Innovation Of Propolis Extraction Machine Based On Vacuum Resistive Heating

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Abstract. In herbal medicine production, extraction technology is an important process because it determines the quality. The extraction of propolis is limited to conventional maceration method which the process is too long. New technology called vacuum resistive heating extraction is technology that utilizes electric current combine with vacuum condition, it has been applied to Makassar propolis extraction, dehydration, evaporation and distillation. This study used method as variations. The extraction process was carried out 20 minutes in two stages. The first process was at 16.6 KPa, 100V and 58 °C using water solvent. While the second process was using 70% ethanol solvent at 16.6 KPa, 220V, and 37 °C. The voltage gradient used in energy consumption analysis is 40 V/cm and 80 V/cm. The power delivered and temperature rate were analysed using 25V/cm, 30 V/cm, and 35V/cm. The results showed that the extraction machine ran well where the electric field affects heat rate of the material. Energy consumption in the process was 0.4225 kWh/L. The highest total phenol and flavonoid in VRH method were 45.72 mg GAE/g and 15.19 mg QE/g whereas higher than maceration method. Vacuum resistive heating as extraction machine is a promising way for aseptically producing herbal medicine especially propolis.

1. Introduction

Herbal medicine has played an important role in life since time immemorial. The various benefits and sources of herbal medicine found from nature have succeeded in bringing herbal medicine into the community's choice in addition to hospital treatment. One of the herbal medicines known to many people is propolis. Propolis is a resin collected by bees from plant sap and mixed with bee enzymes with phenol and flavonoid content as a source of antioxidants [1]. In herbal medicine production, extraction technology continues to develop, one of which is ohmic technology. Ohmic heating basically applies contact between foodstuffs with several electrodes that have a difference in potential or voltage. To produce heat, food must have electrical conductivity. The ohmic heater
construction consists of a current source and a reactor that is inserted with an electrode. Cell vibration causes friction and dissipation in the form of heat [3]. Ohmic heating is now receiving attention from the food industry because it is considered an alternative to indirect heating methods for food processing [4]. Existing applications for Ohmic heating include blanching, thawing, on-line detection of starch gelatinization, fermentation, exfoliation, evaporation, dehydration, fermentation and extraction. The extraction using ohmic heating takes a shorter time than conventional extraction. This technology has advantages including a fast process that reduces the damage to nutrients and bioactive substances, including flavonoids [5], increases the efficiency of raw materials so that it saves, and has an energy efficiency exceeding 90% [6]. The content of materials that are sensitive to heat makes ohmic transform again with the innovation of vacuum resistive heating which is able to heat materials at low temperatures. In vacuum condition, it has been applied to dehydration, evaporation and distillation. The presence of vacuum technology will prevent the usual oxidation reactions such as lipid oxidation, oxidative browning loss, loss of pigment, certain vitamins etc.), to prevent the product from overheating, to increase the heat transfer rate, and to avoid heat damage to products that are highly susceptible to heat [7].

Based on these problems, there emerged innovative tools in the processing of herbal medicines, especially propolis with a short time and competitive quality to be applied in industry, namely using the vacuum resistive heating method. The existence of processing of propolis with vacuum ohmic technology is expected to optimize the production process with sustainable bioactive compounds. This study aims to design and analyse the result of vacuum resistive heating extraction machine design.

