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Performance Analysis of Extraction Machine Using Ohmic Technology for Producing Anthocyanin

Uji Performansi Mesin Ekstraksi Dengan Teknologi Ohmic Untuk Menghasilkan Antosianin

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ABSTRACT
Extraction is one of the important processes for obtaining anthocyanins as natural dyes. The aim of this study is to investigate the performance of the extraction apparatus using ohmic technology to produce anthocyanins. This study used a series of ohmic heating consisting of tubular pipes with a diameter of 6 cm and a length of 5.5 cm with a volume capacity of 100 ml. This extraction machine was completed with two electrodes that each have a thickness of 10 mm. The performance of extraction machines using ohmic technology was analyzed by using various voltages of 20, 30, 40, 50, and 60 Volts/cm. The result showed that the voltage affected the electric current of the machine. The voltage of 60 Volts/cm was able to produce the largest average electric current of 5.28 A with the greatest electric current achievement of up to 6.21 A. The result showed that increasing the voltage during the extraction process reduced the time needed to reach the expected temperature. The fastest time was achieved in the voltage of 60 Volts/cm with an average time of 11.3 seconds. The increased voltage in the extraction treatment also affects the total anthocyanin produced. The highest total anthocyanin was obtained from a voltage gradient of 60 Volts/cm with a value of 288.014 mg/L and a yield of 14.4%.

ABSTRAK
Salah satu proses penting dalam memperoleh antosianin sebagai pewarna alami adalah dengan menggunakan teknologi ekstraksi. Penelitian ini bertujuan untuk mengetahui performansi mesin ektraksi dengan menggunakan teknologi ohmic untuk menghasilkan antosianin. Pada penelitian ini menggunakan teknologi ohmic heating dengan komponen penyusun berupa pipa lubric dengan bentuk tabung yang memiliki diameter 6 cm, panjang 5.5 cm, dan kapasitas 100 ml. Di dalam ohmic heating disisipi dua elektroda yang masing-masing memiliki tebal 10 mm. Uji performansi mesin ekstraksi dengan teknologi ohmic menggunakan perlakuan tegangan atau gradien voltase dengan nilai 20, 30, 40, 50, dan 60

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Volt/cm. Hasil penelitian menunjukkan bahwa semakin besar gradien voltase berpengaruh terhadap peningkatan arus yang dihasilkan. Pada tegangan 330 Volt atau pada gradien voltase 60 Volt/cm menghasilkan rata-rata arus terbesar yakni 5.28 A dengan pencapaian arus terbesar hingga 6.21 A. Selain itu pada penelitian ini didapatkan hasil bahwa dengan peningkatan tegangan akan mempersingkat waktu untuk mencapai suhu yang diinginkan. Waktu tercepat terdapat pada perlakuan gradien voltase 60 Volt/cm dengan waktu rata-rata 11.3 detik. Peningkatan tegangan pada perlakuan ekstraksi juga berpengaruh terhadap total antosianin yang dihasilkan. Total antosianin tertinggi didapatkan dari gradien voltase 60 Volt/cm dengan nilai 288.014 mg/L. Hasil rendemen menunjukkan bahwa peningkatan tegangan akan meningkatkan nilai rendemen. Rendemen terbesar dihasilkan dari gradien voltase 60 Volt/cm dengan besar rendemen 14.4%.

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1. Introduction

Indonesia's diverse food products have led to a rapid growth of the food industry in the country. Despite this, the food industry in Indonesia continues to use harmful chemicals, including synthetic coloring. The long-term and repeated use of synthetic dyes can have serious health implications, such as causing hyperactivity in children, allergies, chest tightness, and even activating cancer cells in the body [1], [2]. Rhodamine is a commonly used synthetic dye. The usage of natural dyes is currently increasing. This is because natural dyes are considered a safe source of vitamins suitable for long-term consumption [3], [4]. Anthocyanin is one of the commonly employed natural colorants. Anthocyanins are pigments found in plants that appear in shades of red, purple, and blue.

