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28th April 2021

Professor Dr. Son Radu
Chief Editor
Food Research
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Dear Sir/Madam,

Please find enclosed our **original research** manuscript entitled **"The Effect of Temperature on Drying Characteristic and Antioxidant Activities of Etlingera Elatior Jack".** This research is a collaboration of multidisciplinary between mechanical engineering on the drying and food technology on the antioxidant activity field.

a. This work has type **original research**
b. This work has a total of around 3633 **words, 28 references and 5 figures** (exclude reference and figures)
   - The novelty and significant findings on this paper are the drying characteristics of the leaves of the flower of Etlingera elatior Jack.
   - It also finds that the temperature difference of 70, 80 and 90 ^{0}C on the rotary drying did not have a significant effect on the antioxidant activity.

Potential Reviewer

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4. xxxxxxx

We hoped to hear from you soon and thanks for the time.

Sincerely,

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Cover letter prepared	√
Manuscript Submission Form filled	√
E-mail address for the corresponding author only	√
Full postal address, with no abbreviations	√
Manuscript compiled in a single MS Word processor file	√
Proof-read finalized version of the manuscript	√
Manuscript has been ‘spell-checked’ and ‘grammar-checked’	√
All figures and tables captioned	√
References are in the correct format for this Journal.	√

The effect of temperature on drying characteristic and antioxidant activities of etlingera elatior jack

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Abstract

The study was conducted to obtain the effect of drying temperature on a rotary type dryer for drying characteristics and antioxidant activity of etlingera elatior flowers. This study used a lab-scale rotary dryer which was a modification of the commercial oven heater from the market. The research design was a Randomized Block Design (RCBD) with one factor, namely the drying temperature, which consisted of four levels, namely 60, 70, 80 and 90 ^{o}C. The experiments were repeated six times. The results showed that drying at temperatures of 70, 80 and 90 ^{o}C had a time difference that was not too much when compared to temperatures of 60 ^{o}C. The drying rate decreased rapidly in the 200th minute, while the temperature of 60 ^{o}C, the decrease in the drying rate was slighter after the 380th minute. The different drying temperature had no significant effect on the DPPH free radical scavenging activity, but the total phenol content of samples at 60 ^{o}C was a significant difference to them in the other drying temperature. The higher drying temperature of samples, such as 70, 80 and 90 ^{o}C did not result in a significant difference in the total phenol content. It means that the rotary drying method was very effective in maintaining the total phenol content and antioxidant activity.

Keywords: *Etlingera elatior* Jack; Rotary drying; Temperature; Drying characteristics; Antioxidant activity

1. Introduction

Etlingera elatior Jack is a spice plant that is quite widespread in Indonesia. This herb plant can be found in several regions in Southeast Asia. *Etlingera elatior* Jack is known by different names in several areas such as *Kincung* in Medan, Rias in North Tapanuli, *Sambuang* in Minangkabau, *Kecicang* in Bali, *Siantan* in Malaya and *Daalaa* in Thailand. The etlingera includes the family of Zingiberaceae so that it is called ginger red or torch ginger. Etlingera is potential as a food flavoring (seasoning) (Noweg et al., 2003). The flowers are cooked, sauteed, or heated, as in fish processing (*pepes* fish, grilled fish, and fried). Fish cooked with *etlingera* will taste better and fishy aroma will be reduced. On the other side, this plant is efficacious as deodorizing body odor and bad breath (Hidayat and Hutapea, 1991), natural cosmetic ingredients (Chan et al., 2007). The profile of e*tlingera elatior* Jack is shown in Figure 1.

The potency of the etlingera flower is correlated with phytochemical compounds content. Naufalin et al. (2005) and Setiawati (2018) gave that etlingera flowers containing phytochemical compositions, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. Apak et al. (2007) state that compounds have the ability to scavenge DPPH free radicals based on their ability to donate hydrogen atoms. Subekti (1998) said that free radicals are molecules or atoms that have one or more unpaired electrons. These free radicals can be sourced from hydrogen atoms, oxygen molecules, or transition metal ions. Free radical compounds are very reactive and will look for lone pairs for stable conditions. Pilar de Torre et al. (2019) informed that antioxidant activity can be analyzed in vitro and in

vivo. Testing antioxidant activity based on the DPPH method is one of the in vitro methods that are widely used, simple, fast, and inexpensive. DPPH (1,1-diphenyl-2-picrylhydrasil) is a stable free radical that can be reduced in the presence of hydrogen transfer from other compounds. Antioxidant activity is characterized by a change in purple DPPH to yellow. Ohtani II et al. (2000) states that testing the antioxidant activity of the DPPH method uses positive control as a comparison to determine the antioxidant activity of samples, such as gallic acid, tocopherol, BHT, and vitamin C.

El-Sayed et al. (2015) and Aksay (2016) explain that secondary metabolites, such as phenolic and flavonoids, are potential sources of antioxidants. Marjoni et al. (2015) informed that flavonoids are the most abundant phenolic compounds found in many fruits and vegetables, which act as antidotes to hydroxyl radical and superoxide so that they can protect lipid membranes from oxidation. Liu et al. (2014) state that gallic acid or 3,4,5-trihydroxy benzoic acid is a potent antioxidant. The structure of gallic acid, which has 3 hydroxyl groups in the ortho position and the para of the carboxylic group, causes this compound to easily donate hydrogen atoms to form radicals that are stabilized by resonance.

Drying is a process to reduce the moisture content of a material to extend a self-life. Fresh vegetables, especially etlingera, usually have moisture contents of > 80% so that they can be classified as highly perishable commodities (Sagar and Kumar, 2010). Dried vegetables also can be easily produced and stored, transported at relatively low cost, reduced packing costs, and reduced spoilage microorganisms that responsible for the deterioration of fresh products (Santos and Silva, 2008). Many various drying techniques are studied, such as air-, freeze-, microwave-, vacuum-, oven- and sun-drying. Each method has certain specifications that influenced to a quality dried product or a dried material. Temperature application for each drying method can influence the higher losses or preserving of e.g. antioxidant compounds (Kamiloglu et al., 2016). Can et al. (2009) has been studied the effect of various drying types, such as oven drying, microwave, oven, sun drying, and freeze-drying to the antioxidant properties of etlingera elatior leaves. The results inform that freeze-drying will give a better total phenolic compared to the other types of drying.

Rotary drying is another drying method that has not been widely applied in food drying. Delele et al. (2015) informed that rotary dryers are capable of processing a variety of agricultural products with a wide range of thermo-physical and flow properties. This researcher also recommended that the use of rotary dryers can improve the efficiency of the drying process. Until now it is no information about using the effect of rotary drying to the antioxidant properties of the etlingera elatior flower.

In a drying process, the drying rate is divided into two groups, namely the constant rate and the falling rate. Constant rate drying is occurring at the beginning of drying, where the decrease in moisture content is held constant for a specified period. In this condition, the amount of moisture content in the material is still quite large. So the drying rate is only controlled by the rate of diffusion of moisture from the surface of the material to the surrounding air. After drying, the constant rate will be followed by the drying period of the falling rate. During this period, the drying rate will be controlled by the rate of diffusion of moisture from the inside to the surface of the material. This process will be continued until it reaches equilibrium or the moisture runs out in the material.

The temperature of the drying air strongly influences the drying rate. The higher the temperature, the more energy is used to evaporate moisture, and also the latent heat value will be smaller. Besides temperature, the surface area will also affect. The more surface area, the more mass transfer process will be achieved. A rotary dryer is a dryer where the material to be dried is put into a rotating drum. Hot air flows into the material to be dried. The material will experience more even heating because it is rotated so that it can speed up the drying time. This screening process is carried out continuously so that the

material will experience a reversal. For drying materials in the form of thin leaves and wide sizes, a rotary type dryer is very suitable for use because it has a stirring function.

Some studies have used rotary drying to preserving food material. Kaleemullah (2005) investigated about dried out of 10.5 kg chili with an initial moisture content of 330% (dry basis) in the temperature range of 50 – 65 ^{o}C, results in a moisture content of 10.0% (dry basis) at time 32, 27, 23 and 20 hours for 50, 55, 60 and 65 ^{0}C, respectively. Tarhana (2010) examined the drying of 15 kg peppermint using a rotary dryer for 15 - 18 hours and 12 – 15 hours. Drying can cause the leaves to darken, but the essential oil content is not much different from 2.08 - 2.7 mL/100 g dry matter. The specific energy consumption values have ranged from 7.88 to 15.08 MJ/kg of moisture removed). Daily fluctuations in ambient air conditions directly affected the specific energy consumption of a rotary dryer. Ademiluyi (2010) uses fermented cassava as a material to be dried in a rotary dryer. This research was conducted with parameters, dry air inlet temperature, dry air inlet velocity, relative humidity, feed rate, drum rotational per minute and feeding. The results show that the dry air inlet temperature, the dry air inlet velocity, and the feed rate have a significant effect on the specific heat transfer coefficient and heat load on the material.

This research was done focused on the effect of drying temperature on a rotary type dryer for drying characteristics and antioxidant activity of etlingera elatior flowers that includes moisture content, drying rate, total phenol, and DPPH free radical scavenging activity. Antioxidant activity testing was carried out to determine the antioxidant ability found in etlingera flowers at different drying temperature treatments using a rotary type dryer. This antioxidant activity is known by comparing the antioxidant activity of water extracts of etlingera flower petal powder at various drying temperatures (60, 70, 80 and 90 ^{o}C) with gallic acid and calculating its ability to reduce DPPH free radicals based on the percentage of inhibition (% inhibition). This study uses a lab-scale rotary dryer which is a modification of the commercial oven heater from the market.

