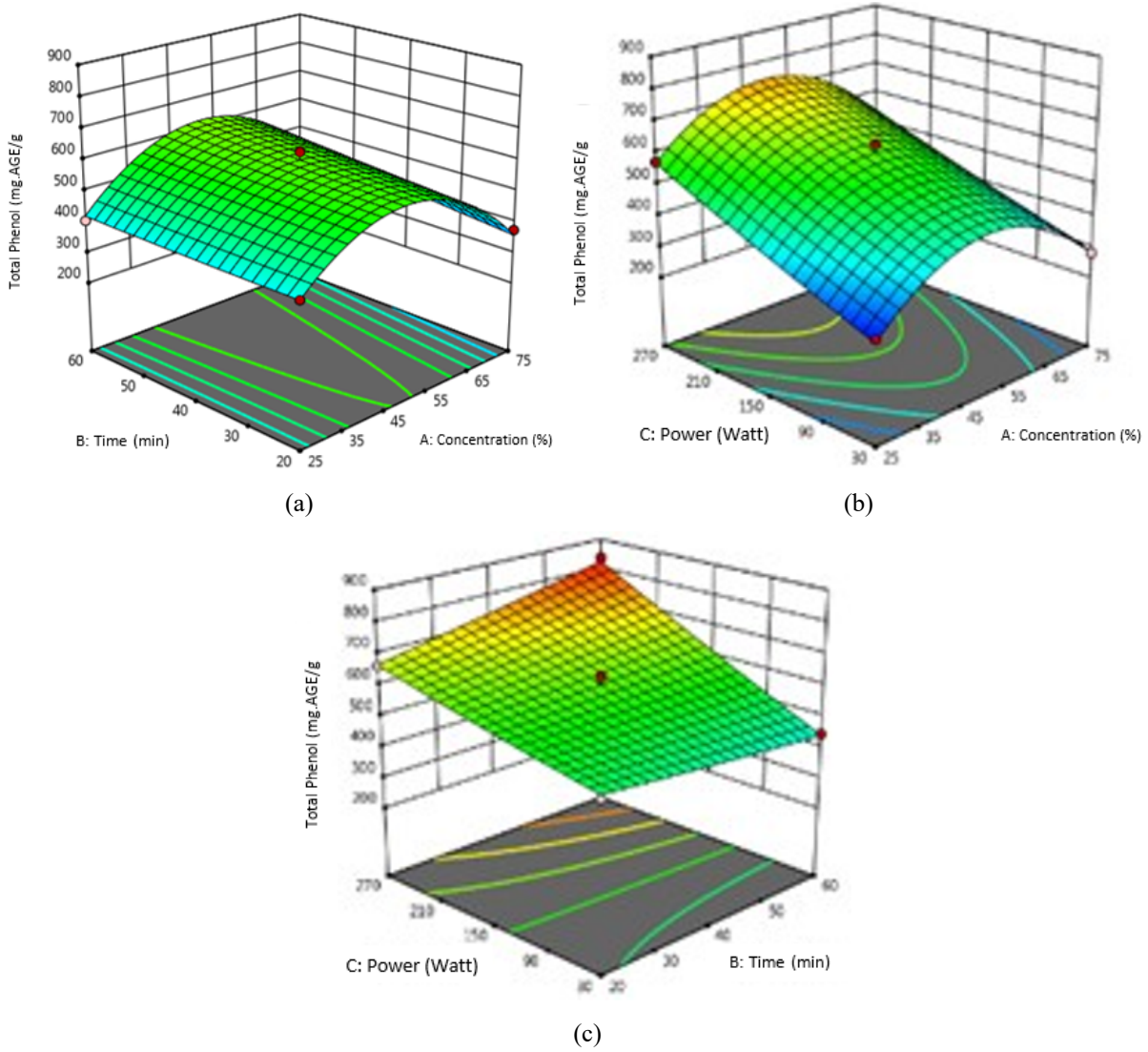


Figure 3. (a) Effect of concentration and time, (b) Concentration, and I, (c) Time, and power on total phenol bioactive compounds using the UAE method

Graph in Figure 3. Point (a) The graph shows the effect of the variable concentration of solvent and extraction time on the levels of total phenol bioactive compounds. The graph shows that at the time of the extraction, for 20 minutes, an ethanol concentration of 25% and 150 watts of power produced a total phenol content of 422.56 mg.AGE/g, the total phenol content produced increased with increasing time. The increase in extraction time can result in more prolonged contact between the material and the solvent. The longer the extraction time, the higher the levels of compounds extracted. This follows the research conducted by [14], which states that the longer the time, the more bioactive compounds are obtained. The longer the sonication time, the longer the contact of the mixture with the microbubble, so that more compounds contained in the sample cells are diffused with the solvent [15].

However, at a certain point, when the ethanol concentration is 50%, and the power is 150 watts for 40 minutes, the optimum total phenol content is 631.54 mg.AGE/g after the optimum point, the total phenol content produced or obtained decreases. The decrease in phenol levels occurred at the highest point or optimum point due to the high temperature, which was possible due to the increase in extraction time, so it was possible to experience the degradation process of bioactive compounds. Degradation is the termination or breaking of bonds in bioactive compounds, decreasing the number of compounds produced. Steam distillation is one example of factors that can affect the chemical composition of bioactive compounds because heat and water vapor can damage the molecular structure and hydrolyze double bonds [16].

The effect of ethanol concentration showed that at the time of extraction, using a solvent concentration of 25% for 20 minutes with a power of 150 watts resulted in a total phenol content of 422.56 mg.AGE/g, the higher the ethanol concentration, the higher the total phenol content obtained. This is because the solvent diffusion process into natural materials is getting better. Extraction of polyphenolic components from natural ingredients using solvents consists of two stages, namely the initiation and diffusion stages. At the initiation stage, the natural material particles will absorb the solvent so that the particles experience bubbles. The diffusion stage is characterized by the diffusion of the solvent to a deeper part, and the polyphenol component will also be extracted. This is based on the research conducted by [17], which indicates that the higher the ethanol concentration, the more metabolites extracted, either patterned or semipolar. The high concentration of ethanol gives a higher total phenol value.

However, at a certain point, the ethanol concentration is 50% and the power is 150 watts for 40 minutes with the optimum total phenol content of 631.54 mg.AGE/g after being at the optimum point, the total phenol content produced or obtained begins to decrease. This indicates a saturation point limit for the variable solvent concentration at the specified operating conditions. The decrease in phenol content occurs at the highest point or optimum point due to differences in the concentration of ethanol that can affect the solubility of phenolic compounds in the solvent. The higher the concentration of ethanol, the lower the polarity of the solvent. This follows the research [18], in *Centella asiatica* (L.), which showed a decrease in total phenol with treatment concentrations above 50%.

The effect of the power used by extraction using the UAE method can be seen in Figure 3, point (b), that the optimum conditions at the time of the extraction for 40 minutes with an ethanol concentration of 50%, and a power of 150 watts resulted in a total phenol content of

627.05 mg.AGE/g. The greater the power used, the higher the phenol content obtained. The results of this study are as follows, as shown by the research results, [19] which show that the addition of power in the UAE can increase the total phenol content. The greater the power given, the greater the ultrasonic waves used in the sample. The magnitude of the vibration of the ultrasonic wave will make it easier for the solvent to diffuse on the material's surface. The high power provided will accelerate the damage to the material's surface so that the extracted compounds will be more easily obtained, and the total phenol content will be greater. However, it should be noted that a power that is too high can potentially damage the content of compounds present in the extract. An increase in power will result in a decrease in the total phenol content. This is because the operating conditions with a power of 270 watts have exceeded the optimum point. This study's optimum point is operating conditions with a power of 150 watts. This is by following [under research [20]. The operating conditions that have passed the saturation point will not increase the extraction yield even though the solvent continues to be added.

Figure 3 point (c) shows the relationship between extraction power and extraction time to the total phenol produced. In the graph, the optimum condition for operating power is 150 watts with a concentration of 50% for 40 minutes to get a total phenol of 631.54 mg—AGE/g sample. The greater the power in the UAE, and the time it takes, the greater the total phenol obtained. This is because the longer the extraction time, the more compounds are extracted, and the power required is also greater, so that when the power is significant, the ultrasonic wave used for the sample is also greater because the magnitude of the vibration of the ultrasonic wave will facilitate the solvent diffusion on the surface of the material. This is by following the research [21], high power because the power acts as a driving force to break the structure of plant cell membranes so that the oil can diffuse out, and dissolve in the solvent. Thus, adding power will generally increase the phenol content and speed up the extraction time.

3.5 The Results of the Optimization of Pegagan Extraction Conditions with the UAE Method

Optimization of total phenol extraction from the Pegagan plant (*Centella asiatica* (L.)) using the UAE method can be seen in Figure 5. shows that the optimal value for the total phenol concentration-response was obtained at 270 watts of power, 50.2525% concentration, and within 60 minutes with a value of 824.422 mg.AGE/g sample obtained when the desirability value reaches 0.97804.

Figure 4. Graph of optimization plot with the UAE method

3.6 Extraction results of Pegagan (Centella asiatica (L.)) using the MAE method

The measurement results of the total phenol content in the Pegagan extract can be seen in Table 3.

Table 3. Total phenol content in the pegagan plant extracted by the MAE method

No.	Power (Watts)	Solvent Concentration (%)	Time (minutes)	Average Absorbance	Total Phenol (mg.AGE/g sample)
1	150	75	10	0.681	597.56
2	450	25	10	0.673	587.31
3	450	50	5	0.64765	553.97
4	300	75	5	0.571	456.54
5	150	50	15	0.687	605.90
6	300	50	10	0.715	641.79
7	450	50	15	0.857	823.85
8	300	75	15	0.951	943.72
9	300	25	15	0.687	605.90
10	300	50	10	0.83	789.23
11	450	75	10	1.191	1251.41
12	150	50	5	0.558	440.51
13	150	25	10	0.584	473.21
14	300	25	5	0.575	462.31
15	300	50	10	0.689	607.82
16	300	50	10	0.697	618.08
17	300	50	10	0.686	604.62

It can be seen from Table 3 that the highest total phenol content is 1251.41 mg—AGE/g of sample at 450Watt MAE power variable with 75% concentration for 10 minutes. The analysis results in this study can be seen in Table 5.

3.7 Analysis of Response Surface Design with ANOVA (*Analysis of Variance*)

Statistical analysis was carried out to prove whether the variables used for the *Centella asiatica* (L.) extraction process affect the resulting product, and the variable can be said to be significant if the p-value of the Analysis of Variance (ANOVA) method has a value of less than (5%) or < 5%. The Analysis of Variance (ANOVA) method can test the difference from the average of more than two independent groups. This is related to the research variables, which amounted to more than two: concentration, power, and extraction time. Each variant will be compared to determine the presence of significance in the data.

Table 4. Results of ANOVA analysis on the pegagan plant extracted using the MAE method

Source	Sum of Square	df	Mean Square	F-Value	P-Value	
Model	5.912E+05	9	65683.91	5.83	0.0150	Significant
There is	1.511E+05	1	1.511E+05	13.40	0.0081	
B-Concentration	1.569E+05	1	1.569E+05	13.92	0.0073	
C-Time	1.421E+05	1	1.421E+05	12.60	0.0093	
AB	72832.52	1	72832.52	2.46	0.0386	
air conditioning	2729.54	1	2729.54	0.2421	0.6378	
BC	29513.52	1	29513.52	2.62	0.1497	
A2	4312.19	1	4312.19	0.3825	0.5559	
B2	7807.82	1	7807.82	0.6925	0.4328	
C2	25783.13	1	25783.13	2.29	0.1742	
Residual	78919.19	7	11274.17			
Lack of Fit	54636.05	3	18212.02	3.00	0.1581	Not Significant
Pure Error	2483.15	4	6070.79			
Total Cast	6.701E+05	16				

From Table 4, the significance of the variables is determined by the p-value, which is said to be significant if the p-value < 0.05.

The F-value of the model obtained from the calculation is 5.83. In the F distribution Table, the value of the F Table with a model of 9, and a df error of 4 at a probability of 0.05, then the percentage point is 6.00, which means that the F-value is greater than the F Table.

In addition, the value of the F-value is inversely proportional to the value of the p-value, as shown in Table 4.2. If the F-value has no significant effect on the variable, then the P-value has a considerable or significant effect. The P-value can be seen as 0.0150, meaning the value is smaller than the set probability of 5% or 0.05. Therefore, the *Centella asiatica* (L.) analysis model significantly affects the extract's total phenol content.

The analysis results in Table 4 also show that the MAE power, extraction time, and solvent concentration significantly affect the total phenol content, with p-values of 0.0081, 0.0093, and 0.0073. Related to the inaccuracy of the test or the value of Lack of Fit, which means that the deviation or imprecision of the model.

In Table 4, the P-value on the Lack of Fit is 0.1581, and the F-value on the lack of fit is 3.00. This value is greater than the probability of 0.05, so that H_0 is accepted and declared insignificant, meaning that the model is suitable, or there is a discrepancy in the research model. The model is considered appropriate if the p-value of the lack of fit is inversely proportional to the e model, so based on the data from Table 4, it can be interpreted that the model is appropriate.