Extraction is a crucial process in obtaining anthocyanins as natural colorants. The extraction process is defined as the use of solvents to separate materials from the mixture [5]-[7]. The current technology development to aid in the extraction process is the utilization of ohmic heating. Ohmic heating technology employs the heat generated from the resistance of a material to produce internal heat energy in the material [2], [8], [9]. The potential of using ohmic heating arises due to the rapid generation of heat, resulting in minimal pigment degradation, and high efficiency [10], [11]. Furthermore, as revealed by [12], ohmic heating distributes uniformly within food because the material is directly subjected to a combination of electric current and voltage. Other advantages of ohmic heating include minimizing the use of solvents [13] and minimizing the degradation of pigments and vitamins [11]. Previous research has used ohmic heating to produce carotenoid and chlorophyll colors from egg yolk and spinach [4].

Aim of this research was to determine the effect of voltage variation or voltage gradient in ohmic heating on the anthocyanin extraction process from red spinach due to the high anthocyanin content of red spinach (0.95-2.21 mg/g) [4]. The variation of the voltage gradient, which is the ratio between the potential difference and the electrode in this study, are 20, 30, 40, 50 and 60 Volts/cm. The application of electrodes in the ohmic heating system is as an electric field generator during the heating process. Therefore, the value of the voltage gradient is the amount of potential difference (voltage) used per unit length or distance of two electrodes. The voltage gradient is expected to produce colored pigments with increased anthocyanin yield.

2. Research Methods

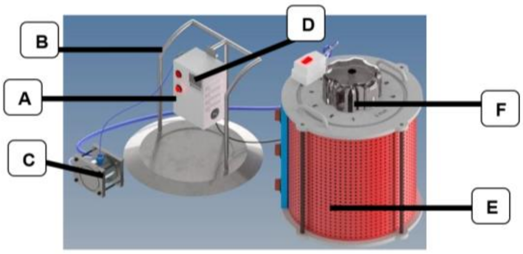
Materials

The equipment employed for this study includes an ohmic heating reactor, temperature detector, control panel, scales, clampmeter, transformer, UV-Vis spectrophotometer, vacuum rotary evaporator, oven, thermometer, AVO-meter, erlenmeyer flask, test tube, pipette, beaker, funnel and wattmeter. The study employed the following materials: red spinach (*Althernanthera amoena Voss*), seal, 70% alcohol, pH 7 distilled water, and tissue.

Preparation of Samples

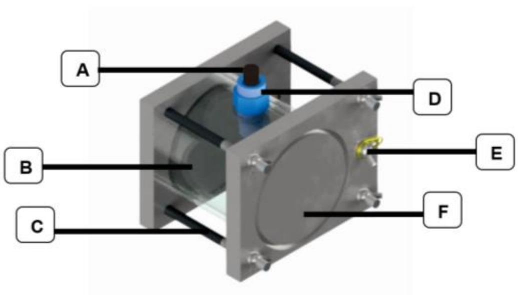
The red spinach used was the red leaf variety purchased from Superindo in Malang. This study utilized both fresh and dried spinach. The red spinach used was in the form of dried powder. The red spinach, to be used as a sample, was dried at 75 °C for 40 minutes using an infrared oven. After drying, the red spinach was mashed for 2 minutes in a QBL-311 platinum type dry blender, resulting in a dried red spinach powder 500 µm in size.

Design of Ohmic Heating



A. Box control
B. Buffer
C. Ohmic tube
D. Control and display of temperature
E. Step-up and step-down transformer
F. Voltage control

(a)



A. Temperature Sensor
B. Ohmic reactor
C. Electrode connecting bolts
D. Input and output hole
E. Power source connector
F. Electrode

(b)

Figure 1. Design of; (a) ohmic heating technology components, (b) ohmic heating device

The design of the ohmic heating system was created using AutoCAD graphic design software. The component employs ohmic heating technology and comprises a lubricant pipe in the shape of a tube, with a diameter of 6 cm, length of 5.5 cm, and a capacity of 100 ml. Within the ohmic heating, two 10 mm-thick electrodes are inserted. Furthermore, it consists of three primary parts: the support, ohmic heating tube, and control panel.