2. Materials and methods

The material used in this study was the fresh etlingera flower, the flower petals were taken and the knob was discarded. This material was bought from the traditional market around Medan city, Indonesia. All chemicals used were of analytical grade. The DPPH (2,2-diphenyl-1-picrylhidrazyl free radical) was purchased from Sigma Adrich Chemicals (St. Louis, Missouri, United States), gallic acid, folin-ciocalteu phenol, sodium carbonate, methanol were obtained from Merck & Co. Pharmaceutical Company (New Jersey, United States), and aquadest was bought from PT. Surabaya Aqua Industry, Indonesia.

The fresh flower petals were chopped to a size of about 1 cm. For each experiment, the raw material around 400 ± 0.1 g (Ohaus PA 224) was used which included about 50% of the drying basket volume. The drying apparatus used the Oxone type OX-8830 oven heater, which has a 30-liter volume. Electric ovens were heated to the set temperature until steady conditions. Then the sample was put in the drying basket and the material dried in the oven. The drying air temperatures used were 60, 70, 80 and 90 ^{o}C and the drying basket rotates around 3 rpm. The experimental setup was shown in Figure 1. During the drying process, the mass weight was weighed periodically every 20 minutes until the sample weight was constant. The sample was picked up quickly, then weighed and then put in the oven again to be heated. Drying was completed when the sample weight was constant. The moisture content in this study was calculated based on a wet basis with Eq. 1:

$$\mathrm{MC} = \frac{\mathrm{M_{H2O}}}{\mathrm{M_{total}}} \mathrm{x}\, 100\% \qquad (1)$$

Where MC = moisture content (%), M_{H2O} = mass of moisture (g) and M_{total} = mass of solid + mass of moisture (g)

The drying rate was calculated from the Eq. 2:

$$DR = \frac{MC_{t0} - MC_{t1}}{\Delta t} \quad (2)$$

Where DR = drying rate (%/min), MC_{t0} = moisture content at time t (g), MC_{t1} = moisture content at t + 20 min (g) and Δt = time interval (min)

In thermal drying, there are two simultaneous transfer processes, namely heat or energy transfer and mass transfer. Energy transfer occurs from the environment to vaporize moisture that is present on the surface of a material/product at T∞ temperature with dry air media. On the surface of the material had occurred convection heat transfer due to differences in temperature between the surface of the material with dry air. The vaporization is the evaporation of moisture found on the surface of the material. While conduction occurs on the inside where heat moves from the outside to the inside, the moisture which is inside of the product will experience diffusion where the moisture moves towards the surface due to differences in moisture content between the inside and the surface of the material.

2.1. Extraction of samples

The samples were extracted by the soxhlet extraction method (Widyawati et al. 2014). 3 g of samples were wrapped in filter paper and then put in a soxhlet tube and added with 50 mL of water solvent. Furthermore, samples are extracted soxhlet at its boiling point for ± 4 hours until the color of the solvent in the soxhlet tube (timbre) is colorless. The extract obtained is evaporated by a rotary evaporator under vacuum at a temperature of 6 5- 80 °C and a pressure of 250 - 300 mbar, a rotational speed of 40 rpm for 10 minutes to obtain 2.5 mL of a concentrated extract. The extract obtained was stored in vials and stored in the freezer until further analysis.

2.2. Total phenol content analysis

Analysis of total phenol was based on the oxidation reaction of phenol compounds to produce a blue solution from reducing yellow hetero polyphosphoric molybdate tungstate anions (Muntana and Prasong, 2010). 20 µL of etlingera flower extract was added with 1 mL of 10% Folin Ciocalteau reagent in a 10 mL flask bottle, shaken and left for 5 minutes. Subsequently, the samples were added 2.0 mL of 7.5% Na_2CO_3 and distilled water until a volume of 10 mL and then allowed to stand for 30 minutes. The absorbance of the samples was measured at λ 760 nm (UV-Vis spectrophotometer, Shimadzu 1800). Data were analyzed with gallic acid as a standard solution (mg GAE/g samples).

2.3. DPPH free radical scavenging activity analysis

The assay of DPPH free radical scavenging activity was based on the modified method of Sompong et al. (2011). 3 mL of DPPH solution (4 mg/100 mL in methanol) was added 20 µL of extract and methanol until volume 10 mL in a 10 mL flask bottle. And then samples were incubated for 30 minutes in a dark chamber. The absorbance of each sample was measured at λ 517 nm by a spectrophotometer (UV-Vis spectrophotometer, Shimadzu 1800). Data were analyzed with gallic acid as a standard solution (mg GAE/g samples).

3. Result and discussion

3.1. Moisture Content and Drying Rate

The initial moisture content of each sample for temperatures 60, 70, 80 and 90 °C were 87.53%; 88.03%; 88.1% and 87.53%. During the drying process, the changes in moisture content occur as shown in Figure 2. The changes in moisture content that occur in drying temperatures of 70, 80 and 90 °C are proportional. As for the temperature of 60 °C, the change is much slower. For each drying temperature of 90, 80, 70 and 60 °C, the moisture content will approach 0% after experiencing the drying process respectively for 240, 260, 320 and 480 minutes. The decrease in moisture content that occurs following a straight line until the moisture content approaches 0%. The decrease indicates that the process of moisture evaporation takes place constantly for each period of measurement. The moisture content for each experiment calculated based on Eq. 1 is shown in Figure 2.

The drying rate during the experiment as calculated by using Eq. 2 is shown in Figure 3. The constant drying rate looks long enough for all types of temperatures used. This constant drying period has nearly the same period for drying temperatures of 70, 80 and 90 °C. The period is around 220 minutes. During this period, the drying rate is around 25 - 30 per 20 minutes of measurement. For temperatures of 60 °C, the drying rate is around 15 g/20 minutes and lasts for about 380 minutes. The duration of this constant rate period is due to the high moisture content contained in fresh etlingera flowers. Moisture content for all samples is around 90%. A large amount of moisture content is present on the surface of the sample. The sample also has a small thickness so that moisture on the inside or middle has no difficulty moving to the surface. The fall rate period has a shorter period than the constant rate period which is around 40 to 100 minutes for experiments with temperatures of 90, 80 and 70 °C. As for the drying temperature of 60 °C, the time is around 240 minutes. The second falling rate period has a shorter time than the previous periods. The shorter time indicates that after experiencing a critical condition, etlingera flowers will run out of moisture content. The drying rate is obtained as shown in Figure 3. The period of constant drying rate lasting up to 20% moisture content. After that, the drying rate will decrease rapidly. Moisture content in this range is a critical condition where the drying rate will be significantly influenced by the rate of moisture transportation from the center to the surface.

3.2. Antioxidant Activity

Testing of total phenol is a suggested activity to provide a comparison of phenol content in a sample. Phenol compounds can improve redox reactions so that they can act as antioxidants (Johari and Khong, 2019). The total phenol in etlingera flower powder at various temperatures is shown in Figure 4. The data showed that the temperature gave a significant effect on the total phenol of etlingera flower powder at a temperature of 60 °C compared to 70, 80 and 90 °C. However, the increase in drying temperatures will decrease even though not significant. The higher drying temperature could increase the total phenol content of flower powder. The total phenol content of the etlingera flower petals powder temperature of 60 °C was 1,216 ± 0.146 mg gallic acid equivalent/g samples, while the total phenol content of etlingera flower powder was ranged from 2.558 ± 0.385 - 2.165 ± 0.609 mg gallic acid equivalent/g samples. Based on the obtained data, it could be concluded that the phenolic compounds in etlingera elatior flowers were thermostable. The thermostable properties of samples were shown at drying temperature up to a temperature of 70 °C while drying at temperatures above 70 °C began to decrease but it was not significantly different. According to Zlotek et al. (2019), phenolic composition in the addition of white

quinoa depends thermostable on various drying variations, namely: 30, 45, and 60 ^{o}C with a single convection dryer type. A suitable drying temperature to produce and to get the highest phenol content must be done at 70 ^{o}C. The secondary metabolite compounds in plants that are not free or contain other secondary metabolites. Vanic acid is thermostable at various dry temperatures, while p- hydroxybenzoic acid, p-coumaric acid, salicylic acid, and ferulic acid. Naufalin et al. (2005) gave etlingera flowers that contained phytochemical compositions, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. Liaotrakoon and Liaotrakoon (2018) also determined the amount of phenol and antioxidant activity of mushrooms, dried at 40, 50, and 60 ^{o}C in oven drying, reducing this amount along with the drying time. Thus, it can be concluded that drying with rotary type will effectively maintain the total phenol content while the drying temperature used is quite high, while the drying time is 4 hours. DPPH (1,1-diphenyl-2- picrylhydrazil) is a free radical that has a maximum absorbance at 517 nm in methanol and color solvents will increase protection from purple to yellow (Sayed et al., 2015). DPPH free radical scavenging activity from flower powder *Etlingera elatior* increased at various temperatures (Figure 5). Different facts occur in the research of Liaotrakoon and Liaotrakoon (2018), which shows that the use of mushrooms with drying ovens results in a decrease in total phenol and the ability to DPPH free radicals scavenging activity. This research showed that drying etlingera flowers with rotary drying for 4 hours at 60 – 90 ^{o}C did not change the DPPH free radical scavenging activity. It means that this drying method was very effective in maintaining the content of phenol compounds and antioxidant activity. However, an increase in the antioxidant activity of etlingera flowers did not correlate with an increase in total phenol levels. This was indicated by a coefficient of determination of less than 0.95 (R^2 = 0.3318), which means an increase in total phenol content was not closely related to an increase in the DPPH free radical scavenging activity. Piluzza and Bullitta (2011) stated that the DPPH and ABTS free radicals scavenging activity was positively correlated with total phenols with R^2 = 0.9152 and R^2 = 0.889. It means that other phytochemical compounds determine antioxidant activity. Setiawati (2018) states that the phytochemical compounds that exist in etlingera flowers are alkaloids, glycosides, phenolics, terpenoids, steroids, saponins, and flavonoids. While alkaloids are the dominant phytochemical compounds in etlingera flowers. Gan et al. (2017) state that total phenol linearly correlates with antioxidant activity (iron ion reducing power, hydroxyl free radical scavenging activity and lipid oxidation inhibition activity). Alkaloids and phenolic compounds are very important as antioxidants, but the alkaloids are a stronger antioxidant.

