Ginger (*Zingiber Officinale*): Drying to Encapsulation in Alginate-PVA Beads

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Abstract. Ginger is one of the most widely produced horticultural commodities from the spice and medicinal plant group compared to other commodities. Ginger can be used in the form of dry powder or the form of ginger essential oil. Ginger essential oil has properties: it is unstable and susceptible to oxidation and degradation in the presence of oxygen, light, metals, and high temperatures. Encapsulation is a solution to maintain the quality of red ginger essential oil. This study provides information about the drying process of red ginger with a rotary dryer, extraction kinetics using the soxhletation method, and encapsulation of red ginger essential oil. 1.5 kg of red ginger cut into cubes with dimensions of ± 4 mm^3. The pieces of red ginger were put into a rotary dryer which rotated at a speed of 19, 30, and 55 rpm. The dried ginger pieces were then mashed. The ginger powder was extracted in a socket at a temperature of 70 ^{o} C using n-Hexane as solvent. The resulting ginger essential oil was then encapsulated in Alginate-PVA beads. Drying with a rotary dryer was still less effective in drying red ginger with a maximum moisture content of 20%. The extraction process using the Soxhlet method with n-Hexan as a solvent resulted in a yield of 7.834% (extraction kinetic constant of 0.211). Ginger essential oil can be encapsulated in Alginate-PVA beads with an average diameter of 1.25 mm.

Keywords: Encapsulation · Ginger · Soxhlet Extraction · Rotary Dryer

1 Introduction

Ginger is one of the most widely produced horticultural commodities from the spice and medicinal plant group compared to other commodities. In the health sector, ginger treats various diseases such as fever, bronchitis, asthma, heart disease, intestinal worms, and gout and improves digestion [1]. The use of ginger rhizome as a raw material for medicines depends on the condition of the ginger rhizome. The active ingredients in the ginger rhizome can change if the quality of the ginger rhizome decreases due to the growth of sprouts, decomposition due to bacterial contamination, and fungal growth on the ginger rhizome. The quality of ginger material can be maintained by drying [2] and

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extracting ginger [3]. Red ginger, in its fresh form, has a hight water content, which is 82.75%. The high moisture content and large volume make it easily damaged, so it is often preserved by drying either in the form of slices or powder. A rack-type dryer is commonly used to dry ginger [3, 4]. However, drying using a rack-type dryer cannot be used at large capacities because the drying process runs steadily. This study used a rotary dryer to dry red ginger continuously. The advantages of the ginger extract are reduced transportation and storage costs, more hygiene because the storage area is well insulated, and the active components in the ginger extract can be standardized. Ginger essential oil is a ginger extraction product using organic solvents that can be used as agents of natural antioxidants, antimicrobials, and anticancer agents [5, 6]. Ginger essential oil is obtained by extracting ginger rhizomes using organic solvents. The solvents used were acetone, ethanol, dichloromethane, dichloroethane, and trichloroethane. Extraction methods commonly used to extract ginger are steam distillation, solvent fractionation, and soxhletation. The steam distillation method is easy to use because it does not require separation between the ginger essential oil produced and the solvent. It is cheaper and environmentally friendly than other methods [1]. However, this method has weaknesses. Some of them is that the yield of red ginger essential oil is small, about 0.2 - 1%, the volatile compound content is easy to disappear, and the increase in temperature causes part or all of the structure of ginger essential oil to be destroyed [7]. Lower extraction temperature conditions can be carried out using solvents with a lower boiling point than water, such as hexane, dichloromethane, ethyl acetate, methanol, as done by Wijaya et al. [8] using the solvent fractionation method. In this method, the ginger that has been blended is put into a sonicator with various types of solvents which is then followed by an evaporation process under vacuum conditions. However, the yield of ginger essential oil produced by the solvent fractionation method is small: 1.48%, 0.37%, 0.08%, and 0.01% using methanol, ethyl acetate, dichloromethane, and hexane as a solvent respectively. The soxhletation method using methanol as a solvent resulted in a relatively large yield of 2.62% [9]. Because the water content in methanol solvent is relatively high (4–2%), the water contained in methanol can cause damage to ginger essential oil because it was hydrolyzed by water [10]. This study used the solvent n-hexane because it did not contain water. In this study, the kinetics model of ginger extraction using the soxhlet method was studied to scale up the soxhlet method. Ginger essential oil is unstable and susceptible to oxidation and degradation in the presence of oxygen, light, metals, and high temperatures [11]. Microencapsulating ginger essential oil is a solution to this problem (Tour et al., 2011) [12]. Encapsulation is a technique of trapping a solid, liquid, and gas using a material [13]. The materials used to encapsulate red ginger essential oil were gum Arabic, maltodextrin, insulin [14], whey protein isolate [15], chitosan, Kappa-Carrageenan, and Alginate [16]. Alginate is a commonly used material for encapsulation because it has biocompatible properties, non-toxic, and inexpensive [17]. However, the capsule wall formed by this alginate compound has drawbacks: large porosity, large permeability, and poor mechanical properties. In this study, the walls of the microcapsules were formed using a mixture of alginate compounds and Poly Vinyl Alcohol (PVA) which were cross-linked with H_3BO_3; the purpose of this study is to provide information about the drying process of red ginger with a rotary dryer, extraction kinetics using the soxhletation method, and encapsulation of red ginger essential oil.