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Flowchart of Implementation Method

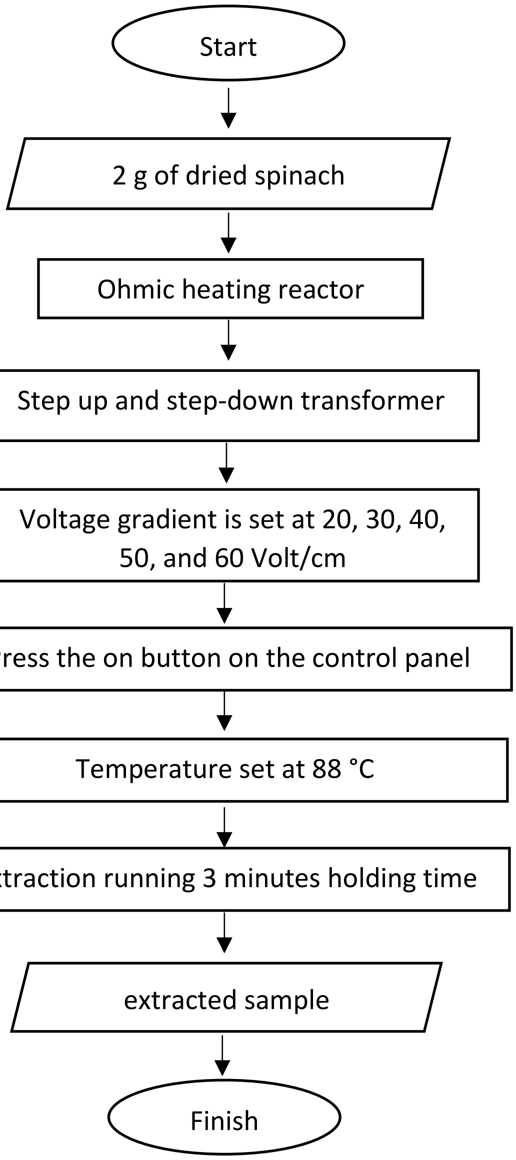

Figure 2. Extraction process with ohmic heating

The study utilized a voltage gradient ranging from 20 V/cm to 60 V/cm. Each treatment was replicated thrice. Two grams of red spinach were weighed with 50 ml solvent. The heating process utilizing ohmic heating involves a temperature of 88 °C and a holding time of 3 minutes [15]. The holding time refers to the duration after the temperature reaches the setting point. The control sample was extracted using the maceration method at a temperature of 25 °C for a period of 7 hours. **Table 1** displays the research design that will be implemented.

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Table 1. Voltage gradient variation of red spinach extraction

Voltage gradient (V/cm)	Replication		
	I	II	III
V1	V1U1	V1U2	V1U3
V2	V2U1	V2U2	V2U3
V3	V3U1	V3U2	V3U3
V4	V4U1	V4U2	V4U3
V5	V5U1	V5U2	V5U3

Voltage gradient:
V1 : Voltage gradient 20 Volt/cm
V2 : Voltage gradient 30 Volt/cm
V3 : Voltage gradient 40 Volt/cm
V4 : Voltage gradient 50 Volt/cm
V5 : Voltage gradient 60 Volt/cm

Experimental Procedure

Absorbance values of each sample were determined using a UV-Vis spectrophotometer. To prepare the sample for testing, the water content reduced using a vacuum rotary evaporator. The sample was evaporated at temperature of 50 °C with a rotation speed of 50 rpm and a pressure of 55 mbar. The evaporation process resulted in a thick extract of the sample. The sample's absorbance value was obtained through testing using a UV-Vis Spectrophotometer. The maximum wavelength utilized was 525 nm. Dilutions of 10 times, 25 times, and 100 times were performed on the sample. The absorbance value of the sample was obtained to determine the total anthocyanins of the tested sample [15]. Following the obtainment of the absorbance value of a specific wavelength, the total value of anthocyanin can be calculated using the subsequent **Equation 1** [15]:

$$Total\ anthocyanins\ \left(\frac{mg}{L}\right) = \frac{absorbance\ x\ DF\ x\ 1000\ mg}{55.9\ x\ 1\ L} \quad (1)$$

Yield Value Determination

Yield calculation used to determine the percentage of anthocyanin content produced from red spinach. The yield resulting from extraction calculated based on the ratio of the weight of the extract to the weight of the dried red spinach used. The yield value of each sample was determined using the **Equation 2** [15]:

$$Yield\ (\%) = \frac{Weight\ of\ dry\ extract}{weight\ of\ sample\ used} x100\% \quad (2)$$