From the ANOVA analysis, the R-squared value was 0.8822 or 88.22%, indicating the model was a good fit under the research results. An adjusted R^2 value of 0.7308 indicates a close relationship between ethanol concentration, extraction time, and MAE power on the response. The value of R-squared is declared according to the model if it is more than 75% [13]. So, the equation of the model can be used to predict the study's actual results. Based on the regression equation obtained, it can be concluded that the effect of concentration, time, and power variables can affect the total phenol concentration. The regression equation is as follows:

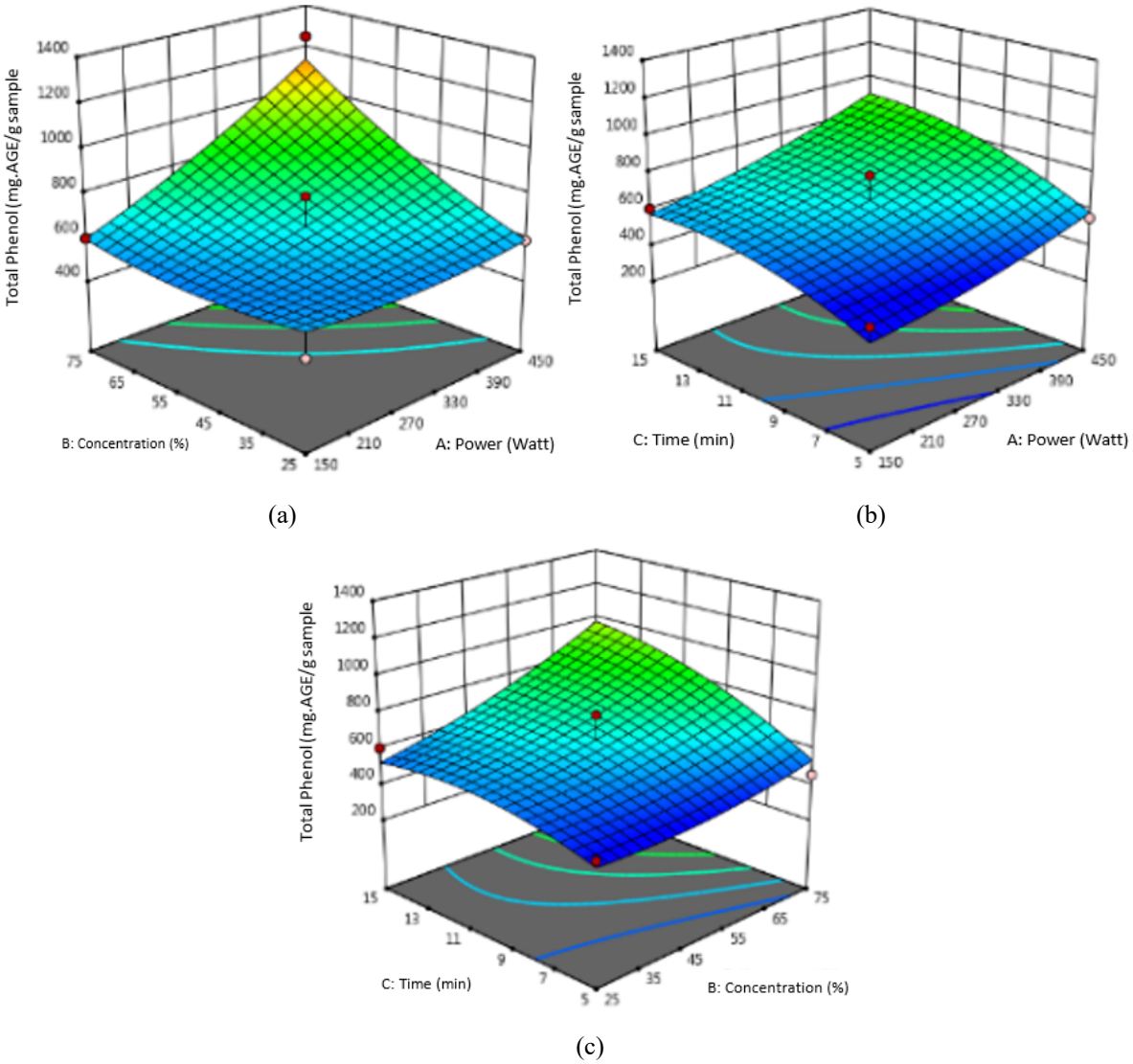
$$\text{Total Fenol} = 652.308 + 137.42A + 140.063B + 133.255C + 134.937AB + 26.1225AC + 85.8975BC + 32.0022A^2 + 43.0622B^2 - 78.2527C^2$$

The total phenol concentration response will decrease with increasing time. A negative constant indicates this.

3.8 Optimization of Total Phenol Content using Response Surface Methodology (RSM) with MAE Method.

Graph in Figure 5, point (a), which shows the effect of variable concentration of solvent and operating power on MAE on total phenol bioactive compounds. From the graph, it can be observed that at the time of the lowest extraction, with operating conditions for 10 minutes in a microwave of 150 watts, and a solvent concentration of 25% ethanol, a total phenol content of 473.21 mg AGE/g sample was produced. The total phenol content also increases with the increase in power and concentration. Thus, it will increase directly proportional to the rise in power and concentration. This is because, following the research conducted by [22], the higher the ethanol concentration, the higher the total phenol obtained. The increase in ethanol concentration is directly proportional to the total phenol obtained [23]. Similarly, the effect of

power, according to research conducted by [24], the higher the power on the MAE used, the hotter the resulting temperature, so that the energy produced in the MAE is radiation and rotation; therefore, the presence of microwave radiation and rotating vibrations will cause the pressure on the cell wall to increase. The cell swells and more bioactive compounds are released or obtained.



(a) (b)

(c)

Figure 5. (a) Effect of concentration and power, (b) Effect of power and time, (c) concentration and time on total phenolic bioactive compounds using the MAE method

On the graph in Figure 5, point (b) shows the effect of variable operating conditions of microwave power and extraction time on total phenol bioactive compounds. The graph shows that at the time of the lowest extraction, with operating conditions of 150 watts of power for 5 minutes, a solvent concentration of 50% ethanol, and a low total phenol content of 440.51 mg AGE/g sample. However, when the time and operating conditions increase, the total phenol content obtained is greater with the optimum condition for the total phenol content of 789.23 at

operating conditions of 300 watts of power, and extraction for 10 minutes with a concentration of 50%. Thus, it will increase directly proportional to the increase in power and time. This is because, according to research conducted by [25], the increase in the extraction time used will increase the penetration of the solvent into the material, making it easier for the solvent to pull chemicals out of the material.

In contrast, the shorter the extraction time, the more difficult it will be for the solvent to penetrate the walls of the material, so the increase in time will be directly proportional. Likewise, the effect of power, as shown in Figure 5 point (b), is that the higher the power, the higher the total phenol content obtained. This is because, according to research [21], the higher the microwave power produced, the greater he tendency to increase the total phenol obtained. This is because the greater the power, the higher the operating temperature, the greater the distillation rate (evaporation). The greater the power, the greater the energy the material receives to be converted into heat, so the total phenol produced is greater.

Graph in Figure 5, point (c), which shows the effect of the variable length of extraction, and the concentration of ethanol solvent on total phenol bioactive compounds. The graph shows that at the time of the lowest extraction, with a solvent concentration of 25% ethanol, for 5 minutes, and 300 watts of power, there was a low total phenol content of 462.31 mg.AGE/g sample. At the operating conditions of 300 watts of power, and extraction for 10 minutes with a concentration of 50%. Thus, it will increase directly proportional to the increase in concentration and time. This follows the research conducted [26], which states that the total phenol will increase, followed by an increase in extraction time until it reaches the optimum limit. If it exceeds the optimum limit, the total phenol will decrease because the compounds contained are degraded over a long time, which can cause the temperature to increase. Microwave heating will cause the extraction temperature to continue to increase, along with the increase in extraction time, which will cause the degradation of phenol compounds. Microwaves can also damage enzymatic compounds that can reduce the activity of the phenolase enzyme. Likewise, the increasing concentration of total phenol increases with increasing solvent concentration. The more that is used, the more the target compound will dissolve in the ethanol [27].

3.9 Result of Optimizing Conditions for The Extraction of Pegagan with the MAE Method

Figure 6 shows that the desirability (D) value reaches its maximum when the factor value is on the red line. The graph in Figure 9 shows that the optimal value for the response to the total phenol concentration was obtained at 450 watts of power, 75% concentration, and within 10 minutes, resulting in a value of 1130.7882 mg.AGE/g sample obtained when the desirability value reached 0.8513.

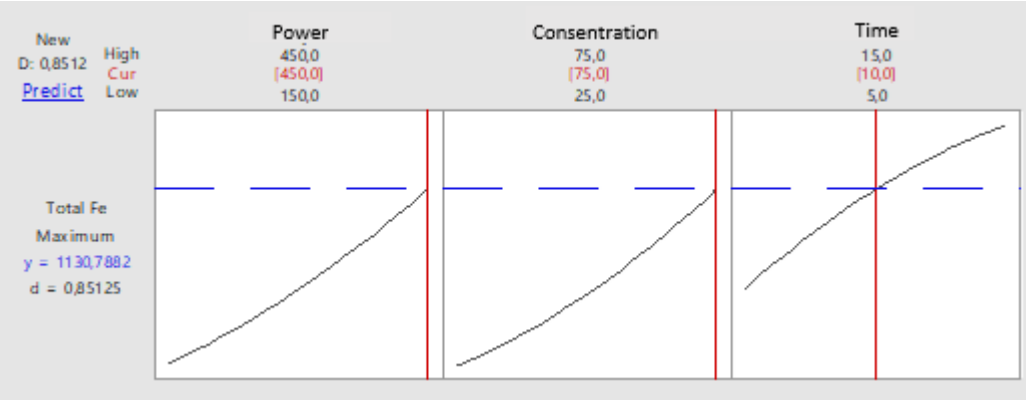


Figure 6. Graph of optimization plot with the MAE method

3.10 Comparison of the results of Pegagan (Centella asiatica (L.)) using the UAE method with the MAE method extraction results.

The analysis of the total phenol content represents the extraction process results for the content of bioactive compounds. From the UAE method using ethanol solvent, the optimal value for the total phenol concentration response was obtained at 270 watts, 50.2525% concentration, and within 60 minutes, resulting in a value of 824.422 mg.AGE/g sample. Obtained when the desirability value reaches 0.97804. While the extraction process results using the MAE method with ethanol solvent, the optimal value in response to the total phenol concentration was obtained at 450 watts of power, 75% concentration, and within 10 minutes, resulting in a value of 1130.7882 mg.AGE/g sample obtained when the desirability value reached 0.8513. So, it can be concluded that the extraction of Pegagan (*Centella asiatica* (L.)) using the microwave method gives the maximum results.

However, extraction using the UAE method also gives significant results, and the difference is not far from the MAE extraction method, so it can be said that the MAE method is the most optimal for producing bioactive compounds through testing for total phenol in the extraction of Pegagan. It can produce a high total phenol content of 1130.7882 mg quickly.AGE/g. This study is quite high in the value of total phenol content compared to similar

studies by comparing the UAE and MAE methods because of the difference in the extraction method used in this study. Extraction using the UAE method also gives significant results, and the difference is not far from the extraction of the MAE method, so it can be said that the MAE method is the most optimal for producing bioactive compounds through testing of total phenol in the Pegagan extract. It can produce a high total phenol content of 1130.7882 mg quickly.AGE/g. This study is quite high in the value of total phenol content compared to similar studies by comparing the UAE and MAE methods because of the difference in the extraction method used in this study. Extraction using the UAE method also gives significant results, and the difference is not far from the extraction of the MAE method, so it can be said that the MAE method is the most optimal for producing bioactive compounds through testing of total phenol in the Pegagan extract. It can produce a high total phenol content of 1130.7882 mg quickly.AGE/g. This study is quite high in the value of total phenol content compared to similar studies by comparing the UAE and MAE methods because of the difference in the extraction method used in this study. It can produce a high total phenol content of 1130.7882 mg quickly.AGE/g. This study is quite high in the value of total phenol content compared to similar studies by comparing the UAE and MAE methods because of the difference in the extraction method used in this study.

A short time can produce a high total phenol content of 1130.7882 mg.AGE/g. This study is quite high for the value of total phenol content compared to similar studies by comparing the UAE, and MAE methods, because of the difference in which extraction method is in this study [28] this study used the maceration method for *Centella asiatica* (L.) extracted with a maximum wavelength of 765 nm to determine the total phenol content, with a sample weight of 150 g in powder form resulting in a total phenol content of only 3.67 mg.AGE/g sample for 30 minutes with a concentration of 3.67 mg.AGE/g sample for 30 minutes with a concentration of 70% ethanol solvent. This differs greatly from the total phenol results obtained in the UAE method, with a lower ethanol concentration of 52.77%. The MAE method has a shorter time of 10 minutes, and both only use 1 gram of sample, but the MAE method has a higher total phenol content, 1130.7882 mg AGE/g, while the UAE method has a total phenol content of 824.422 mg AGE/g.

4. Conclusion

In the ANOVA analysis using the UAE method, variables significantly responded to the total phenol content: power, time, and ethanol concentration, with an R-squared value of 0.9876

or 98.76%. The optimum condition of the total phenol content using the UAE method is the optimal value for the response to the total phenol concentration obtained at 270 watts of power, 50.2525% concentration, and within 60 minutes by obtaining a value of 824.422 mg AGE/g sample. In the ANOVA analysis using the MAE method, variables significantly responded to the total phenol content: power, time, and ethanol concentration, with an R-squared value of 0.8822 or 88.22%.

So that the comparison between the UAE and MAE methods for *Centella asiatica* (L.) extracted with ethanol solvent is more optimal, namely using the MAE method, because in a short time of only 10 minutes, it can produce 1130.7882 mg AGE/g of total phenol sample, and the concentration of ethanol. Which is getting purer at 75%, so the MAE method is more efficient.

ACKNOWLEDGMENTS

The Sumberarum area, Songgon District, Banyuwangi, and the Chemical Engineering Department of Universitas Jember supported and facilitated the study.

REFERENCES

[1] S. J. D. Febrianti, Alifia Putri; Iswarin, Perbandingan kadar asiatikosida dalam ekstrak etanol 70% pegagan (*centella asiatica* L) urban dengan metode ekstraksi maserasi dan sonikasi secara lc-ms/ms, jf fik uinam 4(2) (2016) 50–57.

[2] W. Bylka, P. Znajdek-Awizeń, E. Studzińska-Sroka, A. Dańczak-Pazdrowska, And M. Brzezińska, *Centella asiatica* in dermatology: an overview, phyther. res 28(8) (2014) 1117–1124.

[3] L. Ismaini, Aktivitas antifungi ekstrak (*centella asiatica* L.) urban terhadap fungi patogen pada daun anggrek (*bulbophyllum flavidiflorum carr*.), j. penelit. sain 14(1) (2011) 7–50.

[4] N. Jagtap, S. Khadabadi, D. Ghorpade, N. Banarase, And S. Naphade, Antimicrobial and antifungal activity of *Centella asiatica* (L.) urban, umbeliferae, res. j. pharm. technol 2(2) (2009) 328–330.

[5] M. K. Zainol, A. Abd-Hamid, S. Yusof, And R. Muse, Antioxidative activity and total phenolic compounds of leaf, root and petiole of four accessions of *Centella asiatica* L. urban, food chem 81(4) (2003) 575–581.

[6] W. J. Kim., Extraction of bioactive components from *Centella asiatica* using subcritical water, j. supercrit. fluids 48(3) (2009) 211–216.

[7] L. A. Setiani, B. L. Sari, L. Indriani, And Jupersio, Penentuan kadar flavonoid ekstrak etanol 70% kulit bawang merah (*Alliumm cepa* L.) dengan metode maserasi dan mae (*microwave-assisted extraction*), fitofarmaka 7(2) (2017).

[8] F. Susanty, Bachdim, Perbandingan metode ekstraksi maserasi dan refluks terhadap kadar fenolik dari ekstrak tongkol jagung (*Zea mays* L.), (2012) 87–93.