2. Methods

2.1 Experimental setup and procedures

Figure 1 shows a schematic diagram of experimental setup. In the ohmic tube there is a temperature sensor in the form of an Exposed Junction (Probe) Thermocouple type K, this type of sensor has a fast response to temperature changes, therefore, so it is selected in the tool. The temperature sensor is connected to a thermo control brand OMRON type E5CWL which functions to control the extraction temperature. This thermo control is related to a relay that functions to disconnect and connect the electric current so that the temperature is maintained at the desired temperature. The thermo control output is connected to the transformer input and the transformer output is connected to the ohmic heating reactor. The transformer serves to increase and decrease the electric voltage according to the treatment. The ohmic reactor is connected to a vacuum pump system jet with a black hose. The pressure gauge installed at the top of the glass chamber functions to measure the air pressure in a closed ohmic reactor. The pressure, temperature and power were recorded in a minute time interval. The extraction process was carried out 20 minutes in two stages. The first process was at a pressure of 16.6 KPa, 100V and 58 °C using water solvent. While the second process was using 70% ethanol-water solvent at 16.6 KPa, 220V, and 37 °C. The results were compared with propolis extracted by maceration method. All treatments had three replications were carried out after treatments for biochemical analysis.

![Figure 1 The schematic diagram of experimental setup.](image-url)
2.2 **Conventional heater**

Conventional heating process was performed using a laboratory hot plate (IKA; RH basic 2, Germany) that placed under Pyrex glass cell. The process is carried out at 50 °C for 24 hours.

2.3 **Quality parameters**

2.3.1 **Total phenol (TP)**

0.5 mL of propolis extract from each replicate was homogenized with ethanol 70% based on each concentration needed. TP concentration in the extracts was determined according to the Folin–Ciocalteu procedure [8], using gallic acid as the standard curve. Results were expressed as mg gallic acid per 1 gr of propolis.

2.3.2 **Total Flavonoid**

The total flavonoids of propolis extract were analysed using the spectrophotometric method with aluminium chloride reagent. The standard used is quercetin. The total flavonoids in the material were determined based on the absorbance value of the solution measured using UV-Vis Spectrophotometry [9].

2.3.3 **Heating rate and processing time**

The heating rate was calculated based on the temperature–time graph from when the temperature varied from 28 °C (as initial sample temperature) to beginning of evaporation [10].

2.3.4 **Energy consumption**

Energy consumption is measured by placing a power meter at a power outlet that supplies electricity to the ohmic heating circuit and does not include the electricity consumption of the water pump used in the vacuum process. The voltage gradient used is 40 V/cm and 80 V/cm or the input voltages used are 100V and 220V. The two voltage gradients are applied to Makassar propolis.

3. **Results and Discussion**

3.1 **Vacuum resistive heating model**

Vacuum Ohmic Heating is a method of processing food products by flowing electricity through the product so that internal energy generation occurs in foodstuffs where the process is carried out in a vacuum process. The effective design of the ohmic heating device depends on the electrical conductivity of the food [11]. The rate of ohmic heating is directly proportional to the square of the electric field strength and the electrical conductivity. The value of the electrical conductivity of food can change with the increase in temperature due to ohmic heating. The heating that occurs causes excitation of the food molecules which increase the movement of the molecules due to structural damage. Structural damage can be in the form of softening and damage to the cell walls. The electrical conductivity decreases with increasing temperature after the initiation of bubbles [12]. The decrease in electrical conductivity can be caused by an increase in the concentration of solids (due to water evaporation) which causes obstacles in the movement of food particles and solvents.

The basic principle of vacuum ohmic heating will produce a heating pattern inside and out and can reach a certain temperature faster because of the vacuum condition. The construction consists of a current source, a reactor, electrodes, and a vacuum system. Cell vibration results in friction and dissipation in the form of heat. The application of ohmic heating technology has been widely used in extraction and presents several desirable advantages over conventional methods, such as effective heating, fast energy transfer, saving time and low operating costs, no adverse changes in the chemical composition of a material, and this ohmic heating technology can be said as green technology or environmentally friendly technology.