3. Results and Discussion

Ohmic Heating Circuit Description

The experiment employs an ohmic heating component that includes an ohmic reactor, temperature sensor, temperature controller, pipes, electrodes and a support stative. This research introduces a voltage gradient, which is achieved through the use of transformers to either increase or decrease voltage. The main container of the anthocyanin extraction process is the ohmic reactor, which is made of glass and serves as its container. Glass is a suitable container for the reactor because it offers high temperature resistance, good insulation, is economical and easy to clean. The ohmic reactor has a diameter of 6 cm, 5.5 cm in length, and a capacity of 100

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ml. Food-grade stainless steel electrodes, which are not easily corroded, are placed at the end of the ohmic reactor. The electrodes have a thickness of 10 mm and a diameter of 6.25 cm.

In addition, the electrode side is perforated and fitted with ear bolts to connect the connector cable as a power source. A temperature sensor is placed on the tube by creating a hole with a 1 cm diameter. The temperature detector affixed to the tube is a type K thermocouple that operates within a temperature range up to 200 °C. A temperature detector connected to an Omron temperature controller is used to regulate the extraction temperature in the tube. Transformers that can step up or step down the voltage are used to increase or decrease the voltage. The transformer is capable of increasing the voltage by up to 1 kV.

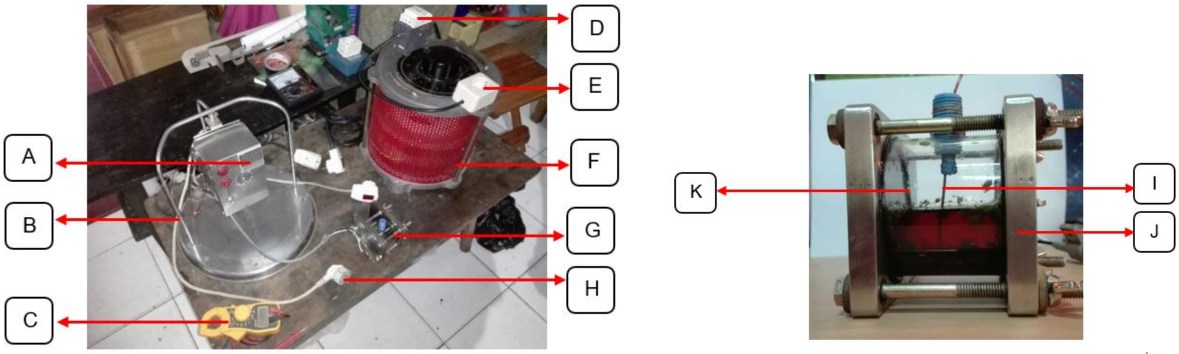

Figure 3. (a) ohmic heating circuit for extraction process, (b) ohmic heating reactor

Description:
A. Temperature Control
B. Buffer
C. Clampmeter
D. Relay
E. Transformer output terminal
F. Transformer
G. Ohmic heating reactor
H. Power source cable
I. Thermocouple (temperature detector)
J. Electrode
K. Glass lubrication pipe

Selection of the Treatment of Raw Materials of Red Spinach

The sample was obtained by using dried red spinach as the raw material. The red spinach samples were dried with an infrared oven at 75 °C for 40 minutes. The first criterion is based on the colour characteristics observed in the results of the ohmic heating extraction tests performed with dried and fresh spinach samples at the same ratio. **Figure 4** shows that the sample prepared using the dry material has a darker shade of red, indicating its higher concentration compared to the fresh spinach sample. The study suggests that the use of dry ingredients is more effective than fresh red spinach, according to the results obtained.

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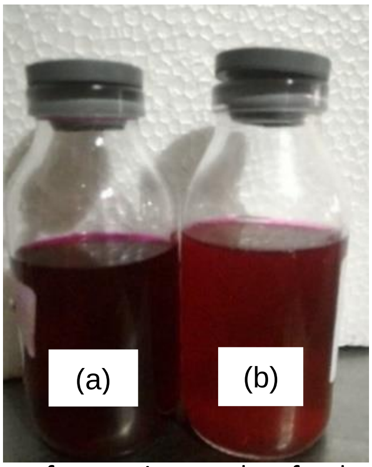