2 Method

2.1 Material

Red Ginger (Pasar Ciracas, Jakarta), n-Hexane (Merck Millipore), Sodium Alginate (Sigma Aldrich), PVA (Merck Millipore), $CaCl_2$ (Sigma Aldrick) dan H_3BO_3 (Merck Millipore).

2.2 Experiment Method

2.2.1 Dryer

1.5 kg of red ginger is cut into cubes with dimensions of $\pm$ 4 mm^3. Pieces of red ginger were put into a rotary dryer (type MC-DE/M100R/1-NO). This rotary dryer was set at a slope of 10°, the airflow rate was 2.2 cm^3s^{-1}, drying time was 2 h, and rotation speed is 19 rpm, 35 rpm, and 55 rpm. The dried red ginger was then weighed to calculate the evaporated water content.

2.2.2 Extraction

Ginger Extract Dried red ginger, finely ground to a powder. Weigh the sample of red ginger as much as 100 g. Put the sample into a soxhlet assembled with a condenser and a boiling flask. 250 ml of n-Hexane was put into a boiling flask. Each cycle of n-Hexan and Ginger Essential oil was separated by evaporation of the resulting n-Hexan. The weight of ginger essential oil produced was then weighed, and FTI-IR analysis was performed.

2.2.3 Encapsulation

Ginger essential oil Encapsulation with Alginate and PVA, one gram of Sodium Alginate and one gram of PVA were dissolved in 100 mL of water at 80 °C. Then 40 mL of ginger essential oil was mixed with 60 mL of Alginate – PVA solution. Ginger-Alginate-PVA oil solution was extruded into CaCl2 solution using a syringe pump. The ginger essential oil encapsulated in the formed alginate-PVA beads was filtered, analyzed for its structure by FTIR, and measured its diameter. Fifty Alginate-PVA beads were measured in diameter using a microscope [18].

2.3 Mathematical Model

2.3.1 First Order Model

Reaction Kinetics Extraction of oil from ginger using n-Hexane as a solvent did not involve a chemical reaction between the oil and the solvent. This study processed the research data using a first order model. Mass transfer balance on film layers [19]:

$$\frac{dm}{dt} = KA(C_s - C) \tag{1}$$

where m is the mass of ginger essential oil (g), K is the mass transfer coefficient (cm s^{-1}), C is the concentration of ginger essential oil in the bulk liquid (g cm^3), and Cs is the concentration of ginger essential oil on the surface of the ginger.

$$m = VC \tag{2}$$

where V is the volume of hexane (cm^3). In batch operation, the value of V is constant so that Eq. (1) becomes:

$$\frac{VdC}{dt} = KA(C_s - C) \tag{3}$$

$$\text{Jika } \frac{KA}{V} = k \tag{4}$$

where k is the extraction rate constant (s^{-1}), Eq. (4) becomes:

$$\frac{dC}{dt} = k(C_s - C) \tag{5}$$

The initial condition of Eq. (5) is when t = 0, C = 0, then the result of integration is obtained

$$\ln\left(\frac{C_S}{C_S - C}\right) = kt \tag{6}$$

To get the value of k then plot $\ln\left(\frac{C_S}{C_S - C}\right)$ vs t. Slope value equivalent with the value of k.

Equation (6) can be simplified to:

$$C = Cs(1 - e^{-kt}) \tag{7}$$

Power Index Model

The power index model can be seen in Eq. (8) [20].

$$\frac{dC}{dt} = k\,C^n \tag{8}$$

where n is the power index and not the order of the reaction, Eq. (8) is integrated with the initial condition when t = 0, then C = 0. Then get the result:

$$\ln C = \frac{1}{(1-n)}\ln[k(1-n)] + \frac{1}{1-n}\ln t \tag{9}$$

The value of n and the value of k are obtained by plotting ln t vs ln C. Slope value equivalent with the value of $\frac{1}{1-n}$ and intercept value equivalent with the value of

$$\frac{1}{(1-n)}\ln[k(1-n)] \tag{10}$$

Equation (6) can be simplified to:

$$C = (k(1-n)t)^{\frac{1}{1-n}} \tag{11}$$

3 Results

Where n is the power index, Eq. 7 is integrated with the initial condition when t = 0, then C = 0. Then get the result:3.1 Drying Red Ginger Drying is an essential factor in maintaining the quality of ginger so that it lasts a long time. The advantage of drying using a rotary dryer is that the process can run continuously. The results of drying red ginger at various rotational speeds of the rotary dryer can be seen in Table 1.