The ohmic heating circuit used generally consists of an ohmic reactor, temperature sensor, temperature control, vacuum system and a transformer or transformer added as a treatment in this study. The ohmic reactor consists of an ohmic tube and a glass chamber which functions as a place for the...
extraction process to take place. Ohmic tube measuring 2 ½ stuck in with a T shape, with a length of 14 cm and height 9 cm is made of steel tubing food grade stainless steel with a capacity of 295 mL. The choice of this material is because stainless is quite good at conducting electricity and remains stable at high temperatures. In addition, food grade stainless steel aims to prevent the process tube from becoming corrosive so it is safe to use for processing food for consumption. The ohmic reactor electrodes are stainless steel pipes and rods that are placed on the shaft of the pipe which runs across the radius of the pipe as the distance between the electrodes. On each electrode there is a threaded bolt that serves to connect the connector cable with the power source. Furthermore, the glass chamber made from a 500 mL flask which has been modified is connected with the top holes section ohmic tube so that capacity can reach 800 mL tool. The ohmic heating reactor can be seen in Figure 2.

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3.2 Temperature rise rate and power delivered

Boiling time is the time needed to produce distillate, measured from the time the tool is first turned on until the first drop is obtained in the distillate container, namely a separating funnel. Based on the test of variance, it is known that the treatment given does not give a significant difference to the duration of boiling, both from the stress factor and the salt concentration factor. This result is different from the literature, where with an increase in stress, the time needed to increase the temperature of the material will be shorter. The ohmic heating time depends on the voltage gradient used [13].

In another research, their research on ohmic heating of pomegranate juice revealed that the formation of bubbles occurs when the temperature of the material reaches 81°C. The formation of bubbles that occurs when the temperature approaches the boiling point affects the power delivered to the material. The following is a graph of the power during the boiling process.
Figure 3. shows in this series of tools, the material that is in the main shell will first experience heating so that at a certain temperature it will reach vapor pressure. In this condition the material will experience convection heat transfer. At that temperature, ohmic heating also produces bubbles as an effect of providing an electric current. These gas bubbles are the result of boiling water due to localized high current density or the formation of by-products from various oxidation / reduction reactions (such
as \( \text{H}_2 \) or \( \text{O}_2 \) gas) [14]. However, at higher mains voltage the resulting bubbles increase. With the increase in the air bubbles, it will push some of the material on the surface towards the condenser. The performance of the ohmic heating process depends on the rate of heat generation in the system, the electrical conductivity of the food, the strength of the electric field, the residence time and the method by which food flows through the system [15].

### 3.3 Energy requirements

This study measured the energy consumption of the ohmic heating device during the propolis extraction process. Energy consumption in the extraction process using ohmic heating on propolis has an average range between 0.0264 - 0.08423 kWh per 200 ml extraction. Energy consumption in the extraction process using ohmic heating on propolis can be seen in Figure 4.

![Graph of Effect of Gradient Voltage on Extraction Energy Consumption](image)

**Figure 4.** Graph of Effect of Gradient Voltage on Extraction Energy Consumption

Figure 4 shows the difference in energy consumption at the two stages of propolis extraction due to differences in voltage gradient. These data indicate that the average energy consumption at a voltage gradient of 40V/cm with distillate water solvent is higher than the average energy consumption at a voltage gradient of 80V/cm with 70% ethanol solvent. The results of analysis of variance (ANOVA) showed that the difference in voltage gradient at each stage had a significantly different effect \((P \leq 0.05)\) on energy consumption in the extraction process, then a further 5% DMRT test was carried out. Further tests with DMRT were carried out to find out the real difference between propolis and different regions of origin. The average effect of voltage gradient on energy consumption of propolis extraction can be seen in Table 1.

| Gradien Voltage (V/cm) | Energy Consumption (kWh) |
|------------------------|--------------------------|
| 40 (Stage 1)           | 0.0842²                 |
| 80 (Stage 2)           | 0.0264²                 |