Figure 4. Comparison of extraction results of red spinach; (a) dried, (b) fresh

The determination of the dry raw materials is also based on finding the duration required to the setting temperature using ohmic heating. On average, samples with fresh raw materials reached the temperature setting in 142.5 ± 1.5 s. On the other hand, the samples with dry raw materials reached the temperature setting much faster, taking on average only 80 ± 2 s. The duration is a determining factor for the effectiveness and efficiency of the extraction process. Some of the results indicated that the raw material used was dried red spinach. Multiple studies suggest that using dry powdered material is more optimal than fresh raw materials. [2] found that oven-dried raw materials yield more anthocyanin than fresh raw materials. This is because the larger surface area of the dry powder enables the solvent to extract more efficiently.

The Impact of Voltage Gradient on Temperature and during the Extraction Process

In order to measure the electric in the circuit, a clampmeter was used, and each treatment was repeated five times. The calculation of the current value in this experiment includes the initial current value before the electric current begins to flow in the circuit and the final electric current value once the target temperature (setting point) is achieved at 88 °C. Temperature measurement was recorded through the temperature detector connected to the control panel display. The initial temperature of the material before entering the ohmic heating tube was 25 °C, as measured in this experiment.

The experiment used five voltage gradients, i.e. 20, 30, 40, 50 and 60 volts/cm. The extraction process used a temperature setting point of 88 °C. In the first experiment, 110 volts or a voltage gradient of 20 Volts/cm was used. At a voltage gradient of 20 Volts/cm, the average electric current recorded was 2.14 A. The material had average electric current recordings of 2.25, 3.41, 4.57, and 6.21 A at respective voltage gradients of 30, 40, 50, and 60 Volts/cm. The graph shows the correlation between temperature increase and electric current when compared against the voltage gradient.

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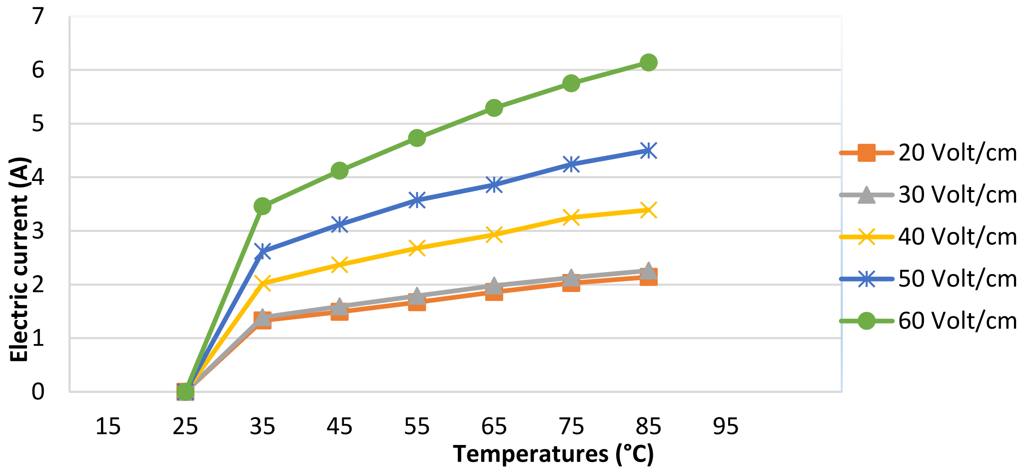

Figure 5. Temperature and electric current rate compared to voltage gradient

The temperature and electric current rate of increase against the voltage gradient can be seen in **Figure 5**. The findings indicate that the rise in electric current is directly proportional to the increase in the extraction temperature. This is due to the decrease in the resistance value in red spinach. Raising the voltage will expedite the electro-osmosis process as the resistance value falls and the thermal conductivity value of red spinach increases. Electric current consumption increases provided that temperature increase occurs rapidly. This can occur because a higher temperature requires more energy to maintain a stable temperature. Moreover, lowering the resistance of the material can enhance its conductivity and thus improve its electrical efficiency.
The greater concentration of ions dissolved in red spinach enhances the electric current flow in the material. It leads to a decrease in resistance value by reducing material thickness which further promotes the electric current flow in the material. This study is consistent with [14] research which suggests that higher conductivity in the material leads to an upsurge in the temperature, thereby making the heating process more efficient.