[9] L. R. Sjahid, A. Aqshari, And S. Sediarso, Penetapan kadar fenolik dan flavonoid hasil ultrasonic assisted extraction daun binahong (*anredera cordifolia [ten] steenis*), j. ris. kim 11(1) (2020) 16–23.
[10] A. Ardiansyah, N. Nurlansi, And R. Musta, Waktu optimum hidrolisis pati limbah hasil olahan ubi kayu (*manihot esculenta crantz var. lahumbu*) menjadi gula cair menggunakan enzim α-amilase dan glukoamilase, indo. j. chem. res 5(2) (2018) 86–95.
[11] M. T. Adiwibowo, Herayati;, K. Erlangga, And D. A. Fitria, Pengaruh metode dan waktu ekstraksi terhadap kualitas dan kuantitas, j. integr. proses 9(2) (2020) 44–50.
[12] F. G. Utami Dewi And F. Gapsari, Optimasi parameter pembubutan terhadap kekasaran permukaan produk, rekayasa mesin 4(3) (2013) 177–181.
[13] B. Yingngam, A. Chiangsom, And A. Brantner, Modeling and optimization of microwave-assisted extraction of pentacyclic triterpenes from *Centella asiatica* leaves using response surface methodology, ind. crops prod 147(112231) 2020.
[14] S. Sekarsari, I. W. R. Widarta, And A. A. G. N. A. Jambe, Pengaruh suhu dan waktu ekstraksi dengan gelombang ultrasonik terhadap aktivitas antioksidan ekstrak daun jambu biji (*psidium guajava* l.), j. ilmu dan teknol. pangan 8(3) (2019) 267.
[15] A. Sasongko, R. W. Nugroho, C. E. Setiawan, I. W. Utami, And M. D. Pusfitasari, Aplikasi metode nonkonvensional pada ekstraksi bawang dayak, jtt (jurnal teknol. terpadu) 6(1) (2018) 8.
[16] A. El-Fallal, M. Abou, A. El-Sayed, And N. Omar, Starch and microbial α-amylases: from concepts to biotechnological applications, carbohydrates - compr. stud. glycobiol. glycotechnol 2012.
[17] S. A. Prayitno, J. K. Kusnadi, And E. S. Murtini, Karakteristik (total flavonoid, total fenol, aktivitas antioksidan) ekstrak serbuk daun sirih merah (*piper crocatum ruiz & pav*.), foodscitech 1(2) (2018) 26.
[18] K. K. Chew, S. Y. Ng, Y. Y. Thoo, M. Z. Khoo, W. M. Wan Aida, And C. W. Ho, Effect of ethanol concentration, extraction time and extraction temperature on the recovery of phenolic compounds and antioxidant capacity of *Centella asiatica* extracts, int. food res. j 18(2) (2011) 571–578.
[19] M. Sholihah, U. Ahmad, And I. W. Budiastra, Aplikasi gelombang ultrasonik untuk meningkatkan rendemen ekstraksi dan efektivitas antioksi dan kulit manggis, j. keteknikan pertan 5(2) (2017) 161–168.
[20] A. Sabathani, S. B. Widjanarko, And S. S. Yuwono, 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) (2018) 193–206.
[21] N. Erliyanti And E. Rosyidah, Pengaruh daya microwave terhadap yield pada ekstraksi minyak atsiri dari bunga kamboja (*plumeria alba*) menggunakan metode microwave hydrodistillation, j. rekayasa mesin 8(3) (2017) 175–178.
[22] I. G. T. Yasa, N. K. Putra, And A. A. I. S. Wiadnyani, Pengaruh konsentrasi etanol terhadap aktivitas antioksidan ekstrak daun sirih merah (*piper crocatum ruitz & pav*) menggunakan metode microwave assisted extraction (mae), j. ilmu dan teknol. pangan 8(3) (2019) 278.
[23] I. B. Januarti, R. Wijayanti, S. Wahyuningsih, And Z. Nisa, Potensi ekstrak terpurifikasi daun sirih merah (*piper crocatum ruiz &pav*) sebagai antioksidan dan antibakteri, jpscr j. pharm. sci. clin. res 4(2) (2019) 60.
[24] U. Suhendar, N. F. Utami, D. Sutanto, And S. M. Nurdayanty, Pengaruh berbagai metode ekstraksi pada penentuan kadar flavonoid ekstrak etanol daun iler (*Plectranthus*

scutellarioides), FITOFARMAKA J. Ilm. Farm 10(1) (2020) 76–83.
[25] Y. Kristanti, I. W. R. Widarta, and I. D. G. M. Permana, Effect of extraction time and ethanol concentration with Microwave Assisted Extraction (MAE) of Antioxidant activity corn silk extract (*Zea mays.L.*), J. Ilmu dan Teknol. Pangan 8(1) (2019) 94.
[26] A. Yuliantari, Antioksidan daun sirsak (*Annona muricata L.*), Media Ilm. Teknol. Pangan 4(1) (2017) 35–42.
[27] L. putri Aulia, Optimasi proses ekstraksi daun sirsak (*Annona muricata L*) metode MAE (*Microwave Assisted Extraction*) dengan respon aktivitas antioksidan dan total fenol, J. Agroindustri Halal 4(1) (2018) 079–087.
[28] Purgiyanti, A. V. Purba, and H. Winarno, Penentuan kadar fenol total dan uji aktivitas antioksidan kombinasi ekstrak herba pegagan (*Centella asiatica L. Urban*) dan buah mahkota dewa (*Phaleria macrocarpa (Scheff.) Boerl.*), J. Ilm. Farm 8(2) (2019) 40–45.

RESEARCH ARTICLE

JOURNAL OF BIOBASED CHEMICALS

Volume 2, Issue 1, 2022, pp. 31 – 42

Journal homepage: http://journal.unej.ac.id/JOBC

Extraction of Antioxidant Compounds from *Sargassum* sp. Using Water and Ultrasound Assisted Extraction Method as A Derivation of Green Chemistry Principles

Samantha Githa Ratna Sonia*, Boy Arief Fachri, Bekti Palupi

Department of Chemical Engineering, Universitas Jember, Indonesia 68121

(Received: 13 January 2022; Revised: 25 March 2022; Accepted: 5 July 2022)

Abstract. The content of bioactive compounds in *Sargassum* sp. has already been used in various fields. The Ultrasound Assisted Extraction (UAE) method and water solvent have met the principles of green chemistry, so it is used in this study to extract antioxidant compounds contained in *Sargassum* sp. The principle of green chemistry primarily aims to reduce or eliminate the impact of environmental damage. This research was conducted with several process variables, including the ratio of the sample mass to the volume of solvent (0.05 – 0.15 g/mL), time (30 – 40 minutes), and power (170 – 180 W) using the UAE method and water solvent (*Aquadest*) on the total phenol value of *Sargassum* sp. Analysis of variance was carried out with the help of Design Expert software, Response Surface Method - Central Composite Design, to determine the effect of the process variables carried out in the extraction process on the total phenol yield. The analysis of variance in this study shows the suitability between the research design and the study results, which is indicated by an R^2 value of 0.9785. The highest results were obtained with a variable ratio of sample mass to solvent volume of 0.18 (g/mL), time of 40 minutes, and power of 180 W, with a total phenol yield of 212.8 mg GAE/g and antioxidant activity of 12.3%.

Keywords: *Sargassum sp., green chemistry, antioxidant, total phenol, ultrasound-assisted extraction (UAE), water solvent*

1. Introduction

Indonesia has the second-longest coastline after Canada, so the marine biodiversity in Indonesia is very high [1]. One of the existing species is seaweed, which is commonly known as marine macroalgae. *Sargassum* species are brown macroalgae scattered around tropical oceans [2]. The content of bioactive compounds in *Sargassum* sp. has already been used in various fields, such as food, bioenergy, biofuels, pharmaceuticals, cosmetics, and textiles [3, 4,

5, 6]. *Sargassum* species in Indonesia have pharmacological potential due to the potent antioxidant activity of the phenolic compounds contained [7].

Bioactive compounds can be obtained by extraction. There are several extraction methods, one of which is Ultrasound Assisted Extraction (UAE). The UAE method is categorized as a non-conventional method [8]. The UAE method can extract bioactive compounds quickly and requires lower energy, solvents, and operating temperatures when compared to conventional methods [9]. Based on this effectiveness, the UAE method has a higher probability of application in the chemical and food industries [10, 11, 12, 13].

Extraction methods and solvents that can reduce the impact of environmental damage are needed because the environment has been experiencing a crisis of environmental damage over the last few decades. Green chemistry provides some methods that can overcome this. A method that can reduce the impact of ecological damage is the 'Green Extraction' method, which is based on the design of an extraction process that will reduce or eliminate energy consumption, allow the use of alternative solvents, and ensure safe and quality extracts. It was stated in green chemistry [14]. The UAE method is one of the methods of green extraction [13]. In addition to the extraction method, alternative solvents, called 'Green Solvent', are also used in green chemistry. Solvents indicated as green solvents are non-volatile organic compounds with high solubility, low toxicity, environmentally friendly, obtained from renewable resources at a reasonable price, and easy to recycle [15, 16].

In this study, the extraction of antioxidant compounds from *Sargassum* sp. was performed using the Ultrasound Assisted Extraction (UAE) method and the water solvent (*Aquadest*). The technique used is a derivation of the principle of green chemistry.

2. Materials and Methods

2.1 Materials

The materials needed in this study were *Sargassum* sp., aquadest, gallic acid, 2% Na_2CO_3 solution, $CuSO_4$ solution, sodium solution, potassium tartrate solution, Folin-Ciocalteu reagent, trolox, methanol solution, DPPH (1,1-*diphenyl*-2-*picrylhydrazyl*), and filter paper.

2.2 Sample Preparation

The sample used in this study was *Sargassum* sp. obtained from Pesawsaran Regency, Lampung. The sample is then dried until there is no moisture content to prevent fungus growth on the sample. The drying process is carried out indoors so that the sample is not exposed to sunlight, which can cause some damage to the sample. The dried samples were obtained from

the constant weight and sieved using an 80-mesh sieve. The sample is weighed based on the value of the variation of the process variable given by the Design Expert.

2.3 Extraction

The prepared sample was then extracted using the UAE method. The mechanism of the UAE method is that ultrasound waves meet a solvent containing a solid sample. Then, cavitation bubbles form, which cause changes in pressure and temperature. This causes an increase in the mass transfer rate of the sample solid to the solvent [18]. Tools for the extraction of the UAE method were prepared, and *Sargassum* sp., which had been weighed, was put into a glass beaker. The solvent in 100 mL of distilled water was put into a glass beaker and mixed with the sample. Extraction with the UAE method was carried out using a variety of treatment variables provided by design experts.

2.4 Total Phenol Analysis

The total phenol analysis method used on the sample was the Folin-Ciocalteu method. Calibration was carried out with different concentrations of gallic acid, namely 0.00, 0.25, 0.50, 0.75, and 1 mM. Then, 200 µL extract of *Sargassum* sp. and 2.0 mL of solution A (10 mL of 2% Na_2CO_3 with 0.1 mL of CuSO4 and 0.1 mL of sodium and potassium tartrate) were mixed, and after 4 minutes, 0.4 mL of 0.5 M sodium hydroxide was added. After 10 minutes, 0.2 mL of Folin-Ciocalteu reagent (1:1 v/v with water) was added. The solution was allowed to stand for 30 min, and the absorbance was measured with a UV-Vis Spectrophotometer at 750 nm. Using a gallic acid calibration curve, the total phenol content was calculated as mg gallic acid equivalent (mg GAE) [19].

2.5 Antioxidant Activity Analysis

The DPPH test took 0.4 mL of *Sargassum* sp. extract, gallic acid antioxidant standard, and trolox (50-400 g/mL) mixed with 3.6 mL of DPPH methanol solution (0.1 mM). The amount of methanol (0.4 mL) was used as a blank (control) with 3.6 mL DPPH solution. All samples were vortexed for 1 min and incubated in the dark for 30 min at 37°C. Each sample's absorbance decrease was measured against methanol as a blank on a UV-Visible spectrophotometer at 517 nm. The percentage of DPPH inhibition was calculated using equation 1 [19]:

$$\text{DPPH Inhibition (\%)} = \frac{A_{control} - A_{sample}}{A_{control}} x100\% \quad (1)$$

When: $A_{control}$: Absorbance control

A_{sample}: Absorbance sample

3. Result and Discussion

3.1 Effect of Extraction Process Variables on Total Phenol Content

The results of the total phenol test on *Sargassum* sp. using the UAE method and water solvent can be seen in Table 1. It shows that the most significant total phenol value is in the ratio of 0.18 (18 g sample: 100 ml solvent), 40 minutes, and power at 180 W is 212.8 mg GAE/g. The smallest total phenol value was found in the 0.016 g/mL ratio, 40 minutes of time and power at 180 W, with 42.7 mg GAE/g.

Table 1. Total Phenol from Treatment Variations Based on Response Surface Methodology Approach - Design Expert

No	Code	Factor 1	Factor 2	Factor 3	Response 1
		A: Ratio (g/mL)	B: Time (menit)	C: Power (W)	Total Phenol (mg GAE/g)
1	C17	0.18	40	180	212.8
2	C20	0.15	50	170	208.7
3	C3	0,.15	30	190	180.4
4	C13	0.15	50	190	177.2
5	C2	0.15	30	170	166.5
6	C6	0.1	57	180	158
7	C1	0.1	40	163	153.9
8	C5	0.1	40	180	151.5
9	C11	0.1	40	197	141.7
10	C9	0.1	40	180	136.7
11	C18	0.1	40	180	135.7
12	C16	0.1	40	180	134.1
13	C7	0.1	40	180	133.1
14	C12	0.1	40	180	131.9
15	C8	0.1	23	180	128.5
16	C4	0.05	50	190	103.3
17	C10	0.05	30	190	92.8
18	C14	0.05	50	170	91.1
19	C15	0.05	30	170	83.1
20	C19	0.016	40	180	42.7

The influence of process variables can be seen in Figures 1 – 3. In Figure 1, the variable that remains is variable C (power) of 180 W, in other words, it shows the relationship between variable A (ratio of sample mass to volume of solvent) and variable B (time) on total phenol yield. Figure 1 shows that the higher the ratio of the mass of the sample to the volume of the

solvent, the higher the total phenol, whereas when the extraction time is carried out, the longer it takes, but at a particular time, the total phenol yield does not show a big difference.

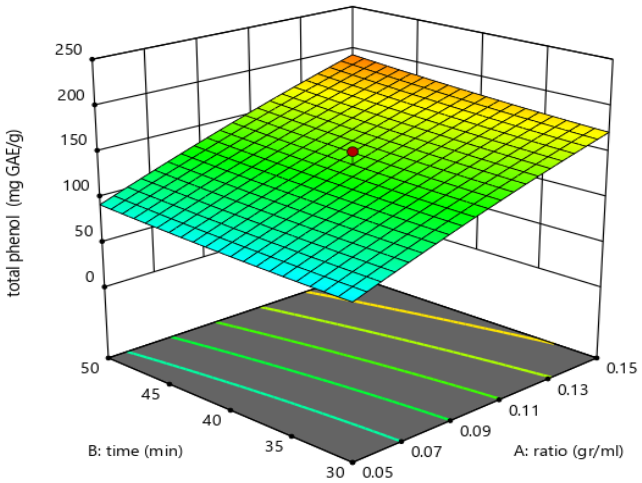


Figure 1. Relationship between total phenol with the ratio of sample mass to solvent volume (A) and time (B) at power (C): 180 W

The variable mass ratio of the sample to the solvent volume has a significant impact. The larger the ratio value or the more samples contained in the extracted solution, the higher the total phenol yield. This happens because the difference in the concentration of a higher solute will increase the diffusivity and dissolution of the solute in the solvent, which will increase during the extraction process. At a high ratio, the ultrasonic intensity applied to the sample is higher, causing more effects of fragmentation, erosion, and pore formation, thereby increasing the yield. A high ratio also increases the contact area between the material and the solvent, increasing the yield [9].