The speed of rotation affects the rate of evaporation of water. The faster the rotation, the more water evaporates; the faster the rotation, the faster the ginger date will be, as shown in Table 1. In this study, the rotary dryer was not effective enough in reducing the water content in ginger, where the water content of ginger is still below the SNI standard of 12% [21].

3.1 Red Ginger Essential Oil Extraction

The dried ginger was extracted with ginger essential oil using the soxhlet method. Extraction results can be seen in Table 2.

The concentration of extracted ginger essential oil is getting bigger and reaches the maximum value in the 30th cycle with a maximum concentration of 313 mg L^{-1}, or the resulting yield is 7.834%. The yield value produced in this study was much larger than

Table 1. Effect of Rotary Dryer Speed on percent Water Content in Ginger

Velocity (rpm)	Initial Weight (Kg)	Final Weight (Kg)	Evaporated Water (Kg)	Resident Time (Minute)	Water Content in Ginger (%)
19	1.5	0.519	0.981	150	20
35	1.5	0.712	0.788	120	33.1
55	1.5	0.798	0.702	100	38.8

Table 2. Yield of Ginger essential oil in Various Cycles

Cycles	Time (s)	Concentration (mg L^{-1})	Yield (%)
1	313	35.6	0.890
2	630	36.016	0.900
5	1562	62.712	1.567
10	3063	117.64	2.941
15	4139	228.596	5.714
20	6120	263.5648	6.589
25	8016	307.22	7.680
30	10700	313.364	7.834

the soxhletation method using methanol as a solvent, which was 2.62%. A kinetic study was studied in this study, where the concentration data is in Table 2. Curve of Regression to find the kinetic constant value, as shown in Figs. 1 and 2.

From the regression results, as shown in Table 3, the Power Index kinetic model can represent the data better than the first order, where the regression value (R^2) obtained is 0.941.