4. Conclusions

Drying at temperatures of 70, 80 and 90 ^{o}C, had a time difference that is not too much when compared to temperatures of 60 ^{o}C. For all three temperatures, the drying rate decreased rapidly in the 200th minute, while for the temperature of 60 ^{o}C, the decrease in the drying rate was slighter after the 380th minute. Drying with rotary drying effectively could maintain the total phenolic content, even though the drying temperature was quite high and the drying time was 4 hours. Drying with rotary drying for 4 hours at 60 – 90 ^{o}C did not change the DPPH free radical scavenging activity. It means that this rotary drying method was very effective in maintaining the content of phenol compounds and antioxidant activity.

Conflict of interest

The authors declare no conflict of interest on this research.

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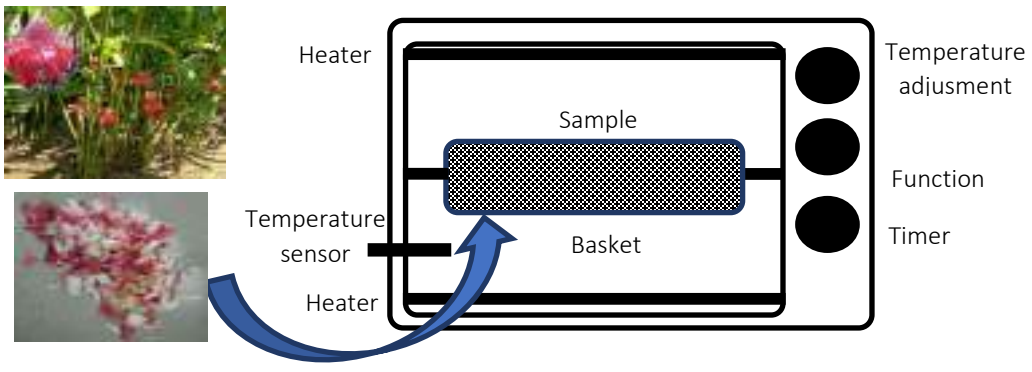


Figure 1. Rotary dryer lab-scale

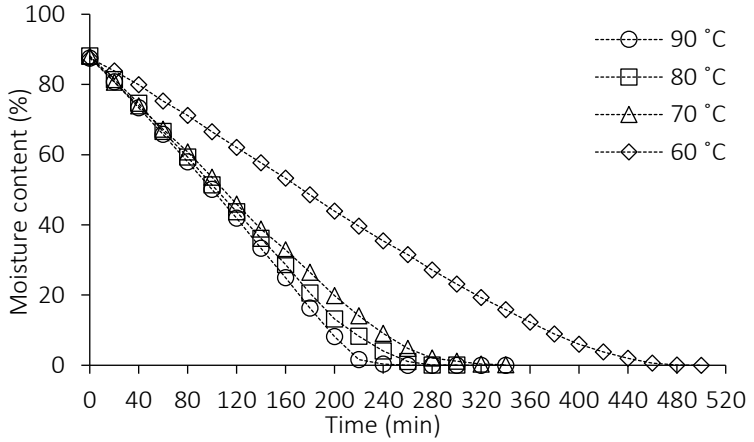


Figure 2. The moisture content of drying

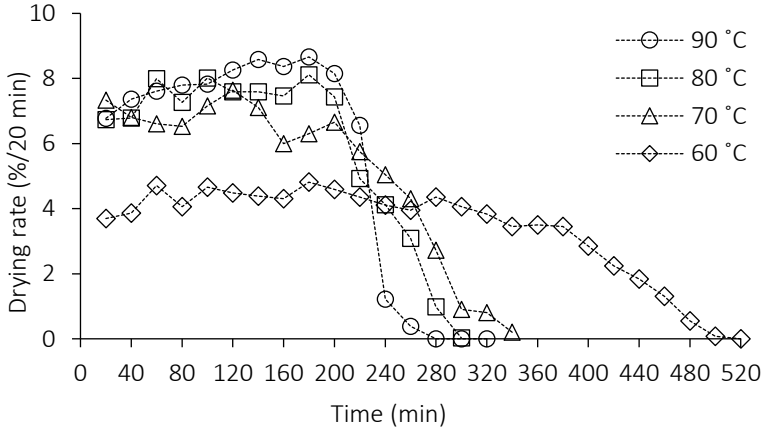
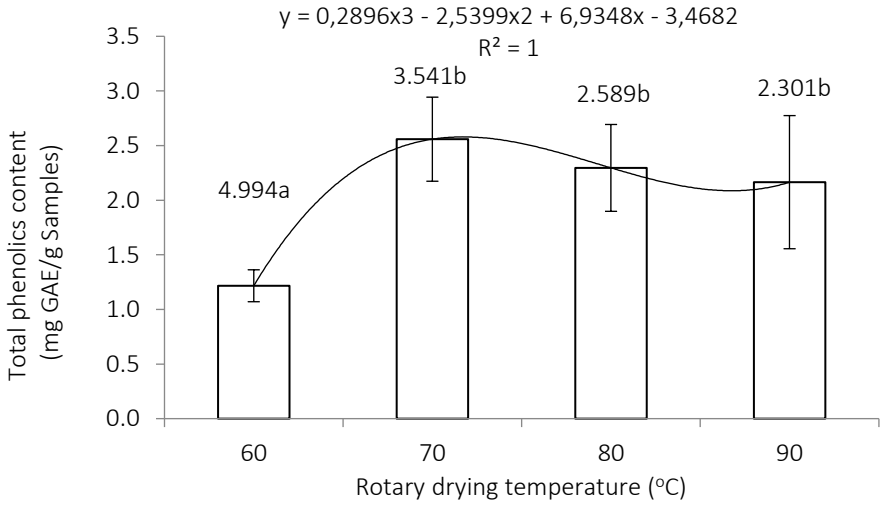
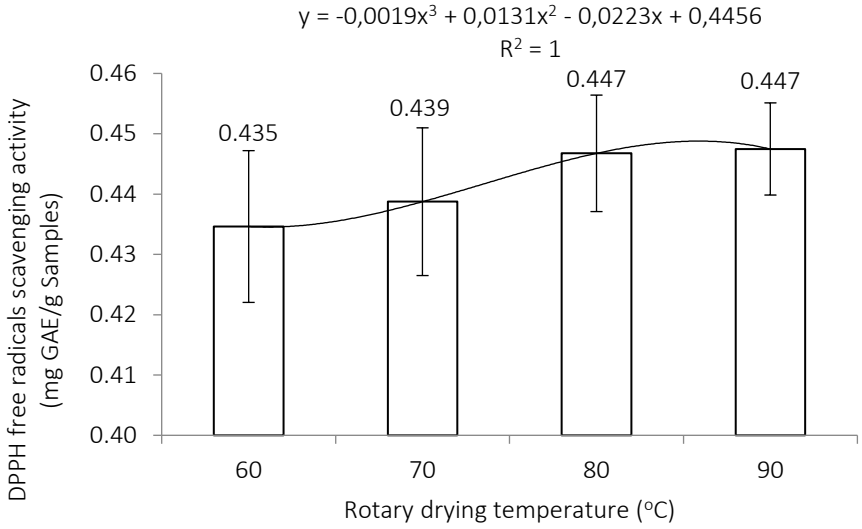


Figure 3. The drying rate



334 Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures.



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336 Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying
337 temperatures.

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2. First Review: Minor Revision (18-5-2021)
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Date	:	18th May 2021
Manuscript ID	:	FR-2021-333
Please return by	:	18th June 2021
Title of Manuscript	:	The effect of temperature on drying characteristic and antioxidant activities of *Etlingera elatior* Jack

1. IF YOU CANNOT REVIEW THIS MANUSCRIPT OR MEET THE DEADLINE, PLEASE INFORM US WITHOUT DELAY.

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(REVIEWER'S SECTION) REVIEWER'S COMMENTS/SUGGESTIONS		(AUTHOR'S SECTION) AUTHOR'S ACTION/RESPONSE *NOTE FOR AUTHOR: Please state your response to the reviewer's comments/suggestion below
1.	**Title** *It should reflect the article* Acceptable	
2.	**Abstract** *Background, Aim, Methodology and Conclusion* Line 15, the word..namely..is not suitable, edit sentence and do not use "namely"..	Agree to the reviewer and has been changed to i. e.
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4.	**Introduction** *Concise with sufficient background* Line 35, do not use those words in RED, rewrite the sentence Line 42, do not use those word in RED, rewrite sentence Lines 45-46..arrange in ascending order according to year of publication Lines 54-57, rewrite this sentence in proper English Lines 61-62, do not use the word..inform/ed..not scientific way of writing..rewrite sentence Lines 55-58, rewrite in proper English Lines 67-69, rewrite in proper English Lines 92-99, rwrite in proper English	Line 35, agree to the reviewer and has been rewrite. Line 42, agree to the reviewer and has been rewrite. Line 45-46, agree to the reviewer and has been rewrite to be ascending. Line 54-57, agree to the reviewer and has been rewrite. Line 61-62, agree to the reviewer and has been changed. Line 55-58 agree to the reviewer and has been rewrite. Line 67-69 agree to the reviewer and has been rewrite. Line 92-99, agree to the reviewer and has been rewrite.
5.	**Research design/Methodology** *Clearly described and reproducible* Line 142, u se word, not number	Line 142, agree to the reviewer and has been rewrite by using word.