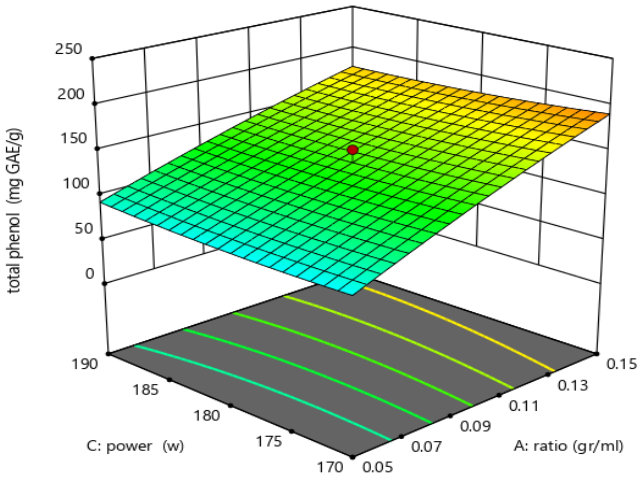


Figure 2. The relationship between total phenol with power (C) and the ratio of sample mass to solvent volume (A) at time (B): 40 minutes

In Figure 2, the variable that remains is variable B (time) for 40 minutes; in other words, it shows the relationship between variable A (ratio of sample mass to solvent volume) and variable C (power). Figure 2 shows that the higher the sample mass ratio to the solvent volume, the higher the total phenol yield. At the same time, the ultrasound power increases with increasing power, giving a low total phenol yield but not a significant difference in the total phenol value. The time variable is influential but does not significantly impact the total phenol value. An increase in total phenol yield was also reported in the study [20], which states that the longer the extraction time, the higher the total phenol yield will be. However, several treatments with a longer extraction time in this study gave smaller results. This is because increasing the ultrasound time initially increases the results; after that, the results decrease, or there is no increase in the results for a longer time. As the time increases, the exposure of the solute and the extraction medium will aid their release into the solvent. Giving ultrasound waves of a very long duration will cause structural damage to the solute, reducing the extraction yield [9]. High total phenol values can be obtained in a short time, and if carried out for a long time, will also allow damage to the extracted compounds.

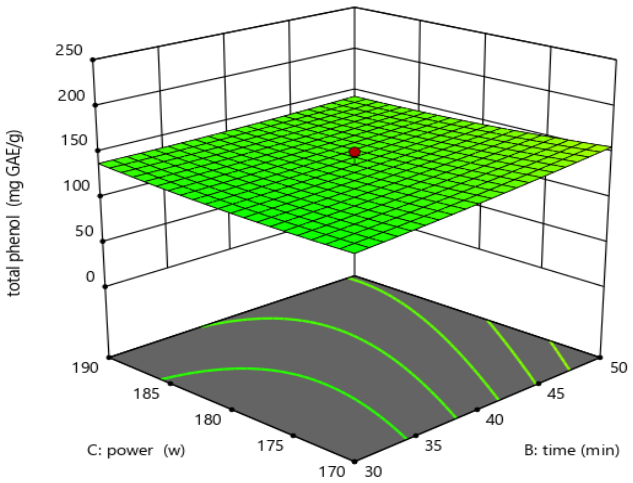


Figure 3. The relationship between total phenol with time (B) and power (C) on the ratio of sample mass to solvent volume (A): 0.1 g/mL

In Figure 3, the constant variable is variable A (sample mass ratio to solvent volume) of 0.1 g/mL, in other words, showing the relationship between variable B (time) and variable C (power). Figure 3 shows that the variable treatment does not significantly affect the total phenol value. The influence of the power variable is less influential in this study; it is intended that when the sample is given an increase in extraction power, the yield increases and then decreases. This is explained by the effect of cavitation bubble collapse, which increases with increasing power, causing fragmentation, pore formation, and mixing in the tissue to increase diffusivity

and increase extraction yield [21]. Very high ultrasound intensity can reduce bioactive compounds. Very high power causes an increase in the number of bubbles formed. The layer of cavitation bubbles around the probe tip (physical device used to connect electronic test equipment to the sample being tested) blocks energy transmission to the extraction medium (saturation effect), thereby reducing yield [9].

3.2 Analysis of Variance

The total phenol results from each variable variation were then analyzed using analysis of variance to determine the equation model that links the independent variables to the response variables. The analysis of variance model in this study is Central Composite Design – Quadratic. The results of the variance analysis for the total phenol response can be seen in Table 2. The F-value of the model is 50.52, which implies that the model is significant, meaning that the variables used substantially affect the total phenol yield of *Sargassum* sp.

Table 2. Results of analysis of total phenol variance from treatment variations based on the response surface methodology approach - Design Expert

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	32588.00	9	3620.89	50.52	< 0.0001	significant
A-ratio	30801.16	1	30801.16	429.74	< 0.0001	
B-time	840.10	1	840.10	11.72	0.0065	
C-power	19.26	1	19.26	0.2687	0.6155	
AB	52.53	1	52.53	0.7329	0.4120	
AC	195.03	1	195.03	2.72	0.1300	
BC	230.05	1	230.05	3.21	0.1035	
A²	199.62	1	199.62	2.79	0.1261	
B²	44.55	1	44.55	0.6216	0.4487	
C²	163.37	1	163.37	2.28	0.1620	
Residual	716.74	10	71.67			
Lack of Fit	455.25	5	91.05	1.74	0.2788	not significant
Pure Error	261.49	5	52.30			
Cor Total	33304.75	19				

From Table 2, the p-value of the model is < 0.0001, which indicates that the quadratic model used is influential or significant. The p-value less than 0.05 indicates a considerable model term. A value greater than 0.1 indicates an insignificant model term, so it can be said that variables A and B (< 0.0001 and 0.0065) are significant models (provide a significant

effect). This shows that the quadratic model can predict the optimum response conditions for total phenol from *Sargassum* sp. using the UAE method and water as a solvent with a variable ratio and time. The R^2 value obtained in this study is 0.9785.

Analysis of variance also provides a quadratic model equation that can be seen in equation 2 of the process variable to total phenol. The total phenol value is directly proportional to the variable mass ratio of the sample to the solvent volume, and the extraction time is indicated by a positive constant, which suggests that when the variable value of the sample mass ratio to the solvent volume and the extraction time increases, the total phenol value produced will also increase. The inversely proportional power variable is indicated by a negative constant, which suggests that when the value of the power variable increases, the total phenol yield will decrease.

$$Y = 11.71 + 2.14\,A + 0.3264\,B - 0.023\,C + 0.058\,AB - 0.2179\,A - 0.1951\,BC - 0.4011\,A^2 + 0.091\,B^2 + 0.1624\,C^2 \quad (2)$$

When Y: total phenol (mg GAE/g)

A: ratio (g sample: mL solvent)

B: time (minutes)

C: power (W)

The statistical comparison between the actual and predicted data can be seen in the graph in Figure 4. This graph aims to determine the suitability of the given model and the actual data.

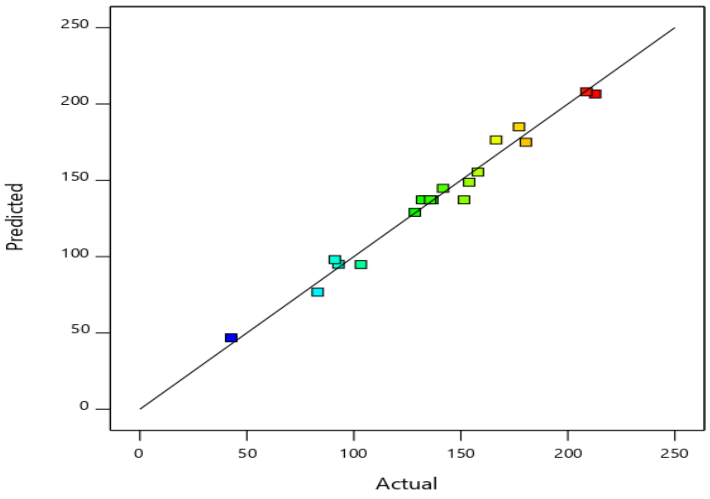


Figure 4. Prediction data plot vs. actual data

From Table 1, the analysis results of the total phenol contained in the extract of *Sargassum* sp. give the highest value to the highest ratio variable of all ratio variations. Apart from Table 1, the response between the total phenol value and the extraction process variable

can be seen in the p-value in Table 2 and the response visualization (3D Surface) in Figures 1 – 3. Table 2 shows that the p-value of variable A (ratio of sample mass to solvent volume) and variable B (time) is said to be significant. In contrast, variable C (power) is not substantial. Likewise, the response visualization (3D Surface) shown in Figures 1 – 3 shows that the response variable A (ratio) is said to be significant, B (time) is quite significant, and C (power) is not significant. The three considerations (result table, p-value, and 3D surface) on the total phenol value of *Sargassum* sp. show that the most influential variable is the ratio treatment variable, followed by the time variable, which is quite influential. At the same time, the power variable is less influential.

3.3 Antioxidant Activity

The results of the antioxidant activity test were carried out on the samples with the highest total phenol test results. This was done because there was a relationship between total phenol content and antioxidant activity. The greater the total phenol content, the higher the antioxidant activity. The antioxidant activity test in this study was the DPPH method. This method is based on the ability of the tested extract to donate hydrogen, which reacts with the DPPH radical, thereby neutralizing the free radical character and giving rise to the reduced form of DPPH (non-radical). Phenol compounds have a hydroxyl group, and the function of the hydroxyl group is to act as a contributor to hydrogen atoms that react with free radicals through an electron transfer mechanism [7]. These conditions were obtained at the ratio variable 0.18 (18 g sample: 100 ml solvent), time 40 minutes, and power at 180 W with a value of 212.8 mg GAE/gr. In the antioxidant test carried out on this sample, the results of DPPH inhibition were 12.3%.

3.4 Comparison with Other Methods

The total phenol yield of *Sargassum* sp. was the highest in this study, at 212.8 mg GAE/g. In another study regarding the total phenol yield of *Sargassum* sp., values obtained with the maceration method and water solvent gave higher total phenol yield, namely 669.33 mg GAE/g with heating for 20 minutes and 352.5 mg GAE/g without heating for 24 hours [23]. Study of *Sargassum muticum* using the maceration method with water solvent also gave a high total phenol yield of 275.8 ± 4.98 5 mg GAE/g. There are variables such as the ratio of the sample to the solvent volume of 0.04 g/mL and 24 hours [22]. The difference in the total phenol yield can be seen from the differences in the extraction method used, the ratio of the sample to the solvent, and the extraction time.

Another study [7] produced a lower total phenol of as much as 45 mg GAE/g compared to this study. The study used the maceration method with heating and the help of a magnetic stirrer, and the ratio of the mass of the sample to the volume of water solvent is 1:20. Comparisons can be made between the study [7] and this study, which uses the same extraction method. In this study, using the ultrasound-assisted extraction (UAE) method, there was a treatment with a ratio of 0.05 (g/mL) and a time of 30 minutes, and the highest total phenol yield was 83.1 mg GAE/g, while in [7] using the maceration method under the same conditions gave 45 mg GAE/g.

Study [20] also showed that the extraction results of macroalgae (one of them *Sargassum* sp.) using the UAE method gave higher yields when compared to conventional methods. Some of these studies show that the UAE method is more efficient than the maceration method. This is also in accordance with [24], which states that the UAE method provides higher polyphenol extraction results when compared to the conventional maceration method. The UAE method is more efficient and gives a higher total phenol yield when compared to the maceration method because, in the UAE method, ultrasound waves will provide effective interference on the sample cell wall, so that it can facilitate the release of more polar bioactive compounds [20]. Study [9] also stated that the UAE method can extract bioactive compounds in a very short time, at a low temperature, and requires lower energy and solvents when compared to conventional methods.

Based on the studies conducted on *Sargassum* sp., the variables that affect the total phenol value are extraction method, ratio, time, power (UAE method), temperature, and type of *Sargassum*.

4. Conclusion

The influence of the variable ratio of sample to solvent on the extraction is very influential; it is shown that the total phenol yield in a high ratio variable will also give a high total yield. As for the time variable is quite influential; with increasing time, the total phenol yield shows an increase. And for the power variable, it is less influential as the intensity of the total phenol yield tends to decrease. The highest value of total phenol from *Sargassum* sp. was obtained in the variable ratio 0.18 (g/mL), time of 40 minutes, and power of 180 W, with 212.8 mg GAE/g and antioxidant activity of 12.3%.

ACKNOWLEDGMENTS

The authors would like to thank the Chemical Engineering Department of the University of Jember for granting the research fund. The author would also like to thank the Chemical Engineering Department, University of Jember, and the Fundamental Laboratory for facilitating this work.

REFERENCES

[1] Puspita, M., Setyawidati, N. A. R., Stiger-Pouvreau, V., Vandanjon, L., Widowati, I., Radjasa, O. K., Bourgougnon, N., Indonesian sargassum species bioprospecting: potential applications of bioactive compounds and challenge for sustainable development. advances in botanical research (2020).

[2] Saldarriaga-Hernández, S., Hernandez-Vargas, G., Iqbal, H. M. N., Barceló, D., & Parra-Saldívar, R., bioremediation potential of sargassum sp. biomass to tackle pollution in coastal ecosystems: circular economy approach. science of the total enviroment (2020).

[3] Hifney, A.F., Fawzy, M.A., Abdel-Gawad, K.M., Gomaa, M., Industrial optimization of fucoidan extraction from *Sargassum* sp. and its potential antioxidant and emulsifying activities. Food Hydrocolloids 2015.

[4] Barquilha, C.E.R., Cossich, E.S., Tavares, C.R.G., Silva, E.A., Biosorption of nickel (II) and copper (II) ions by *Sargassum* sp. in nature and alginate extraction products 2019.

[5] Chandra, R., Iqbal, H.M.N., Vishal, G., Lee, H.S., Nagra, S., Algal biorefinery: a sustainable approach to valorize algal-based biomass towards multiple product recovery. Bioresource Technology (2019) 278: 346-359.

[6] Rahbari, H., Akram, A., Pazoki, M., & Aghbashlo, M., Bio-oil production from Sargassum macroalgae: A green and healthy source of energy. Journal of Health Sciences (2019).

[7] Hidayati, J.R., Yudiati, E., Pringgenies, D., Arifin, Z., Oktaviyanti, D.T., Antioxidant activities, total phenolic compound and pigment contents of tropical sargassum sp. extract, macerated in different solvents polarity. Journal of Tropical Marine (2019).