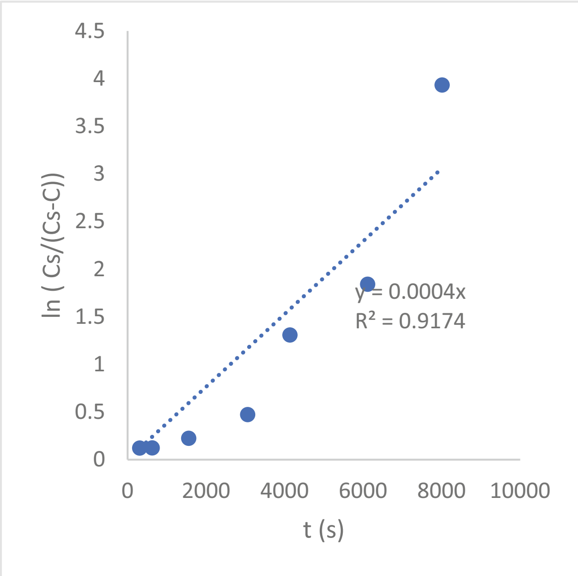

Fig. 1. Regression of First-order model

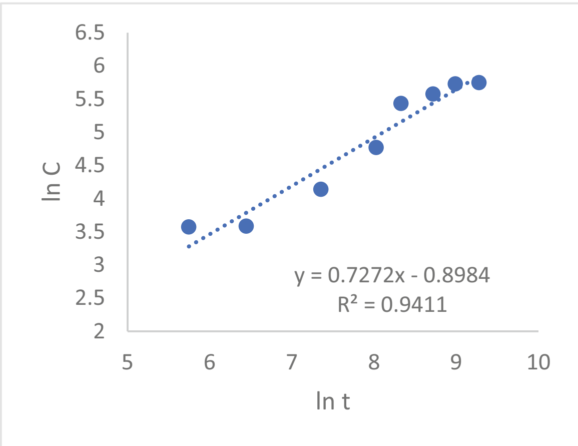

Fig. 2. Regression of power index model

Table 3. Value of Extraction Constant

Model	K	Order	R^2
First Order	1.375	1	0.917
Power Index	0.211	-0.375	0.941

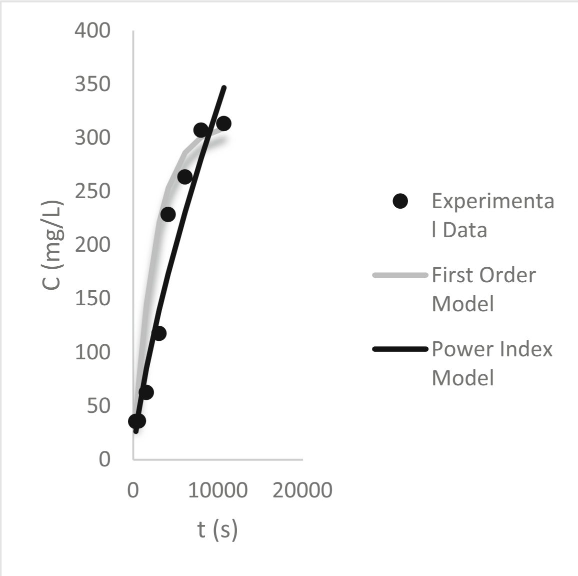

Fig. 3. Comparison of the Concentration of Simulation Results with Experimental Data

The constant values obtained were then used to simulate the concentration of ginger essential oil extracted at various times, as shown in Fig. 3.

3.2 Encapsulation

Red Ginger essential oil can be encapsulated in Alginate-PVA granules by extrusion method with $CaCl_2$ and H_3BO_3 crosslinkers (Fig. 4). The average diameter of the microcapsules produced is 1.25 mm.

Figure 5 shows ginger essential oil encapsulated in the pores of the Alginate-PVA granules. To ensure that the ginger essential oil is encapsulated. Pure ginger essential oil and ginger essential oil encapsulated in Alginate-PVA were analyzed by FT-IR, as shown in Fig. 6.

Wavelengths 2961.25 cm^{-1} and 2915.31 cm^{-1} indicate the Carboxylic acid (RCOOH) group which is a group found in ginger essential oil.

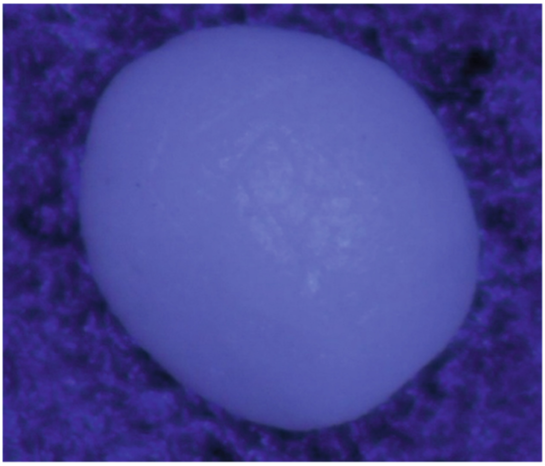

Fig. 4. Ginger Essential Oil Encapsulated in Alginate – PVA Beads

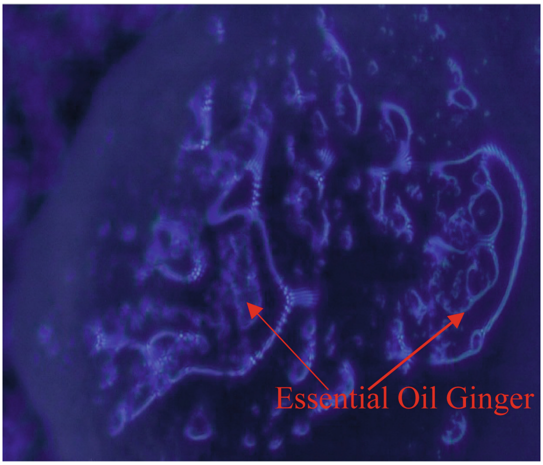

Fig. 5. Cross Section of Alginate – PVA Bead

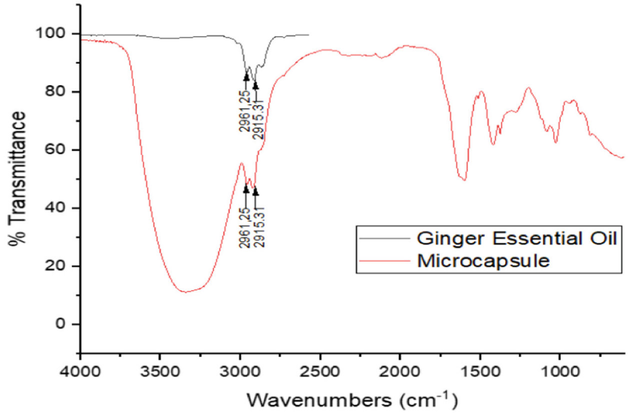

Fig. 6. FTIR spectra of ginger essential oil and ginger essential oil encapsulater in Algiante-PVA Bed

4 Conclusion

Drying with a rotary dryer is still less effective in drying red ginger with a maximum moisture content of 20%. The extraction process using the soxhlet method with n-Hexan as a solvent resulted in a yield of 7.834% (extraction kinetic constant of 0.211). Ginger essential oil can be encapsulated in Alginate-PVA beads with an average diameter of 1.25 mm.

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