	Line 144-145, rewrite in proper English Lines 159-160, rewrite in proper English, start sentence with words rather then using number	Line 144-145, agree to the reviewer and has been rewrite. Line 159-160, agree to the reviewer and has been rewrite by using word.
6.	**Data Analysis** *Results well presented and discussed* Line 170, rewrite the sentence and do not use the word..experiencing… not scientific. Section 3.1..hardly any discussion? Line 199, use 1.2 not 1,2 Line 205, rewrite and do not use the word..namely..not scientific Line 226, rewrite sentence in proper English, and do not use the word..stated… Line 229, rewrite in proper English and do not use the word..states.. Line 231, rewrite and do not use the word..state..	Line 170 ,agree to the reviewer and has been rewrite the sentence. Section 3.1 …. Line 199, agree to the reviewer and has been changed. Line 205, agree to the reviewer and has been rewrite the sentence. Line 226, agree to the reviewer and has been rewrite the sentence. Line 229, agree to the reviewer and has been rewrite the sentence. Line 231, agree to the reviewer and has been rewrite the sentence.
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The effect of temperature on drying characteristic and antioxidant activities of *Etlingera elatior* Jack

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Abstract

The study was conducted to obtain the effect of drying temperature on a rotary type dryer for drying characteristics and antioxidant activity of *Etlingera elatior flower*. This study used a lab-scale rotary dryer which was a modification of the commercial oven heater from the market. The research design was a Randomized Block Design (RCBD) with one factor, i. e. the drying temperature, which consisted of four temperature levels, i. e. 60, 70, 80 and 90°C. The experiments were repeated six times. The results showed that the drying of *Etlingera elatior* flowers at three different temperatures, i.e 70, 80 and 90°C, required a shorter drying time than it at 60°C. The drying rate of the samples at 70, 80 and 90°C was decreased drastically before the 200th minute, while the drying rate at 60°C was slower to 380 minutes. The drying rate pattern had an effect on the total phenol content, where drying at high temperature resulted the total phenol content which was not significantly different, but the drying at low temperature reduced the total phenol content significantly. However, the difference in drying temperature did not have a significant effect on antioxidant activity based on the DPPH (2,2-diphenyl-1-picrylhydrazyl radical) method. It means that the higher temperature using by rotary drying method was very effective to maintain the total phenol content and antioxidant activity.

Keywords: *Etlingera elatior* Jack; Rotary drying; Temperature; Drying characteristics; Antioxidant activity

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1. Introduction

Etlingera elatior Jack (ginger red/torch ginger) is a spice plant included *Zingiberaceae* family that is quite widespread in Indonesia. This herb plant can be found in several regions in Southeast Asia (Wijekoon *et al*., 2010; Nor *et al*., 2020) with different names, such as *Kincung* in Medan, Rias in North Tapanuli, *Sambuang* in Minangkabau, *Kecicang* in Bali, *Siantan* in Malaya and *Daalaa* in Thailand (Health Research and Development Agency of Indonesia, 2000; Lacumy *et al*., 2010; Nor *et al*., 2020). *E. elatior* flower is potential as a food flavoring (seasoning) in cooked, sauteed, or heated (Noweg *et al*., 2003, Juwita *et al*., 2018) as in fish processing (*pepes* fish, grilled fish, and fried). Fish cooked with *etlingera* will taste better and fishy aroma will be reduced (Sukandar *et al*., 2011). In addition, this plant is efficacious as deodorizing body odor and bad breath (Health Research and Development Agency of Indonesia, 2000; Aldi *et al*., 2020), natural cosmetic ingredients (Chan *et al*., 2007). The profile of *E. elatior* Jack is shown in Figure 1a.

The utilization of the etlingera flower is correlated to phytochemical compounds, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides (Naufalin *et al*., 2005; Setiawati, 2018). Using of 80% methanol solvent can extract i. e. flavonoids, terpenoids, saponins, tannins and carbohydrate compounds from etlingera flower (Lachumy *et al*., 2010). The another study also found that the flower contains essential oils around 0.0334%, such as (E)-β-farnesene, β-pinene, 1,1-dodecanadiol diacetate, cycloodecane, (E)-decane (Jaafar *et al*., 2007; Juwita *et al*., 2018). Furthermore, *E. elatior* has described to exhibit many biological activities (Lachumy *et al*., 2010; Nor *et al*., 2020; 2018; Putri, 2021).

Many investigations have found that the phytochemical compounds of etlingera flowers are be potential as antioxidant sources. The methanolic and ethanolic extracts of them have been proven to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical (Chan *et al*., 2007). The concentration of methanolic extract from etlingera flower that can be inhibited DPPH radical is 9.14 mg/ml (Lachumy *et al*., 2010). The percentage of aqueous extracts to scavenge DPPH radical is 76.4% (Gasemzadeh *et al*., 2015). Naufalin and Rukmini (2011) also find that the etlingera flower is higher potential as antioxidant activity (61.61-83.17%) than it of leaf (40.64-60.40%) and stem (57.42-84.65%).

The drying can reduce the moisture content of the fresh etlingera flower to extend the self-life. The fresh etlingera flower has moisture contents more than 80% so it is a very perishable commodities (Sagar and Kumar, 2010). The air-, freeze-, microwave-, vacuum-, oven- and sun-drying methods have different effect of a quality dried product or a dried material. Temperature using of each drying method can influenced losses or preserving of antioxidant compounds (Kamiloglu *et al*., 2016). Can *et al*. (2009) studied the effect of various drying types, such as oven drying, microwave, oven, sun drying, and freeze-drying to the antioxidant properties of *E. elatior* leaves. The study showed that freeze-drying give a better total phenolic than the other types of drying. Rohkyani and Suryani (2015) also showed that using the oven drying at 65°C, results the highest DPPH scavenging activity (66.43%) of etlingera flower compared to 85°C (56.76%).

Rotary drying is another drying method that has not been widely applied in food drying. Delele *et al.* (2015) informed that rotary dryers are capable of processing a variety of agricultural products with a wide range of thermo-physical and flow properties, and improve the efficiency of the drying process. Until now, it is still very difficult to get information regarding the antioxidant characteristics of E. elatior flowers that are dried in a rotary dryer rotary.

In a drying process, the drying rate is divided into two groups, i. e. the constant rate and the falling rate. Constant rate drying is occurring at the beginning of drying, where the decrease in moisture content is held constant for a specified period. In this condition, the amount of moisture content in the material is still quite large. So the drying rate is only controlled by the rate of diffusion of moisture from the surface of the material to the surrounding air. After drying, the constant rate will be followed by the drying period of the falling rate. During this period, the drying rate will be controlled by the rate of diffusion of moisture from the inside to the surface of the material. This process will be continued until it reaches equilibrium or the moisture runs out in the material.

The temperature of the drying air strongly influences the drying rate. The higher the temperature, the more energy is used to evaporate moisture, and also the latent heat value will be smaller. A rotary dryer is a dryer where the material is put into a rotating drum and there are flowed hot air. The material will experience more even heating because it is rotated so that it can speed up the drying time. This screening process is carried out continuously so that the material will experience a reversal. For drying materials in the form of thin leaves and wide sizes, a rotary type dryer is very suitable for use because it has a stirring function.

Several studies have used rotary dryer to preserve food material. Kaleemullah (2005) investigated the drying of 10.5 kg chili with an initial moisture content of 330% (dry basis) in the temperature range of 50 – 65°C. The study showed that the moisture content reduced to 10.0% (dry basis) after being dried for 32, 27, 23 and 20 hours at 50, 55, 60 and 65°C, respectively. Tarhana (2010) examined the drying of 15 kg peppermint using a rotary dryer for 15 - 18 hours and 12 – 15 hours. Drying can cause the leaves to darken, but the essential oil content is not much different from 2.08 - 2.7 mL/100 g dry matter. The specific energy consumption values have ranged from 7.88 to 15.08 MJ/kg of moisture removed). Daily fluctuations in ambient air conditions directly affected the specific energy consumption of a rotary dryer. Ademiluyi (2010) uses fermented cassava to be dried in a rotary dryer. The study was conducted with parameters of dry air inlet temperature, dry air inlet velocity, relative humidity, feed rate, drum rotational per minute and feeding. The results show that the dry air inlet temperature, the dry air inlet velocity, and the feed rate have a significant effect on the specific heat transfer coefficient and heat load on the material.