[8] Meregalli, M.M., Puton, B.M.S., Camera, F.D., Alexandre U.A., Jamile Z., Roge´rio L.C., Marcelo L.M., Geciane, T.B., Conventional and ultrasound-assisted methods for extraction of bioactive compounds from red arac¸a´ peel (*Psidium cattleianum* Sabine). Arabian Journal of Chemistry (2020).

[9] Kumar, K., Srivastav, S., & Sharanagat, V. S., Ultrasound Assisted Extraction (UAE) of bioactive compounds from fruit and vegetable processing by-products: a review. Ultrasonics Sonochemistry (2021).

[10] Barba F.J., Zhu Z., Koubaa M., Sant'Ana A.S., Orlien V., Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: a review. *Trends Food Science Technology*, 49: 96–109.

[11] Chemat, F., Rombaut, N., Sicaire, A.-G., Meullemiestre, A., Fabiano-Tixier, A.-S., & Abert-Vian, M., 2017. Ultrasound assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. a review. Ultrasonics Sonochemistry (2016) 34: 540–560.

[12] Laurora, A., Lund, M. N., Tiwari, B. K., Poojary, M. M., Application of ultrasound to obtain food additives and nutraceuticals. design and optimization of innovative food processing techniques assisted by ultrasound (2021) 111-141.

[13] Naqvi, S. A. R., Akbar, N., Shah, S. M. A., Ali, S., Abbas, A., Green approaches for the extraction of bioactive from natural sources for pharmaceutical applications. Green sustainable process for chemical and environmental engineering and science (2021) 269-291.
[14] Chemat, F., Abert-Vian, M., Fabiano-Tixier, A. S., Strube, J., Uhlenbrock, L., Gunjevic, V., & Cravotto, G., Green extraction of natural products. Origins, current status, and future challenges. trends in analytical chemistry (2019) 118: 248–263.
[15] Yara-Varón, E., Li, Y., Balcells, M., Canela-Garayoa, R., Fabiano-Tixier, A.-S., Chemat, F., Vegetable oils as alternative solvents for green oleo-extraction: *purification and formulation of food and natural products.* molecules 22(9) (2017) 1474.
[16] De Jesus, S. S., & Filho, R. M., Recent advances in lipid extraction using green solvents. Renewable and sustainable energy reviews (2017).
[17] Nazarudin, M. F., Paramisparam, A., Afiqah Khalid, N., Nazihah Albaz, M., Syazwan Shahidan, M., Salwany Md Yasin, I., Aliyu-Paiko, M., Metabolic variations in seaweed, *Sargassum polycystum* samples subjected to different drying methods via 1H-NMR-based metabolomics and their bioactivity in diverse solvent extracts. Arabian Journal of Chemistry (2020).
[18] Pacheco-Fernández, I., & Pino, V., Extraction with ionic liquids-organic compounds. liquid-phase extraction. In C. Poole, Handbooks in Separation Science: 499–537. Amsterdam: Elsevier.2020.
[19] Noreen, H., Semmar, N., Farman, M., & McCullagh, J. S. O., Measurement of total phenolic content and antioxidant activity of aerial parts of medicinal plant *Coronopus didymus*. Asian pacific journal of tropical medicine (2017) 792–801.
[20] Kumar, Y., Singhal, S., Tarafdar, A., Pharande, A., Ganesan, M., Prarabdh C. Badgujar, P.C., Ultrasound assisted extraction of selected edible macroalgae: Effect on antioxidant activity and quantitative assessment of polyphenols by liquid chromatography with tandem mass spectrometry (LC-MS/MS). Algal Research (2020).
[21] Maran, J. P., & Priya, B., Ultrasound-assisted extraction of polysaccharide from *Nephelium lappaceum* L. fruit peel. International journal of biological macromolecules (2014).
[22] Rodrigues, D., Sousa, S., Silva, A., Amorim, M., Pereira, L., Rocha-Santos, T. A. P., Freitas, A. C., Impact of enzyme- and ultrasound-assisted extraction methods on biological properties of red, brown, and green seaweeds from the central west coast of portugal. Journal of agricultural and food chemistry 63(12) (2015) 3177-3188.
[23] Faridah, A., Holinesti, R., Syarif, W., Total phenol and antioxidant activity of brown seaweed extract (*Sargassum* sp.). 2019.
[24] Dzah, C. S., Duan, Y., Zhang, H., Wen, C., Zhang, J., Chen, G., & Ma, H., The effects of ultrasound assisted extraction on yield, antioxidant, anticancer and antimicrobial activity of polyphenol extracts: a review. Food Bioscience (2020).

RESEARCH ARTICLE

JOURNAL OF BIOBASED CHEMICALS

Volume 2, Issue 1, 2022, pp. 43 – 55

Journal homepage: http://journal.unej.ac.id/JOBC

Optimization of Extraction of Bioactive Compound from Pegagan Leaves Using Ethanol Solvent With Microwave-Assisted Extraction Method (MAE)

Fira Ulvatur Romah[1], Atiqa Rahmawati[2,*], Meta Fitri Rizkiana[1], Ari Susanti[3]

[1]Department of Chemical Engineering, Universitas Jember, Indonesia 68121

[2]Department of Leather Engineering and Skin Preservation, Politeknik ATK Yogyakarta, Indonesia 55188

[3]Department of Chemical Engineering, Politeknik Negeri Malang, Indonesia 65141

(Submitted: 25 January 2022; Revised: 27 March 2022; Accepted: 21 July 2022)

Abstract. Treatment using natural ingredients in Indonesia is the leading choice, and it is growing in society. This is because treatment with natural ingredients has relatively milder side effects than synthetic treatment. Therefore, further research is needed on natural ingredients that can be used as natural medicines, including pegagan (*Centella asiatica* (L.)). Several studies have found bioactive compounds in pegagan that can be used in various medical methods. The author wants to know the optimal conditions for extracting pegagan bioactive compounds using the microwave-assisted extraction (MAE) method. This study used the Pegagan leaf size 40 mesh that had been dried. Pegagan leaves were extracted using ethanol as a solvent with microwave power, solvent concentration, and extraction time as variables. Variable power: 150 watts, 300 watts, and 450 watts. Variable solvent concentration 25%, 50%, and 75%. Variable extraction time for 5, 10, and 15 minutes. The results of the study were analyzed using total phenol analysis using the Folin-Ciocalteu method. The research data obtained optimum operating conditions at 75% solvent concentration, 450-watt microwave power, and an extraction time of 10 minutes with a total phenol content of 1251.410225 mg AGE/g sample.

Keywords: *extraction, pegagan, ethanol, bioactive compounds, microwave-assisted extraction, optimum conditions*

1. Introduction

Recently, in Indonesia, treatment using natural ingredients has become the leading choice developed in the community. This is because treatments made with natural ingredients have relatively milder side effects when compared to synthetic treatments. Therefore, more in-

*corresponding author: tiqa054@gmail.com

depth research is needed on the natural ingredients used as natural medicines. One of the natural ingredients that can be used as medicine is pegagan (*Centella asiatica* (L.)) [1].

Pegagan (*Centella asiatica* (L.)) is one of the wild plants that grow in large numbers in various places, such as plantations, fields, and in the yard. Pegagan has good prospects as a medicinal plant. Pegagan has been designated as a traditional medicinal plant since 1884 [2]. Pegagan is commonly used as a food additive, herbal tea, and component in cosmetics. In addition, this plant can also be used in the pharmaceutical world, namely as a therapeutic application [3]. Pegagan has long been used as a traditional medicine in the form of dry ingredients, fresh, or in the form of extracts. This pegagan plant has a pharmacological effect that has been proven from several studies, such as pegagan used as a medicine in healing wounds, rheumatism, inflammation, hemorrhoids, asthma, leprosy, tuberculosis, fever, dysentery, and can increase appetite in Australia [4].

The pegagan plant has been used as a traditional medicinal herb in Asia for centuries, such as in traditional Chinese medicine and Ayurvedic medicine [5]. Pegagan geographically comes from China, Indonesia, India, Madagascar, Sri Lanka, and Malaysia, and grows in humid places. Because of its use in the health sector, this plant can reach the borders of Turkey, the West Indies, and North America [6]. *Centella asiatica* (L.) has many bioactive ingredients, such as asiaticoside, Asiatic acid, betulinic acid, thakuric acid, madecassic acid, and madecassoside [7]. Asiaticoside in pegagan was identified as the most active primary compound [8], so it can be used as a characteristic of the pegagan plant. *Centella asiatica* (L.) contains asiaticoside as an active constituent, which plays an essential role in increasing the stimulation of antioxidant levels that can assist in the wound healing process by helping the proliferation of fibroblasts and extracellular matrix, which have an essential role in the wound healing process [9].

The bioactive compounds in *Centella asiatica* (L.) can be extracted using several methods. Based on several studies that have been carried out, the extraction of these bioactive compounds was carried out using the Soxhlet extraction method, maceration [10], subcritical water [11], viscozyme [12], and microwave-assisted extraction [13]. In its use, the pegagan plant is usually first produced as an extract. Pegagan extract can be made by maceration, fluidization, continuous filtration, and percolation. The solvent specified in the extraction process is ethanol, water, ether, or a mixture of water and ethanol [3].

In the research conducted by [3], pegagan extraction was used to determine the optimal conditions using the microwave-assisted extraction method. This research used dry pegagan

and ethanol as solvents. The results obtained in this study are the optimal conditions obtained with a ratio of 10 ml/g: 58% ethanol (solid/liquid ratio) at 300 W microwave power and in 3.4 minutes. The MAE process accelerates mass transfer and yields higher solvent yields. The proportion of ethanol in water significantly influences the extraction ok the desired product quantity. Other studies have shown that the MAE method in extracting bioactive compounds from pegagan using ethanol as a solvent has a yield that is twice as large as using the Soxhlet extraction method [10]. The advantages of the microwave as an extraction method are time efficiency, reducing the use of organic solvents, and being an environmentally friendly extraction method [14]

In this study, the extraction of bioactive components from the *Centella asiatica* (L.) plant using the microwave-assisted extraction method will be carried out to study the optimization of the extraction of bioactive compounds from pegagan extract using ethanol as a solvent. Optimization results will be obtained using the Box-Behnken design (BBD) model, and to determine the bioactive content contained in pegagan plants, a total phenolic analysis will be carried out.

2. Materials and Methods

2.1 Materials

The materials used in this study included 40 mesh size dried pegagan leaves, 96% technical ethanol, Aquadest, Na_2CO_3, Folin-Ciocalteu reagent, and gallic acid.

2.2 Methods

Pegagan leaves were dried in the sun for 2 days with the determination of physical drying and then mashed with a size of 40 mesh with a mass of 1 gram. Extraction was carried out with several variables, including at a solvent concentration of 25%, 50%, and 75%, 150 watts of microwave power, 300 watts, and 450 watts, and variable extraction time for 5 minutes, 10 minutes, and 15 minutes. The extraction results were stored in an 8 ml vial at a temperature of 4 °C.

2.2.1 Preparation of Gallic Acid Solution 100 ppm

Weigh 0.01 grams of gallic acid, then add 1 ml of ethanol and distilled water to a volume of 100 ml.

2.2.2 Determination of the Maximum Wavelength of Gallic Acid

Take 1 ml of 100 ppm gallic acid mother liquor, put it in a test tube, and add 1 ml of Folin's reagent, shake the two liquid mixtures until they are homogeneous, and allow to stand at room temperature for 4-8 minutes. Add 4 ml of 10% Na_2CO_3 solution into a test tube, shake until homogeneous, and allow to stand for 15 minutes at room temperature. Then the solution was analyzed with a UV-vis spectrophotometer with a wavelength range of 700-800 nm.

2.2.3 Preparation of the Gallic Acid Calibration Curve for the Folin-Ciocalteu Reagent

100 ppm gallic acid mother liquor, taken 1 ml each, 3 ml, 5 ml, and 7 ml. Then, it is diluted with distilled water to a final volume of 10 ml so that a solution with a concentration of 10 ppm will be obtained: 30 ppm, 50 ppm, and 70 ppm. Each solution was taken as much as 0.2 ml, put into a test tube, and 1 ml of Folin-Ciocalteu reagent was added, shaken until homogeneous, and allowed to stand for 8 minutes. Then 3 ml of 10% Na_2CO_3 was added, shaken until homogeneous, and allowed to stand for 30 minutes at room temperature. Measure the absorption using the maximum wavelength that has been obtained previously. Then a calibration curve is made using the regression equation $y = ax + b$.

2.2.4 Determination of Total Phenolic Content by the Folin-Ciocalteu Method

Take 0.1 ml of the extract, add 9.9 ml of distilled water (dilution 100 times), and add 1 ml of Folin-Ciocalteu reagent, then shake until homogeneous and allow to stand for 8 minutes. Then add 3 ml of 10% Na_2CO_3 to the mixture, shake until homogeneous, and let the solution stand for 1 hour at room temperature. Measure the absorption with a UV-vis spectrophotometer at its maximum wavelength. The content analysis was repeated 3 times to obtain the phenol content as mg gallic acid equivalent/gram of fresh sample.

3. Result and Discussion

The research was carried out in November 2020 s.d. December 2020 at the Basic Chemistry Laboratory and Bioprocess Laboratory, Chemical Engineering Study Program, Department of Mechanical Engineering, Faculty of Engineering, University of Jember. This study uses the microwave-assisted extraction method to extract the pegagan plants to obtain bioactive compounds or components. The results of measuring the total phenol content in the pegagan plant extract can be seen in Table 1.

Table 1. Total phenol content in the pegagan plant extract

No.	Power (Watt)	Concentration Pelarut (%)	Time (minute)	Absorbance Rata-Rata	Total Phenol (mgAGE/g sampel)
1	150	75	10	0.680	597.564102
2	450	25	10	0.672	587.307692
3	450	50	5	0.646	553.974359
4	300	75	5	0.570	456.538461
5	150	50	15	0.687	605.897435
6	300	50	10	0.715	641.794871
7	450	50	15	0.857	823.846153
8	300	75	15	0.950	943.717948
9	300	25	15	0.687	605.897435
10	300	50	15	0.830	789.230769
11	450	75	10	1.190	1251.41025
12	150	50	5	0.558	440.512820
13	150	25	10	0.583	473.205128
14	300	25	5	0.575	462.307692
15	300	50	10	0.688	607.820512
16	300	50	10	0.696	618.076923
17	300	50	10	0.686	604.615384

3.1 Gallic Acid Standard Curve

Gallic acid standard curves were made using several concentrations of gallic acid, namely 10 ppm, 30 ppm, 50 ppm, and 70 ppm. The absorbance was measured with a maximum wavelength of 765 nm, which had been previously obtained. The standard curve for gallic acid and the straight-line equation that will be used in determining the concentration of gallic acid can be seen in Figure 1.