**Table 1.** Average Effect of Gradient Voltage on Extraction Energy Consumption

Information:  
1) Each data is the mean of 3 replications  
2) Different notations show significant differences in the DMRT test \((\alpha = 0.05)\)
The energy consumption of the propolis extraction process between stage one and stage two with different solvent has different notation so that it shows a significant difference. Although the distilled water voltage gradient is smaller (40 V / cm) than the ethanol voltage gradient (80V / cm), the energy consumption of the first stage extraction process using distilled water is greater. Energy consumption in the process was 0.4225 kWh/L. Ohmic heating is a process in which the alternating electric current is passed through the material and can be used to generate heat in the product [16]. This technology works in the presence of the conductivity of the materials and solvents used due to the importance of ion movement in the process. The greater the intensity of the voltage gradient, the higher the electrical conductivity and the faster the heating rate [17]. The voltage gradient in ohmic heating is the ratio between the potential difference and the distance between the two electrodes. The electrodes on ohmic heating function as an electric field generator that is used during the process. Materials with low electrical conductivity such as ethanol-water mixture or a mixture of fermented alcohol requires the addition of extra electrolyte to improve conductivity [18]. Based on this, it is suspected that the difference in solvent in the extraction process is the trigger for the difference in energy requirements in the process. Water conductivity is greater than 70% ethanol. Conductivity is the main parameter in the heating rate of ohmic heating, which affects the extraction time. Increasing conductivity can be done by adding electrolytes to the process such as adding salt.

3.4 Total phenol and Total Flavonoid

Average total phenol extract of propolis vacuum method ohmic heating and maceration treatment as the control can be seen in Figure 5.

![Figure 5. Graph of Average Total Phenol of Propolis Extract](image)

Figure 5 shows the difference in the total phenol of propolis extract with different extraction method. Vacuum ohmic heating value are higher than total phenol of maceration extraction as a control. Total phenol in the vacuum ohmic heating method was 45.72 mg GAE / g while the maceration method was 24.21 mg GAE / g.

Furthermore, the total flavonoids of propolis extract with vacuum ohmic heating method and maceration treatment as a control can be seen in Figure 6.
Figure 6. Graph of Average Total Flavonoids from Propolis Extract

Based on Figure 6 regarding the average total flavonoids of propolis extract using vacuum ohmic heating method and maceration treatment as a control. Vacuum ohmic heating value are higher than total flavonoid of maceration extraction as a control. Total flavonoid in the vacuum ohmic heating method was 15.19 mg QE / g while the maceration method was 3.00 mg QE / g.

The resistive heating method result is the higher nutritional value compared to conventional heating because resistive heating is able to heat the material quickly and uniformly, its effect on the permeabilization of the cells of the material where the electric current in the cell membrane triggers electroporation. The existence of flavonoid compounds as one of the polyphenols can be better protected by the ohmic heating treatment. This is supported by several previous studies which stated that ohmic heating treatment can maintain bioactive compounds in the ingredients, namely in research on extracting polyphenols from red wine, extracting phytochemicals from potatoes, and extracting dyes from rice bran [19]. Ohmic heating applications with a voltage gradient below 100 V / cm can cause changes in the permeability of plant cell membranes, thus triggering an increase in the extraction yield of carotenoids, flavonoids and total polyphenols from plant tissue. Ohmic heating allows a decrease in the overall processing time by reducing heating time due to the fast heating rate. Shorter processing times play a role in reducing the damage to bioactive compounds, including heat sensitive flavonoids [20]. Vacuum conditions used to reduce the temperature required for a balanced state so that the boiling point is reached more quickly in the presence of increasing the rate of heat transfer. The vacuum ohmic heating method can prevent overheating of the product, avoid excessive heat damage to products that are very susceptible to thermal damage and prevent oxidation reactions (such as lipid oxidation, loss of certain vitamins, oxidative brown, loss of pigment).

4. Conclusion
Vacuum resistive heating as extraction machine is a promising way for aseptically producing herbal medicine especially propolis. Propolis that was extracted by resistive vacuum heating had higher phenol and flavonoid content than maceration method. Food processing that involves electricity is often used as alternative to other thermal processing because electricity increase extraction yields and preserve bioactive compounds. By this advantageous, this model is feasible to be developed with various variants.
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