This study was aimed to obtain the effect of drying temperature on drying characteristics and antioxidant activity of *E. elatior* flowers that includes moisture content, drying rate, total phenol, and DPPH free radical scavenging activity on a rotary dryer type. Antioxidant activity testing was carried out to determine the antioxidant ability found in etlingera flowers at different drying temperature treatments using a rotary type dryer. This antioxidant activity is known by comparing the antioxidant activity of water extracts of etlingera flower petal powder at various drying temperatures (60, 70, 80 and 90°C) with gallic acid and calculating its ability to reduce DPPH free radicals based on the percentage of inhibition (% inhibition). This study uses a lab-scale rotary dryer which is a modification of the commercial oven heater from the market.

2. Materials and methods

The material used in this study was the fresh *E. elatior* flower, the flower petals were taken and the knob was discarded. This material was bought from the traditional market around Medan city, Indonesia. All chemicals used were of analytical grade. The DPPH (2,2-diphenyl-1-picrylhidrazyl free radical) was purchased from Sigma Adrich Chemicals (St. Louis, Missouri, United States), gallic acid, folin-ciocalteu phenol, sodium carbonate, methanol were obtained from Merck & Co. Pharmaceutical Company (New Jersey, United States), and aquadest was bought from PT. Surabaya Aqua Industry, Indonesia.

The fresh flower petals were chopped to a size of about 1 cm. For each experiment, the raw material around 400 ± 0.1 g (Ohaus PA 224) was used which included about 50% of the drying basket volume. The drying apparatus used the Oxone type OX-8830 oven heater, which has a 30-liter volume. Electric ovens were heated to the set temperature until steady conditions. Then the sample was put in the drying basket and the material dried in the oven. The drying air temperatures used were 60, 70, 80 and 90°C and the drying basket rotates around 3 rpm. The experimental setup was shown in Figure 1b. During the drying process, the samples were weighed periodically every 20 minutes until the sample weight was constant. The sample was picked up quickly, then weighed and then put in the oven again to be heated. Drying was completed when the sample weight was constant. The moisture content in this study was calculated based on a wet basis with Eq. 1:

$$\mathrm{MC} = \frac{\mathrm{M_{H2O}}}{\mathrm{M_{total}}} \mathrm{x}\, 100\% \qquad (1)$$

Where MC = moisture content (%), M_{H2O} = mass of moisture (g) and M_{total} = mass of solid + mass of moisture (g)

The drying rate was calculated from the Eq. 2:

$$DR = \frac{MC_{t0} - MC_{t1}}{\Delta t} \quad (2)$$

Where DR = drying rate (%/min), MC_{t0} = moisture content at time t (g), MC_{t1} = moisture content at t + 20 min (g) and Δt = time interval (min)

In thermal drying, there are two simultaneous transfer processes, i. e. heat or energy transfer and mass transfer. Energy transfer occurs from the environment to vaporize moisture that is present on the surface of a material/product at T∞ temperature with dry air medium. On the surface of the material had occurred convection heat transfer due to differences in temperature between the surface of the material with dry air. The vaporization is the evaporation of moisture found on the surface of the material. While conduction occurs on the inside where heat moves from the outside to the inside, the moisture which is inside of the product will experience diffusion where the moisture moves towards the surface due to differences in moisture content between the inside and the surface of the material.

2.1. Extraction of samples

The samples were extracted by the soxhlet extraction method (Widyawati *et al*. 2014). As much as 3 g of samples were wrapped in filter paper and then put in a soxhlet tube and added with 50 mL of water solvent. Then the samples was extracted soxhlet at its boiling point for ± 4 hours until the color of the solvent in the soxhlet tube (timbre) was colorless. The extract obtained was evaporated by a rotary evaporator under vacuum at a temperature of 6 5- 80°C and a pressure of 250 - 300 mbar, a rotational speed of 40 rpm for 10 minutes to obtain 2.5 mL of a concentrated extract. The extract obtained was stored in vials and stored in the freezer until further analysis.

2.2. Total phenol content analysis

Analysis of total phenol was based on the oxidation reaction of phenol compounds to produce a blue solution from reducing yellow hetero polyphosphoric molybdate tungstate anions (Muntana and Prasong, 2010). 20 µL of etlingera flower extract was added with 1 mL of 10% Folin Ciocalteau reagent in a 10 mL flask bottle, shaken and left for 5 minutes. Subsequently, the samples were added 2.0 mL of 7.5% Na_2CO_3 and distilled water until a volume of 10 mL and then allowed to stand for 30 minutes. The absorbance of the samples was measured at λ 760 nm (UV-Vis spectrophotometer, Shimadzu 1800). Data were analyzed with gallic acid as a standard solution (mg GAE/g samples).

2.3. DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging activity analysis

The assay of DPPH free radical scavenging activity was based on the modified method of Sompong *et al.* (2011). As much as 3 mL of DPPH solution (4 mg/100 mL in methanol) was added with 20 µL of the extract and methanol until the volume reached 10 mL in a 10 mL flask bottle. And then samples were incubated for 30 minutes in a dark chamber. The absorbance of each sample was measured at λ 517 nm by a spectrophotometer (UV-Vis spectrophotometer, Shimadzu 1800). Data were analyzed with gallic acid as a standard solution (mg GAE/g samples).

3. Results and discussion

3.1. Moisture content and drying rate

The initial moisture content of each sample for temperatures 60, 70, 80 and 90°C was 87.53%; 88.03%; 88.1% and 87.53% (w/w). During the drying process, the changes in moisture content occur as shown in Figure 3. The changes in moisture content that occur in drying temperatures of 70, 80 and 90°C are proportional. As for the temperature of 60°C, the change is much slower. For each drying temperature of 90, 80, 70 and 60°C, the moisture content will approach 0% after drying for for 240, 260, 320 and 480 minutes, respectively. The decrease in moisture content that occurs following a straight line until the moisture content approaches 0%. The decrease indicates that the process of moisture evaporation takes place constantly for each period of measurement. The moisture content for each experiment calculated based on Eq. 1 is shown in Figure 2.

The drying rate during the experiment as calculated by using Eq. 2 is shown in Figure 3. The constant drying rate looks long enough for all types of temperatures. This constant drying period has nearly the same period for drying temperatures of 70, 80 and 90°C. The period is around 220 minutes. During this period, the drying rate is around 25 - 30 per 20 minutes of measurement. For temperatures of 60°C, the drying rate is around 15 g/20 minutes and lasts for about 380 minutes. The duration of this constant rate period is due to the high moisture content contained in fresh *E. elatior* flowers. Moisture content for all samples is around 90%. A large amount of moisture content is present on the surface of the sample. The sample also has a small thickness so that moisture on the inside or middle has no difficulty moving to the surface. The fall rate period has a shorter period than the constant rate period which is around 40 to 100 minutes for experiments with temperatures of 90, 80 and 70°C. As for the drying temperature of 60°C, the time is around 240 minutes. The second falling rate period has a shorter time than the previous period. A shorter time indicates that after experiencing a critical condition, *E. elatior* flowers will run out of moisture content. Data in Figure 3 showed that a period of constant drying rate lasting up to 20% moisture content. After that, the drying rate will decrease rapidly. Moisture content in this range is a critical condition where the drying rate will be significantly influenced by the rate of moisture transportation from the center to the surface.

3.2. Antioxidant activity

Testing of total phenol is a suggested activity to provide a comparison of phenol content in a sample. Phenol compounds can improve redox reactions so that they can act as antioxidants (Johari and Khong, 2019). The total phenol in etlingera flower powder at various temperatures is shown in Figure 4. The data showed that the temperature gave a significant effect on the total phenol content at a temperature of 60°C compared to 70, 80 and 90°C. However, the increase in drying temperatures will decrease even though not significant. The higher drying temperature could increase the total phenol content of flower powder. The total phenol content of the etlingera flower petals powder temperature of 60°C was 1.216 ± 0.146 mg gallic acid equivalent/g samples, while the total phenol content of etlingera flower powder was ranged from 2.558 ± 0.385 - 2.165 ± 0.609 mg gallic acid equivalent/g samples. Based on the data obtained, it could be concluded that the phenolic compounds in *E. elatior* flowers were thermostable. The thermostable properties of samples were shown at drying temperature up to a temperature of 70°C while drying at temperatures above 70°C began to decrease but it was not significantly different. According to Zlotek *et al.* (2019), phenolic composition in the addition of white quinoa depends thermostable on various drying variations, i. e. 30, 45, and 60°C with a single convection

dryer type. A suitable drying temperature to produce and to get the highest phenol content must be done at 70°C. The secondary metabolite compounds in plants that are not free or contain other secondary metabolites. Vanic acid is thermostable at various dry temperatures, while p- hydroxybenzoic acid, p-coumaric acid, salicylic acid, and ferulic acid. Naufalin *et al.* (2005) gave etlingera flowers that contained phytochemical compositions, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. Liaotrakoon and Liaotrakoon (2018) also determined the amount of phenol and antioxidant activity of mushrooms, dried at 40, 50, and 60°C in oven drying, reducing this amount along with the drying time. Thus, it can be concluded that drying with rotary type will effectively maintain the total phenol content while the drying temperature used is quite high, while the drying time is 4 hours. DPPH (2,2-diphenyl-1- picrylhydrazil) is a free radical that has a maximum absorbance at 517 nm in methanol and color solvents will increase protection from purple to yellow (Sayed *et al*., 2015). DPPH free radical scavenging activity from flower powder *Etlingera elatior* increased at various temperatures (Figure 5). Different facts occur in the research of Liaotrakoon and Liaotrakoon (2018), which shows that the use of mushrooms with drying ovens results in a decrease in total phenol and the ability to DPPH free radicals scavenging activity. This research showed that drying etlingera flowers with rotary drying for 4 hours at 60 – 90°C did not change the DPPH free radical scavenging activity. It means that this drying method was very effective in maintaining the content of phenol compounds and antioxidant activity. However, an increase in the antioxidant activity of etlingera flowers did not correlate with an increase in total phenol levels. This was indicated by a coefficient of determination of less than 0.95 (R^2 = 0.3318), which means an increase in total phenol content was not closely related to an increase in the DPPH free radical scavenging activity. Piluzza and Bullitta (2011) showed that the DPPH and ABTS free radicals scavenging activity was positively correlated with total phenols with R^2 = 0.9152 and R^2 = 0.889. It means that other phytochemical compounds determine antioxidant activity. Setiawati (2018) shows that the phytochemical compounds that exist in etlingera flowers are alkaloids, glycosides, phenolics, terpenoids, steroids, saponins, and flavonoids. While alkaloids are the dominant phytochemical compounds in etlingera flowers. Gan *et al.* (2017) shows that total phenol linearly correlates with antioxidant activity (iron ion reducing power, hydroxyl free radical scavenging activity and lipid oxidation inhibition activity). Alkaloids and phenolic compounds are very important as antioxidants, but the alkaloids are a stronger antioxidant.