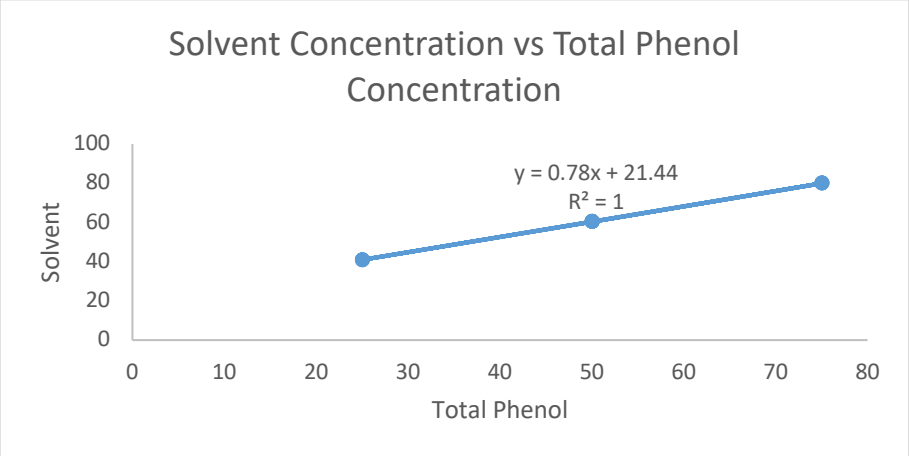


Figure 1. Gallic acid standard curve with various concentrations of 10, 30, 50, 70 ppm

From the curve, a straight-line equation is obtained, y = 0.78x + 21.44, with R^2 = 1, showing that the straight-line equation can determine the total phenol content.

3.2 Analysis of Total Phenol by Response Surface Method (RSM)

The response surface method (RSM) analysis of total phenol was carried out to prove whether the variables used in the pegagan extraction process could affect the resulting product. The variable can be significant if the p-value of the RSM analysis method has an alpha value of 5%. P-value <0.05 indicates that the antioxidant activity produced is a response to the treatment variables, including solvent concentration, power, and extraction time. The F-value is inversely proportional to the F-table value, seen in Table 2.

Table 2. Results of Analysis of Variance (ANOVA) response of antioxidant activity

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	607455	67495	7.54	0.007
Linear	3	486103	162034	18.11	0.001
Power	1	151074	151074	16.89	0.005
Concentration	1	156944	156944	17.54	0.004
Time	1	178086	178086	19.91	0.003
Square	3	32114	10705	1.20	0.378
Power*Power	1	6743	6743	0.75	0.414
concentration * concentration	1	10973	10973	1.23	0.305
Time*Time	1	11390	11390	1.27	0.296
2-Way Interaction	3	105074	35025	3.92	0.062
Power* Concentration	1	72831	72831	8.14	0.025
Power*Time	1	2729	2729	0.31	0.598
Concentration *Time	1	29513	29513	3.30	0.112
Error	7	62620	8946		
Lack-of-Fit	4	61771	15443	54.57	0.004
Pure Error	3	849	283		
Total	16	670075			

The F-value is 7.54, the df value is 9, with the number of samples 17 at alpha 0.05, and the F-table value is 2.49. So, the F-value is greater than the F-table, indicating that the model used significantly affects the response. The P-value can be seen as 0.007, meaning that the value is smaller than the set probability of 0.05. The analysis model of the Pegagan (*Centella asiatica* (L.)) plant extract significantly affects the extract's total phenol content.

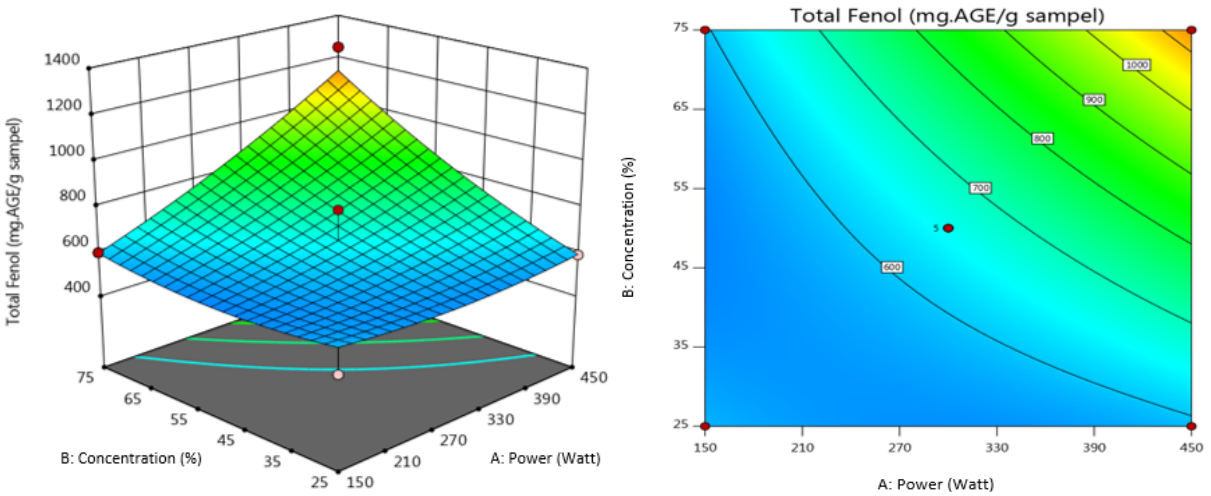
Table 3. Model Summery

S	R-sq	R-sq(adj)	R-sq(pred)
94.5819	90.65%	78.64%	0.00%

This analysis also obtained an R-squared value of 90.65%, indicating that the study's results support the model used. The value of R-squared can be stated according to the model if the value is more than 75% (Yingngam et al., 2020). The adjusted R-sq value of 78.64% indicates a strong relationship between ethanol concentration, extraction time, and microwave power on the response.

3.3 Effect of variables (power, ethanol concentration, and radiation time) on the total phenol content

Figures 2, 3, and 4 show the effect of each variable (concentration, power, time; power, concentration, time) on the total concentration of phenol. The figure shows that combinations of parameters influence the response value through the presence of different colors. The lines that consist of the dots on the counterplot graph are a combination of 3 factors. The combination is formed from differences in the proportion of factors and produces the same response value for the total phenol content.



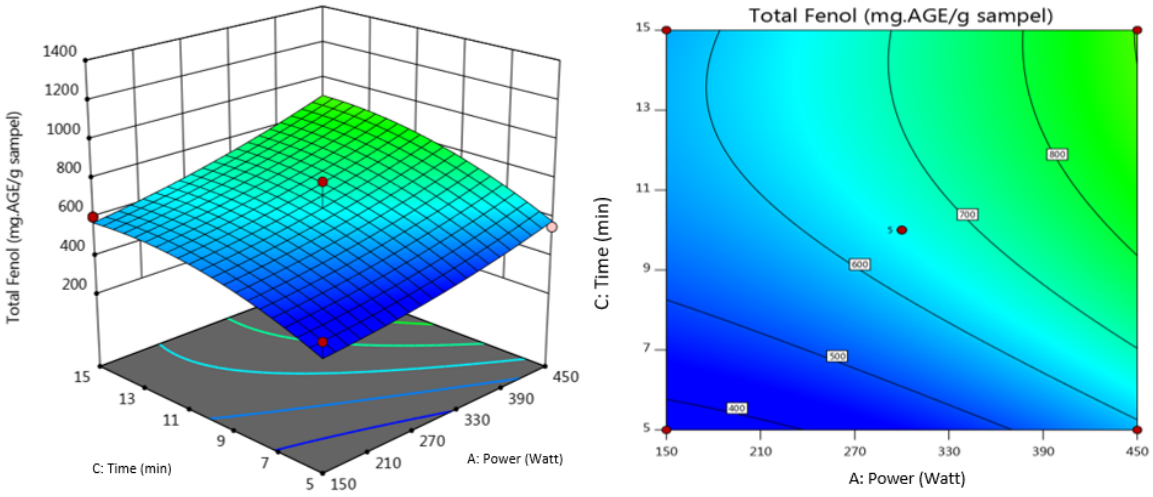
(a) (b)

Figure 2. Effect of Concentration and Power on Total Phenol of Pegagan Bioactive Compounds

The graph in Figure 2, point (a), shows that the extraction that produces the lowest yield at the operating conditions of the microwave power is 150 watts, and the solvent concentration of ethanol is 25%. Thus, it can be seen that the total phenol content will increase with the increase in microwave power and solvent concentration. The effect of microwave power in this study follows the research conducted by [15], which shows that the higher the microwave power

used, the greater the temperature increase caused by the energy generated in the microwave (radiation and rotation), so that there is microwave radiation and rotating vibrations, which cause pressure on the cell wall to increase. The cell will swell, so that more and more bioactive compounds are produced.

In Figure 2, point (b), the X-axis shows the extraction power used, the Y-axis shows the concentration of ethanol solvent used (%), and the lines in the contour indicate the response. The figure shows that the total phenol concentration will increase with increasing power and solvent concentration. This can be seen from the change in the area's color, starting from the lowest in the blue area and rising to the orange area, namely the area with a higher total phenol concentration.



(a) (b)

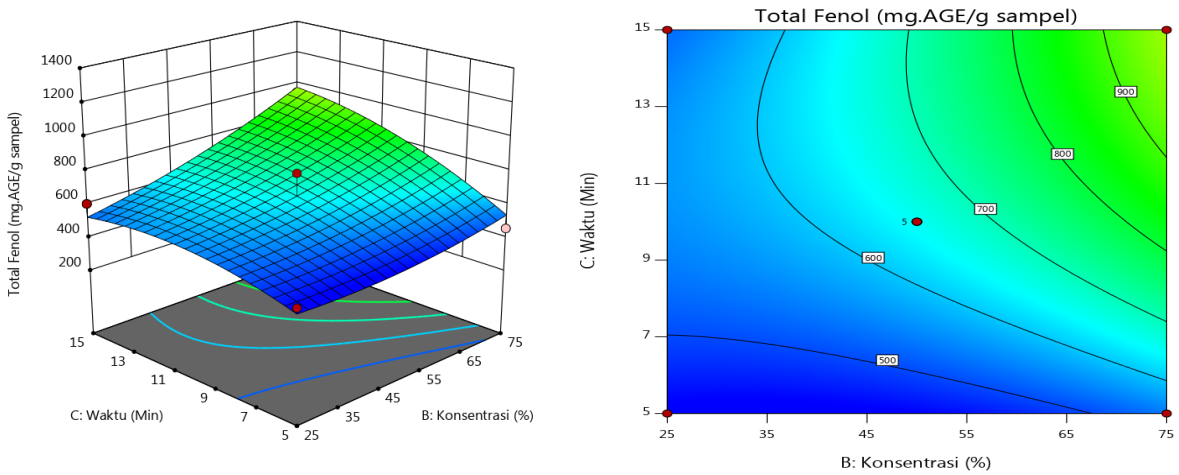
Figure 3. Effect of time and power interaction on total phenol of pegagan bioactive compounds

Figure 3 point (a) shows the response surface graph for the yield response, namely the relationship between extraction time and power to the total phenol produced. The graph in the figure indicates that the extraction that produces the lowest yield is at the operating conditions of 150-watt microwave power for 5 minutes. When the extraction time and microwave power are increased, the total phenol content produced will increase to the optimum total phenol content. This shows that the increase in total phenol content is directly proportional to the rise in power and extraction time.

The results are from research by [16] on extracting soursop leaves using the microwave-assisted extraction method, which increases antioxidant activity response with increasing extraction time. More and more target compounds can be extracted with ethanol solvent and the MAE method, but the extraction time, which increases beyond the optimal extraction time, will decrease the total phenol content. Microwave heating will cause the extraction temperature

to increase with the increase in extraction time, which causes the degradation of phenol compounds. In addition, microwaves can also reduce enzymatic activity, which results in damage to the extracted compounds. The result of microwave heat will be an inhibitor of phenolase enzyme activity. And in [17], regarding extracts of phenolic compounds from rosella flower petals with microwaves, it was stated that an increase in the total phenol produced was in line with an increase in microwave power. This increase is due to the direct influence of microwave energy on biomolecules by ionic conduction and dipole rotation, resulting in molecular motion and heating.

Figure 3 point (b) shows the response lines, where the outer line shows the lowest response value and the inner line shows the highest response value. The figure shows that the total phenol concentration increases with extraction time and power. This can also be seen from the color change in the contour graph. This is also by the research conducted by [18] in determining the optimization of the total flavonoid content of brown algae by producing a significant effect of the interaction between power and extraction time, namely, the flavonoid content increased with an increase in power of 300-450 watts and at 7-9 minutes.



(a) (b)

Figure 4. Effect of time and concentration interaction on the total phenol of pegagan bioactive compounds

In Figure 4, point (a), it is known that when the operating conditions of time and power increase, the total phenol content obtained increases. This shows that the rise in total phenol content is directly proportional to the increase in solvent concentration and extraction time. This follows the research conducted by [19], namely, extraction with the MAE method on the antioxidant activity of corn silk extract, by obtaining results showing that the higher the

concentration of ethanol solvent and the longer the extraction time, the yield of corn silk extract will also increase.

Figure 4 point (b) also shows the response to the total phenol concentration, which increases with increasing time and solvent concentration as evidenced by a change in color from the outermost (low) region to the deepest area, which shows a higher response value.

3.4 Regression Equation

Total phenol concentration = 932 – 2.30 power – 20.25
concentration + 25.24 time + 0.00178 power*power + 0.0819 concentration * concentration – 2.09 time*time+ 0.0360 power* concentration + 0.0348 power*time + 0.678 concentration *time

The regression equation above can determine the response value of the total phenol concentration obtained if the solvent concentration, power, and extraction time differ. The coefficient of power, concentration, and time shows the increase or decrease in the value of the total phenol concentration. Suppose the coefficients of power, concentration, and time are negative. In that case, it will decrease the value of the total phenol concentration, whereas if it is positive, it will increase the value of the total phenol concentration. In this equation, the value of the interaction coefficient between time and time is negative. This indicates a maximum stationary point of the response surface [20].

The equation shows the interaction coefficient between power and time, power and concentration, and the interaction between concentration and time is positive, which means that the interaction between these variables can affect the response. The extraction time in the equation shows a positive value, where increasing the extraction time will increase the total phenol response until it reaches the optimal value. This is by [21], namely, the longer the extraction time used, the longer the exposure time to microwaves in the sample, resulting in a high value of the antioxidant activity.