The Impact Of Voltage and Temperature on The Extraction Time

During the extraction process, the temperature increase is gauged via a thermocouple temperature sensor, while the extraction time is determined with the aid of a stopwatch. The extraction time is assessed during the reaction process until the ultimate product is successfully manufactured. Accurately measuring time is important for controlling product quality and determining production process efficiency. As such, the equipment and instrumentation used must be capable of measuring time with high accuracy and precision. The following graph displays the temperature increase plotted against time. The obtained data indicates a correlation between time and temperature, with the temperature value increasing along with time.
The difference in voltage directly affects the time taken to reach the temperature setting point. In the first experiment, with a voltage gradient of 20 Volts/cm, the time taken to reach the temperature setting point at 88 °C was 90 seconds. In the second experiment, with a voltage gradient of 30 Volts/cm, it took 63 seconds to reach the temperature setting point. In the third experiment, with a voltage gradient of 40 Volts/cm, the temperature setting point was reached in 26 seconds. A high voltage gradient of 50 volts per centimetre was used, and it took 21 seconds to reach the set temperature. The last experiment was conducted with a higher voltage gradient of 60 volts per centimetre, which took 13 seconds to reach the set temperature. It can be observed that the voltage gradient of 60 volts per centimetre can achieve the fastest temperature setting point. Conversely, it takes a longer duration for the voltage gradient of 20 volts per centimetre to reach the temperature setting point.

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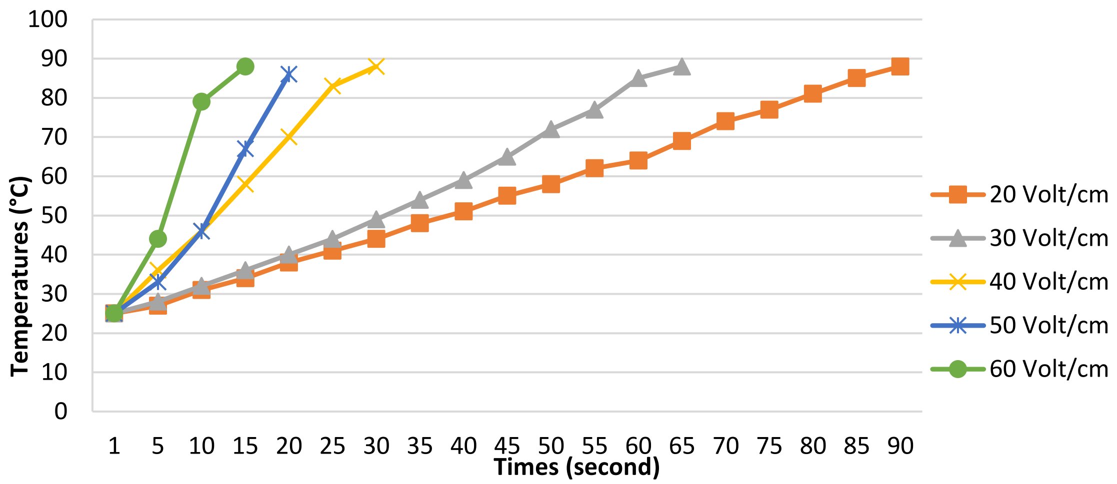

Figure 6. Comparison of temperature to time

According to the experimental results, a higher voltage gradient (Volt/cm) leads to a quicker attainment of the temperature set point. This corroborates [5] research indicating that a stronger voltage gradient during the extraction process results in a faster heating rate. With an increase in the voltage gradient, the heating produced per unit of time also increases. Consequently, the heating occurs faster and, as a result, the time taken to attain a certain temperature decrease. [6] stated that the improvement in the process per unit time is a result of the electric current flowing through the material that has a specific composition, resistance value, and material conductivity. An increase in the voltage gradient would cause an increase in the current flowing through the material, thus reducing the time taken to attain the desired temperature. Employing high potential differences would move ions through the cell wall membrane, resulting in increased conductivity of the material. As a result, the efficiency of heating would increase, reducing the time required to attain the desired temperature. An increase in voltage gradient intensifies the electro-osmosis process, thereby accelerating the rate of temperature rise. It is evident that using high voltage gradient values enhances the efficiency of the ohmic heating technology in the extraction process, as the temperature setting point is attained faster.