4. Conclusion

Drying at temperatures of 70, 80 and 90°C, had a time difference that is not too much when compared to temperatures of 60°C. For all three temperatures, the drying rate decreased rapidly in the 200th minute, while for the temperature of 60°C, the decrease in the drying rate was slighter after the 380th minute. Drying with rotary drying effectively could maintain the total phenolic content, even though the drying temperature was quite high and the drying time was 4 hours. Drying with rotary drying for 4 hours at 60 – 90°C did not change the DPPH free radical scavenging activity. It means that this rotary drying method was very effective in maintaining the content of phenol compounds and antioxidant activity.

Conflict of interest

The authors declare no conflict of interest on this research.

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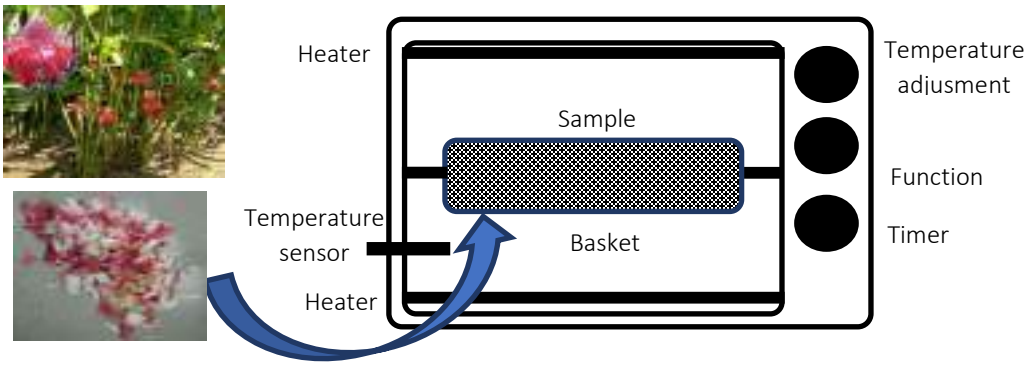
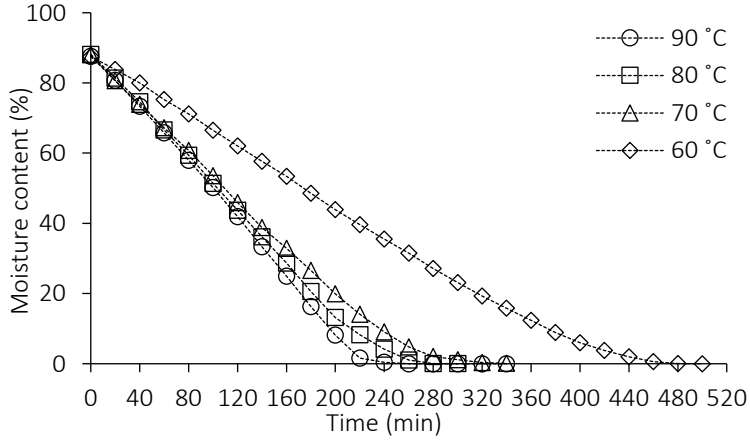


(a) (b)

Figure 1. *Etlingera elatior* Jack (a) and Rotary dryer lab-scale (b)


100
80
60
40
20
0
Moisture content (%)
0 40 80 120 160 200 240 280 320 360 400 440 480 520
Time (min)
90 ˚C
80 ˚C
70 ˚C
60 ˚C

391 Figure 2. The moisture content of *Etlingera elatior* Jack flowers at various drying temperatures.

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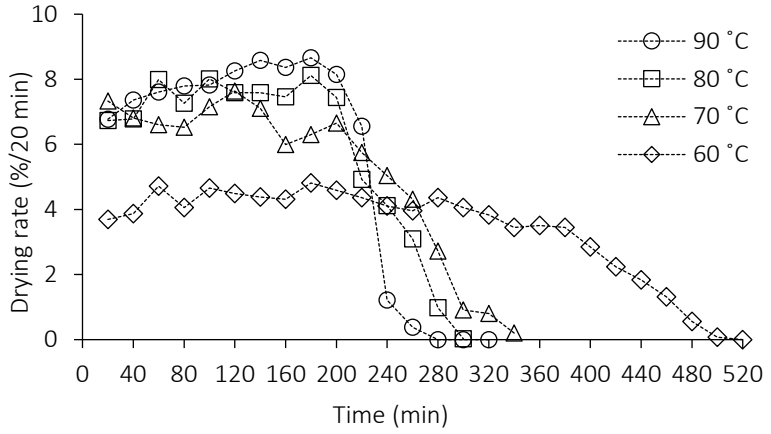

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394 Figure 3. The drying rate of *Etlingera elatior* Jack flowers at various drying temperatures.

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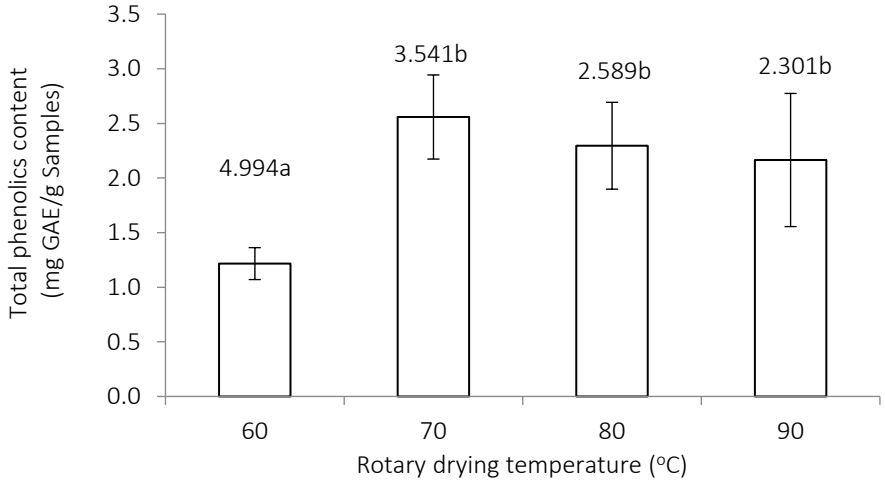

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397 Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures.

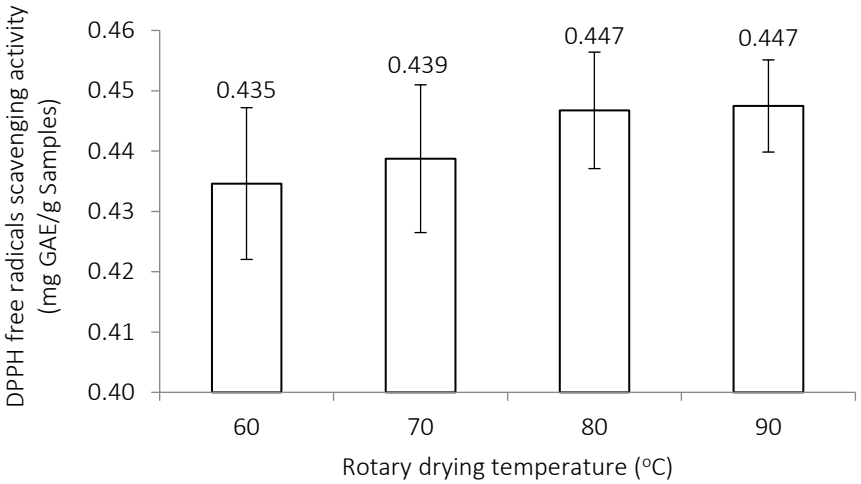

Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying temperatures.

3. Second Review: Major Revision (18-5-2021)

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MANUSCRIPT EVALUATION FORM

Date : 18th May 2021

Manuscript ID : FR-2021-333

Please return by : 18th June 2021

Title of Manuscript : The effect of temperature on drying characteristic and antioxidant activities of *Etlingera elatior* Jack

1. IF YOU CANNOT REVIEW THIS MANUSCRIPT OR MEET THE DEADLINE, PLEASE INFORM US WITHOUT DELAY.

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COMMENT SHEET

Using item 2 in page 1 as a guideline, please indicate the reasons for your recommendations. Most author(s) will appreciate frankness, combined with a modicum of tact. Even if you recommend that the manuscript be accepted for publication, please provide some general comments to the author(s).