3.5 Optimization of Total Phenol

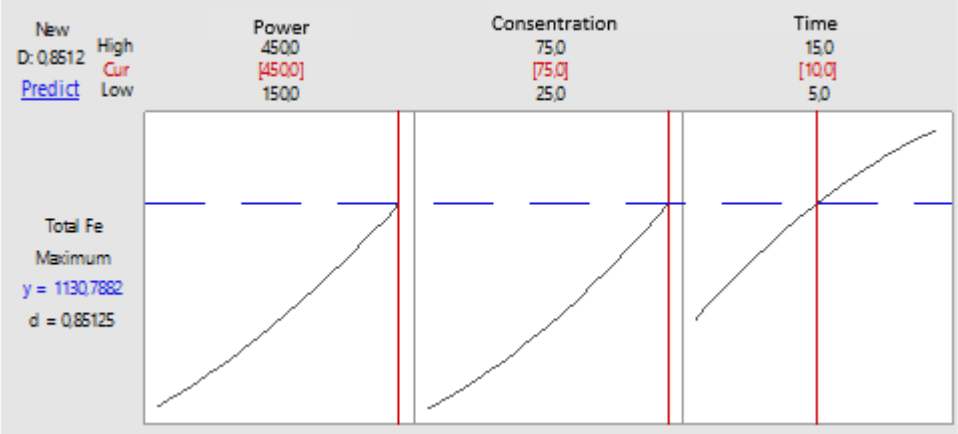


Figure 5. Graph of Optimization Value

Figure 5 shows that the desirability value reaches its maximum when the factor value is in the red line. The desirability value is used to determine the accuracy of the optimal solution results, where on a scale of 1.00 - 0.80, it shows an excellent number [22]. From Figure 5, the desirability value obtained is 0.85125, indicating that the variables used have a perfect effect on the response. In the figure, the black line shows the desirability value for each response, and the blue dotted line shows the response value at a specific desirability value. The graph in Figure 5 shows that the optimal value for the total phenol concentration-response was obtained at 450 watts of power, 75% concentration, and within 10 minutes by obtaining a value of 1130.7882 mgAGE/g samples obtained when the desirability value reached 0.85125.

4. Conclusion

The maximum total phenol content in extracting gotu kola bioactive compounds using the MAE method resulted in a total phenol of 1251.410225 mg AGE/g sample. The operating conditions resulted in optimum total phenol at 75% solvent concentration, 450 watt microwave power, and within 10 minutes with an R-square value of 90.65%.

ACKNOWLEDGMENTS

The Basic Chemistry Laboratory and Bioprocess Laboratory, Chemical Engineering Department of Universitas Jember, supported and facilitated the study.

REFERENCES

[1] Lestari, A B S., Susanti, L U., dan Dwiatmaka, Y. Optimasi pelarut etanol-air dalam proses ekstraksi herba pegagan (*Centella asiatica* [L.] Urban) pada suhu terukur. Jurnal immu Hayati dan Fisik 14(2) (2012) 87-93.

[2] Winarto, W.R. dan M. Surbakti. khasiat dan manfaat pegagan. Jakarta: Agromedia Pustaka.2003.

[3] Yingngam, B., Chiangsom, A., & Brantner, A. 2020. Modeling and Optimization of microwave-assisted extraction of pentacyclic triterpenes from *Centella Asiatica Leaves* using response surface methodology. Industrial Crops and Products 147 (2020) 112231.

[4] Besung, I. N. Pegagan (*Centella asiatica*) Sebagai Alternatif Pencegahan Infeksi Pada Ternak. *Jurnal Penelitian* 1(2) (2009) 61-67.

[5] Ramadhan, N.S., Roslaili R., & Elmatris S. Daya hambat ekstrak daun pegagan (*Centella asiatica*) yang diambil di batusangkar terhadap pertumbuhan kuman vibrio cholerae secara in vitro. Jurnal Kesehatan Andalas 4(1) (2015) 202-206.

[6] Lokanathan Y., Omar N., Ahmad Puzi NN., Saim A., dan Hj Idrus R. Recent updates in neuroprotective and neuroregenerative potential of *Centella asiatica*. Malays J Med Sci 23(1) (2016) 4-14.

[7] Jiang H., Zheng G., Lv J., Chen H., Lin J., Li Y., Fan G., dan Ding X. Identification of *Centella asiatica's* effective ingredients for inducing the neuronal differentiation. Evid Based Complement Alternat Med (2016) 9634750.

[8] Plohman B, Bader G, Hiller K, Franz G. Immunomodulatory and antitumoral effects of triterpenoid saponins. Die Pharm 52(12) (1997) 953-957.

[9] Sabila, Fidya C & Muhartono. Efektivitas Pemberian ekstrak daun pegagan (*Centella Asiatica*) terhadap penyembuhan luka. Jurnal Agromedicine Unila 7(1) (2020) 23-29.

[10] Puttarak, P., & Panichayupakaranant, P. A new method for preparing pentacyclic triterpene rich *Centella asiatica* extracts. Natural Product Research 27(7) (2013) 684–686.

[11] Kim, W. J., Kim, J., Veriansyah, B., Kim, J. D., Lee, Y. W., Oh, S. G., & Tjandrawinata, R. R. Extraction of bioactive components from *Centella asiatica* using subcritical water. Journal of Supercritical Fluids 48(3) (2009) 211–216.

[12] Binh, N. T., & Oanh, H. N. Optimization of the treatment and extraction procedures for 6(6) (2017) 15–21.

[13] Sadeghi, A., Hakimzadeh, V., & Karimifar, B. Microwave assisted extraction of bioactive compounds from food: a review. International journal of food science and nutrition engineering 7(1) (2017) 19–27.

[14] Bintari, Y.R, Winarto H., & Tri Joko R. Ekstraksi lipida dengan metode microwave assisted extraction dari mikroalga yang potensial sebagai biodiesel. Jurnal Ketahanan Pangan 2(2) (2018) 180-189.

[15] Suhendra, C., I Wayan R., & Anak Agung I. Pengaruh konsentrasi etanol terhadap aktivitas antioksidan ekstrak rimpang ilalang (*Imperata cylindrica* (L) Beauv,) pada ekstraksi menggunakan gelombang ultrasonik. Jurnal ilmu dan teknologi pangan 8(1) (2019) 27-35.

[16] Aulia, L.P., & Simon, B.W. Optimization extraction process of sorsoup leaves (*Annona Muricata L*) with MAE methode (*Microwave-Assisted Extraction*) by antioxidant activity and total phenol. Jurnal agroindustri halal 4(1) (2018) 79-87.

[17] Maksum, A & Ike S.M.P. Optimasi ekstraksi senyawa fenolik dari kelopak bungan rosella (*Hibiscus sabdariffa*). Agrin 21(2) (2017) 91-104.

[18] Sari, Bina L., Triastinurmiatiningsih, dan Tri Saptari H. Optimasi metode Microwave-Assisted Extraction (MAE) untuk menentukan kadar flavonoid total alga coklat padina australis. ALCHEMY jurnal penelitian kimia 16(1) (2020) 38-49.
[19] Kristanti, Y., I.W.R. Widarta., & I. D. G. Permana. Pengaruh waktu ekstraksi dan konsentrasi etanol menggunakan metode Microwave Assisted Extraction (MAE) Terhadap aktivitas antioksidan ekstrak rambut jagung (*Zea Mays L.*). Jurnal Ilmu dan Teknologi Pangan 8(1) (2019) 94-103.
[20] Edwards, J. R. Polynomial regression and respins surface methodology. In Ostroff, C and Judge, T. A (ed). San Fransisco: Perspective on Organizational Fit. 2007.
[21] Faadhilah, A. Optimasi microwave assisted extraction terhadap senyawa bioaktif antioksidan dari sarang semut Papua (*Myrmecodia pendans*) dengan variasi konsentrasi etanol, suhu dan lama ekstraksi. Skripsi. Malang: Universitas Brawijaya. 2019.
[22] Trihaditia, R., Melissa S., & Aliyah A. Penentuan formulasi optimum pembuatan *cookies* dari bekatul padi pandanwangi dengan penambahan tepung terigu menggunakan Metode RSM (*Response Surface Method*). Agroscience 8(2) (2018) 2579-7891.

RESEARCH ARTICLE

JOURNAL OF BIOBASED CHEMICALS

Volume 2, Issue 1, 2022, pp. 56 – 64

Journal homepage: http://journal.unej.ac.id/JOBC

Essential Oil Extraction from Citronella (*Cymbopogon nardus* L.) Using Solvent-Free Microwave Extraction Method (SFME)

Siti Fatimah, Ditta Kharisma Yolanda Putri*

Department of Chemical Engineering, Universitas Jember, Indonesia 68121

(Submitted: 20 January 2022; Revised: 20 March 2022; Accepted: 18 July 2022)

Abstract. Indonesia is one of the countries that produces essential oils, a commodity that can generate foreign exchange. Therefore, essential oils receive special attention from the Indonesian government. Indonesia generates 40-50 types of plants that produce essential oils and are traded worldwide. Extraction using a microwave, with the basic mechanism of microwave heating, involves stirring polar molecules or ions that oscillate due to the influence of electric and magnetic fields, called dipolar polarization. From the results of physical analysis, citronella essential oil obtained using the Solvent Free Microwave Extraction (SFME) method has met the standards and quality of citronella oil based on SNI 06-3953-1995, according to the parameters of color, specific gravity, and solubility in water. 80% ethanol shows citronella oil of good quality. The results of GC-MS (Gas Chromatography-Mass Spectrometry) analysis on the extraction of citronella essential oil using the Solvent Free Microwave Extraction (SFME) method obtained two components, namely citronella and geraniol, with citronellal percentages of 8.64% and 7.53%. Optimal operating conditions for extracting essential oils from citronella raw materials using the Solvent Free Microwave Extraction (SFME) method.

Keywords: *extraction, lemongrass, microwave, GC-MS (Gas Chromatography-Mass Spectrometry)*

1. Introduction

Indonesia is a country that produces essential oils, which are also a commodity that can generate foreign exchange for the country. Thus, essential oils receive special attention from the Indonesian government. Indonesia produces 40-50 types of plants that produce essential oils and are traded worldwide. Until now, Indonesia has only produced several essential oils, such as clove essential oil, ylang leaf essential oil, patchouli leaf essential oil, vetiver essential oil, nutmeg essential oil, eucalyptus essential oil, citronella essential oil, and sandalwood essential oil. In Indonesia, there are six types of essential oils, the most prominent of which are: nutmeg oil, vetiver oil, patchouli oil, eucalyptus oil, clove oil and citronella oil.

Lemongrass (*Cymbopogon nardus* (*L.*)) is one of the essential oil-producing plants

*corresponding author: dittakharisma@unej.ac.id

from the Poaceae family and was known in Indonesia before World War II. Citronella contains about 1-2% essential oil on a dry basis, and the composition of the essential oil depends on the diversity of treatments, habitats, and plant genetics [1]. According to Citronella, the essential oil is called Citronella oil in the trading world. Citronella essential oil is included in one of the essential oil commodities with considerable prospects among other essential oils [2].

The citronella plant has a characteristic lemon scent due to the main content of citronella, which is citral. Citral combines neutral and geraniol isomers, usually used as a raw material for ionine, beta carotene, and vitamin A products. Lemongrass essential oil has also shown high antioxidant, antibacterial, and antifungal properties [3].

The process of extracting essential oils usually uses the conventional method, namely the hydrodistillation method. Previous studies have shown that this distillation method takes a long time and requires a lot of solvents to yield results, which is less efficient in terms of time and energy and less environmentally friendly [4]. Therefore, a method was developed for extracting essential oils, namely the Microwave Assisted Extraction (MAE) method. The Microwave Assisted Extraction (MAE) method consists of Microwave Assisted Hydrodistillation (MAHD), Microwave Steam Distillation (MSD), Microwave Steam Diffusion (MSDf), and others.

Based on the above method, further development of the next Microwave Hydrodistillation (MHD) method was carried out, namely the Solvent-Free Microwave Extraction (SFME) method. In this method, the extraction process is carried out without using any solvent or heat from the microwave [5]. This method also combines microwave heating and distillation with atmospheric pressure. The principle of this method is that it does not use water or organic solvents, so the extraction process uses the water content contained in the plant. During the extraction process, the raw materials will not be exposed to chemicals [4].

Based on the description above, this research uses citronella to extract essential oils using the extraction method, namely Solvent-Free Microwave Extraction (SFME), which has never been done before, so this research was carried out using the Solvent-Free Microwave Extraction (SFME) and analyzed the quality of citronella essential oil produced based on the standard of SNI 06-2386-2006.

doi.org/10.19184/jobc.v2i1.120

2. Materials and Methods

2.1 Materials

The materials used in this study were citronella leaves with a water content of 48-52% and 80% ethanol. The primary tool consists of a microwave for the schematic of the tool in the Solvent Free Microwave Extraction method. The specifications of this research equipment are Microwave, 100 ml beaker glass, 250 ml beaker glass, Vial bottle, Spatula, Analytical balance, 1000 ml round-bottom flask, 1000 ml wide 2nd round flask, Oven, Clamps, static, Gas Chromatography Mass Spectrophotometry (GC-MS), and Scanning Electron Microscope (SEM).

The research was conducted at the Basic Chemistry Laboratory and the Bioprocess Laboratory of the Chemical Engineering/Engineering Study Program, Department of Mechanical Engineering, Faculty of Engineering, University of Jember. Research activities are carried out from November 2020 to January 2021.

2.2 Material Preparation

The first step is to take the raw material in the form of citronella leaves fresh from the field. The citronella leaves are cleaned of dirt that sticks so as not to interfere with the extraction process, and then the citronella leaves are cut into sizes of 2-3 cm.

2.3 Extraction using the Solvent Free Microwave Extraction (SFME) Method

The extraction process begins by weighing the raw materials according to the variables then installing the extraction tool then inserting the raw material for citronella into a distillation flask, for the next step to drain the water in the cooling water system then insert the flask into the microwave, after the flask is inserted the next step is to turn on the microwave and adjust the microwave power according to the variable, then record the distillation time starting from the first drop of distillate out, then stop the extraction process after the specified time according to the variable and for the last step to store the essential oil in a vial.

3. Result and Discussion

This study used citronella raw material obtained from Kemuning Lor Village, Arjasa District, Jember Regency, and was determined according to the variable, namely, in a fresh condition. Here, as seen in the Figure below:

Figure 1. Fresh scented lemongrass plant

The variables used in this study are the ratio of raw materials' mass to the distiller's volume, microwave power, and extraction time. The ratio of the mass of raw materials in this study is 0.05; 0.10 and 0.15 g/ml in fresh condition and put in a distiller flask with a volume of 1000 ml, the size of cutting the material is 2-3 cm long because the citronella leaves are surrounded by oil glands, oil pockets and vessels so that if not cut it will cause oil is not extracted optimally. The selection of this material mass ratio variable aims to predict yield results for microwave power in this study using power levels of 300 W, 450 W, and 600 W. The choice of microwave power in this extraction is due to the influence on the amount of heat energy that will be received by the raw materials [7].

This study's extraction of citronella essential oil used the Solvent-Free Microwave Extraction (SFME) method from fresh raw materials. The yield produced using this method is significant due to the influence of the water content in the fresh ingredients. This is because the extraction with fresh raw materials has a much smaller amount of water in the distiller. A small amount of water will accelerate the increase in temperature. This rapid increase in temperature will accelerate the opening of the oil glands and cause a faster rate of growth in yield.

The solvent-free microwave extraction method is an extraction method that does not use solvents and utilizes microwaves as a heater. The extraction process of the Solvent Free Microwave Extraction method occurs through synergy between mass transfer and heat transfer from inside and outside due to internal overheating, so the extraction process is faster. In this method, the water contained in the material is refluxed into a distiller flask using a Clevenger.