The total Anthocyanin Content Was Measured Based on Variation in Voltage Gradient (Volts/cm)

Anthocyanins are water-soluble pigments commonly found in fruits and flowers. These pigments can give materials red, purple, and blue. The anthocyanin content that is successfully extracted from the material is one of the parameters of the extraction result. Anthocyanin content can be determined by using the Uv-Vis spectrophotometric method, which involves determining the absorbance value of the tested sample. The sample obtained via the extraction process utilising ohmic heating appears red in colour. The anthocyanin content is calculated for the sample by measuring the maximum wavelength value of 525 nm after 25-fold dilution.

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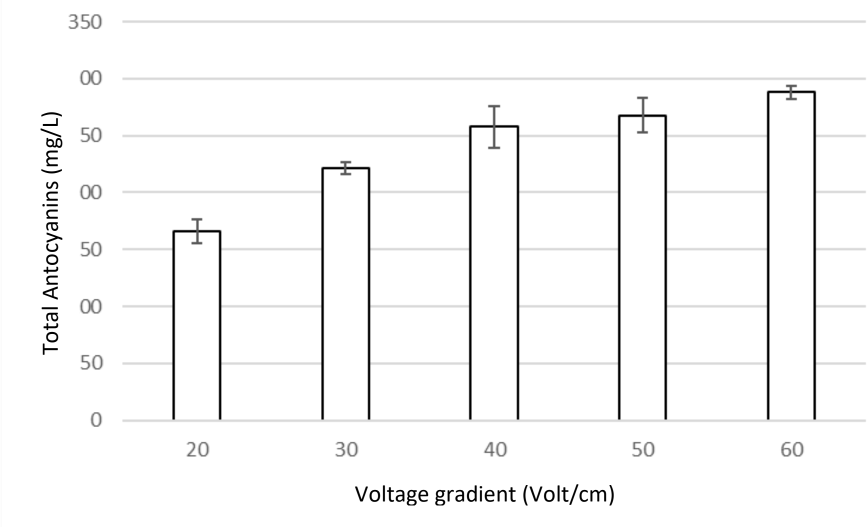

Figure 7. Relationship of total anthocyanins with voltage gradient

Anthocyanin content was initially determined using samples extracted through a 20 Volts/cm voltage gradient. The average total anthocyanin content was calculated from three replicates, with a value of 165.47 ± 10.51 mg/L. The total anthocyanin content obtained at a voltage gradient of 20 Volts/cm was the lowest. Additionally, when using a 30 Volts/cm voltage gradient, the average total anthocyanin content obtained through three replicates was 221.38 ± 5.68 mg/L. The third analysis was performed using a voltage gradient of 40 Volts/cm. The average total anthocyanin content value was 257.60 ± 18.56 mg/L, as per the calculation results. Moreover, it was conducted using a voltage gradient of 50 Volts/cm. The sample's mean total anthocyanin content value was 267.88 ± 15.44 mg/L, according to the calculation results. The most recent analysis was performed on samples extracted using an electric field strength of 60 V/cm. The average value obtained for the total anthocyanin content was 288.01 ± 5.53 mg/L.

When extracting red spinach, a higher voltage gradient leads to the release of more pigments, ultimately resulting in an increase in total anthocyanin value. This happens because a higher voltage gradient leads to an increase in the amount of anthocyanin pigment being released from the red spinach cell wall. As described above, an increase in the voltage gradient results in a higher extraction yield of the pigments from the red spinach. According to the research conducted by [2], electro-osmosis occurs during ohmic heating and is dependent on the magnitude of the potential difference applied to the heated material. As a result, the electro-osmosis effect will induce the opening of the cell wall in the form of electroporation. The effect is to amplify the pigment released from the cellular tissue. Past studies researched the incidence of electroporation or development of pores in the cell membrane that happens in an electric field. This increase in permeability makes the cell wall more permeable [13], [15].

Value of the Extraction Yield

The yield is a crucial factor for evaluating the efficiency of the extraction process. The yield calculation involves determining the amount of anthocyanin content that was successfully extracted from the red spinach by dividing the mass of the extract produced by the mass of dried red spinach used. Therefore, the yield may provide an indication of the efficiency of the extraction process and the quantity of anthocyanins that were extracted successfully from the raw material. To determine the yield, the average of three test results was calculated.