Evaluation Criteria	Grade				
	A (Excellent)	B	C	D	E (Worst)
1. Appropriateness of Contents			/		
2. Originality of Topic		/			
3. Manuscript Format			/		
4. Research Methodology				/	
5. Data Analysis			/		
6. Relevance to the Journal			/		

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(REVIEWER'S SECTION) REVIEWER'S COMMENTS/SUGGESTIONS		(AUTHOR'S SECTION) AUTHOR'S ACTION/RESPONSE *NOTE FOR AUTHOR: Please state your response to the reviewer's comments/suggestion below
1.	**Title** *It should reflect the article* -	Agree to the reviewer and has been revised
2.	**Abstract** *Background, Aim, Methodology and Conclusion*	
3.	**Keywords** *Min. 3 and Max. 6* -	
4.	**Introduction** *Concise with sufficient background* 1. Introduction related to drying background was enormous. Please try to make a concise statement related to such topic (detail from line 50 – 92). Some part should be in discussion. 2. P1 L39, the author mentioned "the flower contains essential oil", but the examples were terpenoids. Please correct them accordingly. 3. P2 L43, please check grammar of the sentence. 4. P2 L51, self-life must be shelf-life in this context.	L 50-92, agree to the reviewer and has been revised/and made more concise P2- L43, agree to the reviewer and has been revised
5.	**Research design/Methodology** *Clearly described and reproducible* 1. Extraction of samples, "at its boiling point for ±4 hours" it was not understandable. It should be ≥ (equal or greater than). 2. L142, it was a space between 6 and 5. Actually it must be 65. 3. The method for DPPH antioxidant activity was normally using ascorbic acid as a	

	standard. The author used gallic acid as a standard. Please provide references for such a method using by the author.	
6.	**Data Analysis** *Results well presented and discussed* 1. L174, there was no unit for drying rate. Drying rate has to show with unit. 2. L187, the author stated only antioxidant activity, while the content was phenolic content and antioxidant activity. Please correct it. 2. In 3.1 Moisture content and drying rate, there was mostly result with less discussion as well as no reference/in text citation. Please correct and discuss about drying rate/moisture content. All information was previously mentioned in introduction. Please try to correct and blend the information between two sections. 3. L219-222, the author mentioned that phenolic content and antioxidant activity was not correlated. This finding is different from other researchers. The author also mentioned that alkaloids are dominant without any supported reference. Please provide reference to support the statement. 4. From the result, rerun of the data was found that the correlation between phenolic content and antioxidant was 0.9357 which is different from the author. Please recheck and correct the result.	L174, agree to the reviewer and has been revised 3.1, agree to the reviewer and has been revised and a reference has been added
7.	**Conclusion** *A clear summary of the study* -	
8.	**References** *References should follow the journal's format* 1. italics has been found in issue number of the first reference.	Agree to the reviewer and has been revised
9.	**English Proficiency** There were a lot of mistake on writing as mentioned in each section above.	Agree to the reviewer and has been revised

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10.	**Additional comments/suggestions by the reviewer about the article** 1. According to technical term, flower has to change to inflorescence. 2. Figure 4, labeling numbers were not corresponding to the Y-axis. Please correct them.	

Overall Evaluation

Please choose one.

Accept		**Major Revision**	**/**
Minor Revision		**Reject**	

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The effect of rotary drying temperature on drying characteristic and antioxidant activity of *Etlingera elatior* Jack

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Abstract

The study was conducted to investigate the effect of drying temperature on a rotary type of dryer for drying characteristics and antioxidant activity of *Etlingera elatior* flower. This study used a lab-scale rotary dryer which was a modification of the commercial oven heater from the market. The research design was a Randomized Block Design (RCBD) with one factor, i.e. the drying temperature, which consisted of four temperature levels, 60°C, 70°C, 80°C and 90°C. All experiments were repeated six times. The results showed that the drying of *Etlingera elatior* flowers at three different temperatures (70°C, 80°C and 90°C) required a shorter drying time than that of 60°C. The drying rate of the samples at 70°C, 80°C and 90°C was drastically decreased before the 200th min, while 60°C took a long time to 380 mins. The drying rate pattern with the drying temperature of 60°C showed a significantly lower total phenolic content of *Etlingera* flowers compared to 70°C, 80°C and 90°C, while there was no significant

difference in total phenolic content among 70°C, 80°C and 90°C. In addition, different drying temperatures did not give a significant effect on the antioxidant activity based on the DPPH (2,2-diphenyl-1-picrylhydrazyl radical) method. This study proposed the effectiveness of drying using a rotary dryer in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Keywords: *Etlingera*, Rotary drying, Drying characteristics, Antioxidant

1. Introduction

Etlingera elatior Jack (ginger red/torch ginger) is a spice plant that is included in the *Zingiberaceae* family that is quite widespread in Indonesia. This herb plant can be found in several regions in Southeast Asia (Wijekoon *et al*., 2010; Nor *et al*., 2020) with different names, such as *Kincung* in Medan, Rias in North Tapanuli, *Sambuang* in Minangkabau, *Kecicang* in Bali, *Siantan* in Malaya and *Daalaa* in Thailand (Health Research and Development Agency of Indonesia, 2000; Lacumy *et al*., 2010; Nor *et al*., 2020). *Etlingera elatior* flower is potential as a food flavouring (seasoning) in cooked, sauteed, or heated (Noweg *et al*., 2003, Juwita *et al*., 2018) as in fish processing (*pepes* fish, grilled fish, and fried). Fish cooked with *Etlingera* will taste better and the fishy aroma will be reduced (Sukandar *et al*., 2011). In addition, this plant is efficacious in deodorizing body odour and bad breath (Health Research and Development Agency of Indonesia, 2000; Aldi *et al*., 2020), natural cosmetic ingredients (Chan *et al*., 2007). The profile of *E. elatior* Jack is shown in Figure 1a.

The benefits offered by *Etlingera* flower are correlated to phytochemical compounds, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides (Naufalin *et al*., 2005; Setiawati, 2018). A previous study showed that flavonoids, terpenoids, saponins, tannins, and carbohydrate compounds from *etlingera* flowers can be extracted using 80% methanol as the solvent (Lachumy *et al*., 2010). Furthermore, *E. elatior* has been described to exhibit many biological activities (Lachumy *et al*., 2010; Chan *et al*., 2009; Puttarak *et al*., 2014; Juwita *et al*., 2018; Nor *et al*., 2020; Putri, 2021).

Several investigations revealed that the phytochemical compounds of the *Etlingera* flowers have the potential of becoming a source of antioxidants. The methanolic and ethanolic extracts of them have been proven to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical (Chan *et al*., 2007). The inhibition of DPPH radical was successfully performed by *Etlingera* flowers' methanolic extract at the concentration of 9.14 mg/mL (Lachumy *et al*., 2010) as well as its aqueous extracts at the concentration

of 76.4% (Gasemzadeh *et al*., 2015). Naufalin and Rukmini (2011) also found that the *Etlingera* flower has a higher potential antioxidant activity (61.61-83.17%) than its leaf (40.64-60.40%) and stem (57.42-84.65%).

In general, fresh *etlingera* flower usually has moisture contents of more than 80%, so it is a very perishable commodity (Sagar and Kumar, 2010). The shelf life of *Etlingera* flower can be extended by reducing its moisture content using drying methods. Several drying methods, such as air-, freeze-, microwave-, vacuum-, oven- and sun-drying, have different effects on the quality of dried material. Variation of drying temperature using a specific drying method can also influence the losses or preservation of antioxidant compounds (Kamiloglu *et al*., 2016). Can *et al*. (2009) studied the effect of various drying types, such as oven drying, microwave, oven, sun drying, and freeze-drying on the antioxidant properties of *E. elatior* leaves. The total phenolic content of *E. elatior* leaves subjected to freeze-drying was found to be higher compared to other drying methods. Another study by Rohkyani and Suryani (2015) showed drying using an oven at 65°C resulted in the highest DPPH scavenging activity (66.43%) of *Etlingera* flowers compared to 85°C (56.76%).

Rotary drying is another drying method that has not been widely applied in the drying of food commodities. Delele *et al.* (2015) informed that rotary dryers are capable of processing a variety of agricultural products with a wide range of thermo-physical and flow properties, and improve the efficiency of the drying process. To the best of our knowledge, there is still few information regarding the antioxidant characteristics of *E. elatior* flowers dried using a rotary dryer.

Several studies utilized the rotary drying method to preserve food material. Kaleemullah (2005) used rotary drying to 10.5 kg chilli with an initial moisture content of 330% (dry basis) in the temperature range of 50 – 65°C. The study showed that the moisture content is reduced to 10.0% (dry basis) after being dried for 32 hrs, 27 hrs, 23 hrs, and 20 hrs at 50°C, 55°C, 60°C and 65°C, respectively. Tarhana (2010) examined the drying of 15 kg peppermint using a rotary dryer for 15 - 18 hrs and 12 – 15 hrs. Drying can cause the leaves to darken, but the essential oil content is not much different from 2.08 - 2.7 mL/100 g dry matter. The specific energy consumption values have ranged from 7.88 to 15.08 MJ/kg of moisture removed). Daily fluctuations in ambient air conditions directly affected the specific energy consumption of a rotary dryer. Ademiluyi *et al*. (2010) also uses a rotary dryer to dry fermented cassava with parameter tests, including dry air inlet temperature, dry air inlet velocity, relative humidity, feed rate, drum rotational per min and feeding. The results showed that the dry air inlet temperature, the dry air inlet velocity, and the feed rate give a significant effect on the specific heat transfer coefficient and heat load on the material.