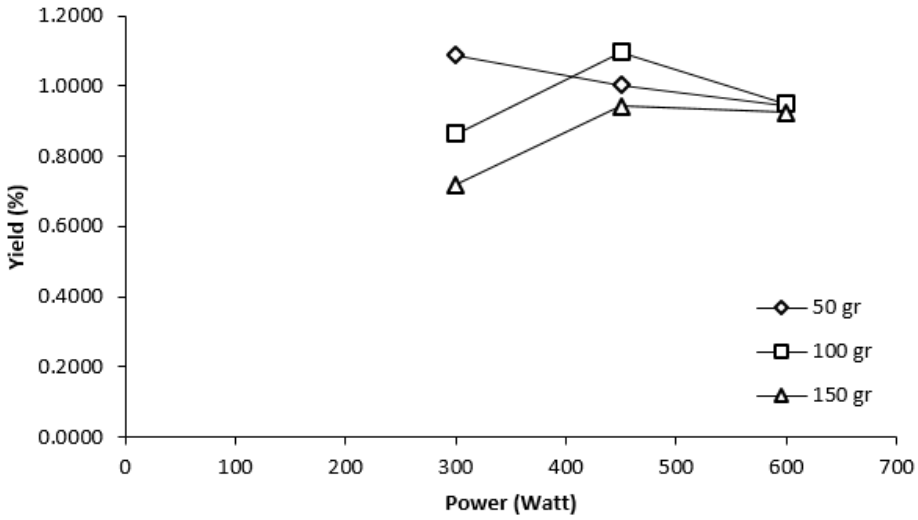


Figure 2. Graph of the effect of microwave power on the oil yield of fragrant lemongrass leaves

Power is the amount of energy delivered per unit time. In the extraction process, power significantly influences the yield of citronella oil that will be produced. Microwave power is closely related to process temperature, where the greater the power to be used, the faster the system temperature in the extraction process will increase [7]. The effect of power on temperature lies in the increase in temperature. The greater the power, the faster the temperature rises in the extraction process.

Based on Figure 2, it can be seen that the highest yield is at 450 watts at a mass ratio of 0.10 g/ml. Similar to research [9] on vetiver extraction, the highest yield value was obtained when the power was 450 watts in fresh raw material conditions. This is because the power is stable (power is not too low and high, so if low power causes heat transfer to be hampered and difficult to enter into the material, while for high power it can cause the material to burn quickly due to high heat transfer heat and damage the glands oil), then with a stable power can result in the material can be adequately extracted. In this parameter, if the microwave power used is greater, the polar molecules in the material, when exposed to microwave radiation, will experience a faster rotation (oscillatory motion and collide with each other) and produce heat energy (*heat*) so that the target molecule can be extracted from the material. Yield reduction occurred at 300, 450, and 600 watts at a 0.05 g/mL mass ratio. The cause of the decrease in yield is due to the small mass of raw materials used. At the same time, the small power also affects the small energy transfer in the sample and causes the yield to be not optimum due to material degradation. Supported by research, namely the extraction of pomelo peels using the SFME method at 300 watts and 450 watts, the yield decreased by 5.3% due to damage to the

oil glands at higher microwave power. Power that is too high can also cause raw materials to dry faster. According to [7], the water content in the plant also has an effect, so the higher the power used, the faster the boiling point. This study obtained the optimum yield at 300 watts and 450 watts of power with a mass ratio of 0.10 g/ml. The water content in the plant also has an effect, so the higher the power used, the faster the boiling point. This study obtained the optimum yield at 300 watts and 450 watts of power with a mass ratio of 0.10 g/ml. 2008), the water content in the plant also has an effect, so the higher the power used, the faster the boiling point. This study obtained the optimum yield at 300 watts and 450 watts of power with a mass ratio of 0.10 g/ml.

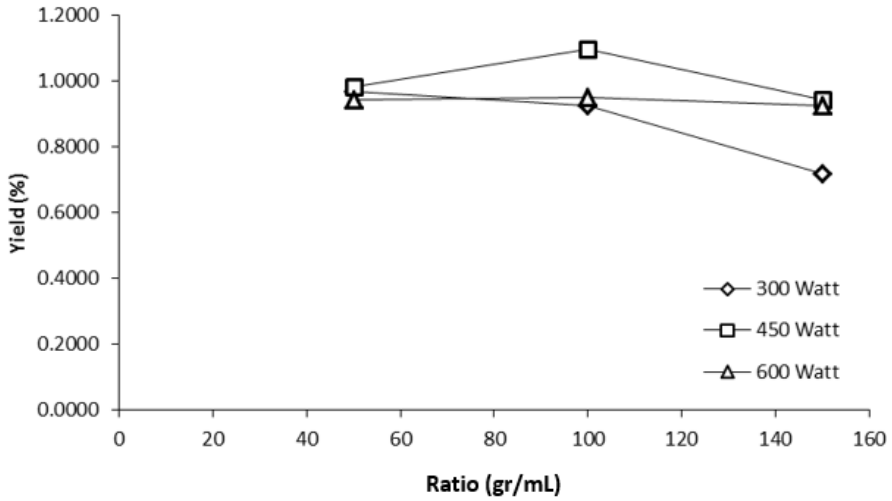


Figure 3. Graph of the effect of the ratio between the material mass standard and the distiller volume (f/d) against the yield of citronella oil

Extraction of citronella oil by solvent-free microwave extraction method using a mass ratio of 0.05, 0.10, and 0.15 g/mL; for each variable, a distiller flask with a volume of 1000 mL will be used. The effect of material mass per distiller volume (F/D) on yield can be seen in Figure 3.

Based on Figure 3, the optimum ratio is 0.10 g/mL. This is supported by research on the extraction of essential oil of eucalyptus leaves using the Solvent Free Microwave Extraction (SFME) method in fresh conditions, where the optimum yield was obtained at a mass ratio of 0.10 g/ml. Furthermore, in the extraction of citronella essential oil, there was an increase in yield from a ratio of 0.05 g/ml to 0.10 g/ml at 450 watts of power. However, there was a decrease in yield at a ratio of 0.15 g/ml. This is supported by research on the extraction of essential oils from stems, leaves, and peels of limes with the Solvent Free Microwave Extraction method on the effect of the ratio between the mass of raw materials and the volume

of the distiller on the yield of fresh kaffir lime leaf oil. Optimal at 0.25 g/ml, broadly speaking, the yield increased from a ratio of 0.05 g/ml to 0.25 g/ml. Still, at a ratio of 0.3 g/ml, it decreased and was caused by several factors, such as the amount of material in the distiller flask, the density of the material can cause the formation of pathways, "rat holes" steam, which will affect the yield of essential oils, either increasing the yield or reducing the yield of essential oils. The material density factor is the ratio between the material's mass and the distiller flask's volume capacity. This can cause the steam generated by microwave heat to be challenging to penetrate the material to carry the diffused oil molecules out of the material [6]. In addition, the ratio used relates to the amount of raw materials included in the distiller flask, which causes the yield of citronella oil to decrease, for the lowest yield, based on Figure 2, which is 0.7181 at 300 watts of power, 150 grams of material, and 60 minutes.

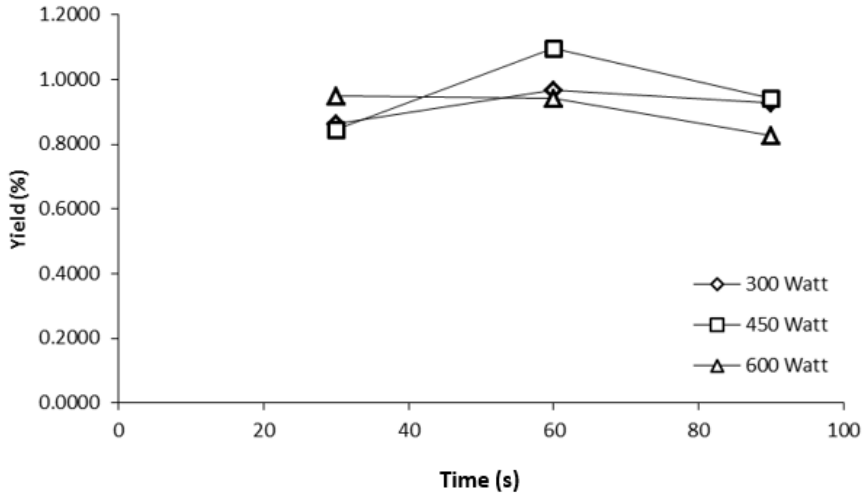


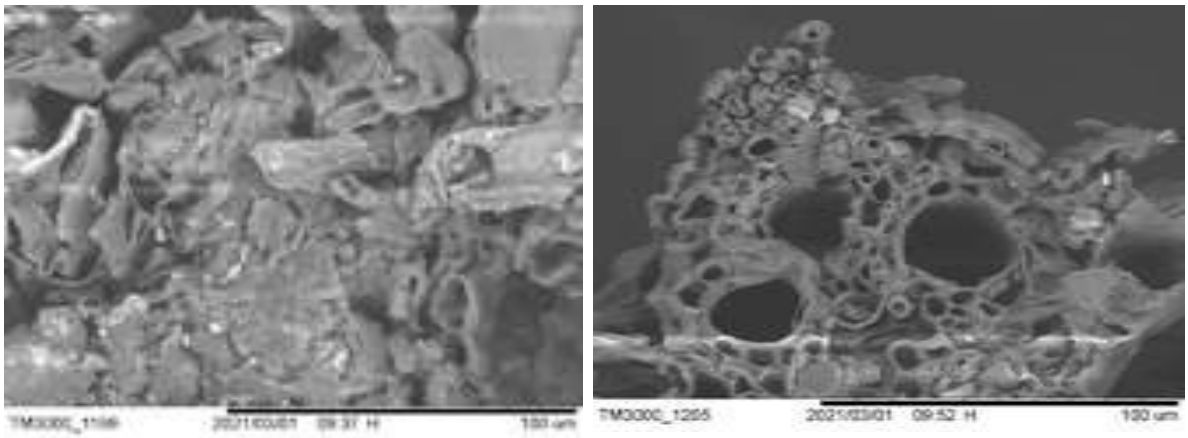
Figure 4. Graph of the effect of time on the yield ok lemongrass oil

Figure 4 shows the relationship between extraction time and yield of citronella oil. The extraction of citronella oil using the Solvent Free Microwave Extraction method for 30 and 60 minutes, namely at 300 and 450 watts, produces yields that tend to increase constantly with increasing extraction time. However, at 600 watts, the yield decreases due to the high heat released, causing the raw material to dry quickly. The lowest yield is at 90 minutes of 600 watts of mass 100 grams with a yield of 0.8259. This is because the high power and long time cause the raw materials to dry up and become charred. With the longer extraction time, the increase in yield obtained becomes smaller and smaller.

The quality of essential oils is influenced by several factors such as raw materials, post-harvest handling, production, and storage processes. Based on the results of this study, it is

known that the quality of citronella essential oil is influenced by one factor, namely raw materials, the raw materials in this study are in different conditions, such as differences in material conditions from post-harvest to the extraction process, material conditions from fresh to slightly wilted. and this causes the content of the essential oil is different. From the results of the Gas Chromatography-Mass Spectroscopy (GC-MS) test, 84 components are contained in the essential oil of citronella. There are two compounds with the highest % area, namely 6 6-octenal,3,7-dimethyl, and geraniol, 6 6-octenal,3,7-dimethyl, which is another name for citronellal, with a yield of 8.64% and a molecular weight of 154, and belongs to the class of oxidized monoterpenes. The second highest compound was geraniol with a yield of 7.53%, a molecular weight of 154, and was included in the oxidized monoterpene class.

In a previous study, the results of geraniol and citronellal citronella essential oil, using methanol as a solvent, were 20.07% and 36.11%, respectively. These results differ due to several factors, such as the method used and the raw materials' area of origin, including weather factors and soil conditions during the citronella planting process. The GC-MS analysis test in this study used a random sample.



(a) (b)

Figure 5. SEM results of citronella leaves with 1000 times magnification (a) before extraction, (b) after extraction

4. Conclusion

The effect of microwave power, the ratio of the mass of raw materials to the volume of the F/D distiller and the resulting extraction time as well as the suitability of the extraction results to SNI, namely the increase in yield occurs at a power of 300 - 450 watts, but decreases at 600 watts with a raw material ratio of 0.10 g /ml, the amount of raw materials contained in the distillation flask causes an increase in the amount of yield, namely in the ratio of 0.05 g/ml – 0.10 g/ml, but there is a decrease in the ratio of 0.15 g/ml due to the density of raw materials,

time extraction tends to increase in the variable 30-60 minutes, but there is a decrease in the extraction time of 90 minutes, the results of the GC-MS analysis show that there are 2 main components of citronella essential oil, namely citronella and geraniol with an abundance percentage of 8.64% and 7.53%, the study of the physical properties of citronella essential oil has good quality because it meets the Indonesian National Standards, namely the parameters of color, specific gravity, and 80% alcohol solubility. The optimum conditions for extracting citronella essential oil using the Solvent Free Microwave Extraction (SFME) method are as follows, the optimal power obtained when using 450 watts of power with a yield of 1.096%, the ratio between citronella and distiller (F/D) obtained the optimum conditions at the mass ratio 0.10 gr/ml, with a yield of 1.0969%, the optimal time for the extraction process is 60 minutes, with a yield of 1.0873%.

ACKNOWLEDGMENTS

Kemuning Lor Village, Arjasa District, Jember Regency, and the Chemical Engineering Department of Universitas Jember supported and facilitated the study.

REFERENCES

[1] Ranitha, M., AH Nour, ZA Sulaiman, AH Nour, and ST Raj. A comparative study of Lemongrass (*Cymbopogon citratus)* essential oil extracted by Microwave-Assisted Hydrodistillation (MAHD) and Conventional Hydrodistillation (HD) Method. International journal of chemical engineering and applications 5(2) (2014).

[2] Sulaswatty, A., MS Rusli, H. Abhimanyu, and S. Tursiloadi. Quo vadis citronella oil and its derivatives products. Jakarta: LIPI Press2019.

[3] Ranade, SS and P. Thiagarajan. Lemon grass. International journal of pharmaceutical sciences review and research 35(2) (2015) 162-167.

[4] Lucchesi, ME, Chemat, F. & Smadja, J. Solvent-free microwave extraction: an innovative tool for rapid extraction of essential oils from aromatic herbs and spices. The Journal of microwave power and electromagnetic energy, 39(3-4) (2004) 135-139.

[5] Li, Y., Fabiano-Tixier, AS, Vian, MA & Chemat, F. Solvent-free microwave extraction of bioactive compounds provides a tool for green analytical chemistry. TrAC Trends in analytical chemistry, 47(6) (2013) 1-11.

[6] Guenther, E, The essential oil, New:Van Nostrand Company Inc IV.1950.