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The control sample was obtained through maceration extraction method by replicating three times at 25 °C for 7 hours. The average yield of three replicates of the control sample was recorded as 9%. Samples with a 20 Volts/cm voltage gradient had the smallest yield, with an average of 9.3 ± 0.51%. An average yield value of 11.05 ± 0.74% was obtained at a 30 volts/cm voltage gradient. The average yield value was 12.90 ± 0.63% at a voltage gradient of 40 Volts/cm. A voltage gradient of 50 Volts/cm resulted in an average yield value of 13.44 ± 0.33%. The largest voltage gradient, 60 Volts/cm, resulted in an average yield value of 14.4 ± 0.56%. The sample with a voltage gradient of 60 Volts/cm recorded the highest average yield value among other samples.

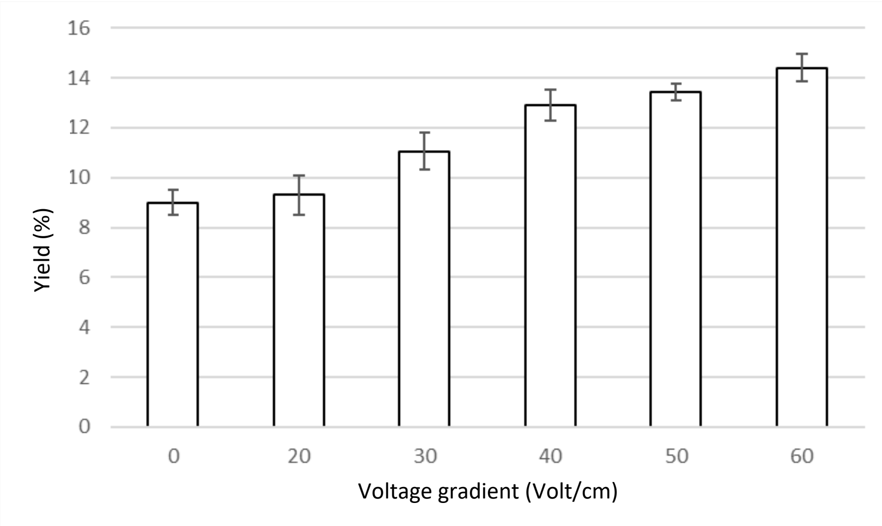

Figure 8. Comparison of yield with voltage gradient

Based on the explanation above, it is evident that the yield value proportionally with the increase in the applied electric field strength. Some studies have revealed that a voltage gradient at a certain level can enhance the release of the material's cell wall content. The content is released due to increased cell wall permeability. According to reference [16], increased permeability of the cell wall has a constructive impact on the reaction process, diffusion rate of components through the cell wall, extract yield of constituents and liquids from the cell, and drying rate. This is supported by [2], which suggests that consistent exposure to an electric field increases the permeability of the material cell membrane. Electricity-based heating methods, like ohmic heating, can facilitate the extraction process compared to non-electric methods. This is because electrical heating increases the materials' conductivity and accelerates the extraction process. Ohmic heating involves passing an electric current through the raw material, leading to direct heating and thus increasing the efficiency of extraction. As such, the use of electrical heating methods, such as ohmic heating, in the extraction process can achieve better and more efficient outcomes compared to processes conducted without electrical heating.

4. Conclusion

The research concludes that extraction using ohmic heating technology with dried red spinach raw materials is more optimal than with fresh materials. Increasing the voltage gradient leads to higher current production. The largest average electric current of 5.28 A is produced by the voltage treatment of 330 Volts or at a voltage gradient of 60 Volts/cm. The largest electric current achieved amounts to 6.21 A. The higher the voltage used in the extraction process, the less time is required to reach the target temperature. The treatment with a voltage gradient of 60 Volt/cm has the shortest time, with an average of 11.3 seconds. The total anthocyanin production

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is affected by increasing the voltage during extraction treatment. The voltage gradient of 60 volt/cm produced the highest amount of total anthocyanin of 288.014 mg/L. The yield value increases with the increase in voltage treatment. A yield of 14.4% was obtained using an electric field strength of 60 Volts/cm, indicating the highest yield. Thus, using a voltage gradient of 60 Volts/cm is the optimal treatment in this study.

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