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This study aimed to investigate the effect of rotary drying temperature on drying characteristics and antioxidant activity of *E. elatior* flowers that including moisture content, drying rate, total phenol, and DPPH free radical scavenging activity. Antioxidant activity analysis was carried out to determine the potential antioxidant activity of *Etlingera* flowers dried under different drying temperatures (60°C, 70°C, 80°C and 90ºC) using a rotary dryer. The antioxidant activity was obtained by comparing the antioxidant activity of water extract of *Etlingera* flower petal powder at various drying temperatures with gallic acid and calculating its ability to reduce DPPH free radicals based on the percentage of inhibition (% inhibition). This study used a lab-scale rotary dryer made from a modified commercial oven heater.

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2. Materials and methods

Fresh *E. elatior* flowers were obtained from the traditional market around Medan city, Indonesia. All chemicals used were of analytical grade. The DPPH (2,2-diphenyl-1-picrylhidrazyl free radical) was purchased from Sigma Aldrich Chemicals (St. Louis, Missouri, United States), gallic acid, Folin-ciocalteu phenol, sodium carbonate, methanol was obtained from Merck and Co. Pharmaceutical Company (New Jersey, United States), and aquadest was bought from PT. Surabaya Aqua Industry, Indonesia.

The petals of fresh *E. elatior* flowers were collected and the knobs were discarded. The fresh flower petals were chopped to a size of about 1 cm. For each experiment, around 400±0.1 g (Ohaus PA 224) of fresh petals was inserted into the drying basket and filled about 50% volume of the basket. Commercial electric oven (Oxone type OX-8830, 30 L in volume) with modification was pre-heated to the set temperature until a steady condition was achieved, followed by inserting the drying basket containing samples into the oven. The drying air temperatures used were 60°C, 70°C, 80°C, and 90ºC while the basket rotates at around 3 rpm. The experimental setup was shown in Figure 1b. The experimental setup is shown in Figure 1b. During the drying process, the samples were taken out, immediately weighed, and put back into the oven. The process was done periodically every 20 min until the samples reached a constant weight and the drying process was terminated. The moisture content was calculated based on a wet basis with Equation 1:

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$$\mathrm{MC}\ (\%) = \frac{\mathrm{M_{H2O}}}{\mathrm{M_{total}}} \times 100\% \quad (1)$$

Where MC = moisture content (%), M_{H2O} = mass of moisture (g) and M_{total} = mass of solid + mass of moisture (g)

The drying rate was calculated from the Equation 2:

$$\mathrm{DR}\ (\%/\mathrm{min}) = \frac{\mathrm{MC_{t0}} - \mathrm{MC_{t1}}}{\Delta t} \quad (2)$$

Where DR = drying rate (%/min), MC_{t0} = moisture content at time t (g), MC_{t1} = moisture content at t + 20 min (g) and Δt = time interval (min)

The two transfer processes simultaneously occur in thermal drying: i.e. heat or energy transfer and mass transfer. Energy transfer occurs from the environment to vaporize moisture present on the surface of a material/product. Convection heat transfer takes place due to temperature differences between the surface of the material and the dry air. Vaporization is the evaporation of moisture located on the surface of the material. When heat moves from the outside to the inside of the material, moisture that is located inside the material will diffuse out to the material's surface due to differences in moisture content.

2.1 Extraction of samples

The samples were extracted by the soxhlet extraction method (Widyawati *et al*., 2014). As much as 3 g of fresh *E. elatior* petals were wrapped in a filter paper and put into a soxhlet tube (timbre) that had been filled with 50 mL of water as the solvent. The extraction was carried out at its boiling point for 4 hrs until the solvent's colour in the timbre became colourless. The obtained extract was evaporated by a rotary evaporator under a vacuum at a temperature of 65-80°C, a pressure of 250 - 300 mbar, and a rotational speed of 40 rpm. The evaporation was run for 10 mins to obtain 2.5 mL of a concentrated extract. The concentrated extract was placed in vials and stored in the freezer until further analysis.

2.2 Total phenolic content analysis

Analysis of total phenolic content was based on the oxidation reaction of phenol compounds to produce a blue solution from reducing yellow hetero polyphosphoric molybdate tungstate anions (Muntana and Prasong, 2010). In brief, 20 µL of *Etlingera* flower extract was added to 1 mL of 10% Folin Ciocalteau reagent in a 10 mL flask bottle. The mixture was shaken and left for 5 mins Then, 2.0 mL of 7.5% Na_2CO_3 and distilled water were subsequently added to the mixture until a volume of 10 mL was achieved. The mixture was allowed to stand for 30 mins and the absorbance of the samples was measured at λ 760 nm (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples) (Siddiqui *et al.*, 2017).

2.3. DPPH free radical scavenging activity analysis

The assay of DPPH free radical scavenging activity was based on Sompong *et al.* (2011) with some modifications. As much as 3 mL of DPPH solution (4 mg/100 mL in methanol) was added to 20 µL of the extract and methanol until the volume reached 10 mL in a 10 mL flask bottle. The samples were incubated for 30 mins in a dark chamber. The absorbance of each sample was measured at λ 517 nm by a spectrophotometer (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples).

3. Results and discussion

3.1. Moisture content and drying rate

The initial moisture content of each sample for temperatures 60°C, 70°C, 80°C, and 90°C was 87.53%, 88.03%, 88.1%, and 87.53% (w/w). During the drying process, the changes in moisture content occurred as shown in Figure 3 and these changes in moisture content are proportional. As for the temperature of 60°C, the change is much slower. For each drying temperature of 90°C, 80°C, 70°C, and 60°C, the moisture content will approach 0% after 240, 260, 320, and 480 mins, respectively. The decrease in moisture content follows a straight line until the moisture content approaches 0%. The decrease indicates that the process of moisture evaporation takes place constantly for each period of measurement. The moisture content for each experiment calculated based on Equation 1 is shown in Figure 2.

The drying rate during the experiment calculated using Equation 2 is shown in Figure 3. The constant drying rate looks long enough for all types of temperatures. The constant drying period of around 220 mins was nearly the same for drying temperatures of 70°C, 80°C, and 90°C. During this period, the drying rate is around 1.25 – 30 g/min of measurement. At 60°C, the drying rate is around 0.75 g/min and lasts for about 380 mins. The duration of this constant rate period is due to the high moisture content contained in fresh *E. elatior* flowers. Moisture content for all samples was around 90% and a large amount of moisture content is present on the surface of the sample. The low thickness of the sample also allows the moisture on the inside or middle to evaporate to the surface with minimum difficulty. The fall rate period was shorter than the constant rate period, which was around 40 to 100 mins for experiments with temperatures of 90°C, 80°C, and 70°C. As for the drying temperature of 60°C, the time was around 240 mins.

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The second falling rate period has a shorter time than the previous period. A shorter time indicates that after experiencing a critical condition, the moisture content of *E. elatior* flowers will then be low. During the second falling rate period, the drying rate would be controlled by the diffusion rate of moisture from the inner surface of the sample. This process was conducted until it reached an equilibrium state or until the moisture content has completely evaporated (Nurafifah *et al*., 2018). Data in Figure 3 showed a constant drying rate lasting up to 20% of moisture content. After that, the drying rate will decrease rapidly. Moisture content in this range is a critical condition where the drying rate will be significantly influenced by the rate of moisture transportation from the centre to the surface.

3.2 Antioxidant activity

The total phenolic content describes the amount of phenol compounds present in a sample. Phenol compounds can facilitate redox reactions, thus can act as antioxidants (Johari and Khong, 2019). The total phenolic content of *Etlingera* flower powder produced using various temperatures of rotary dryer is shown in Figure 4. The results showed total phenolic content of *Etlingera* flower powder produced under the temperature of 60°C (1.216±0.146 mg gallic acid equivalent/g samples) was statistically lower from that of 70°C, 80°C, and 90°C (2.558±0.385 - 2.165±0.609 mg gallic acid equivalent/g samples). The trend of increasing total phenolic content was observed when the drying temperature increased to 70°C, followed by a decrease after the heating temperature was elevated to 90°C. However, no significant difference in total phenolic content was found from the drying temperatures of 70°C, 80°C, 90°C. The obtained results revealed that the phenolic compounds in *E. elatior* flowers were thermostable and could be maximally extracted under the drying temperature of 70°C. Zlotek *et al.* (2019) also discovered the thermostability of phenolic compounds derived from white quinoa after being subjected to drying using a single convection dryer under various drying temperatures (30°C, 40°C, 60°C). Generally, the secondary metabolites contained in plants are in the form of free metabolites or bonded to other metabolites. Vanic acid possesses a thermostable characteristic at various dry temperatures, which is similar to p-hydroxybenzoic acid, p-coumaric acid, salicylic acid, and ferulic acid. Naufalin *et al.* (2005) reported *etlingera* flowers contained phytochemical components, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. In contrast, Liaotrakoon and Liaotrakoon (2018) observed a decrease in the total phenolic content and antioxidant activity of mushrooms after being dried using an oven under the temperatures of 40°C, 50°C, and 60°C with an extended drying time. Therefore,

it can be concluded that drying using the rotary dryer with a higher temperature and longer time up to 4 hrs could maintain the total phenolic content of a material.

DPPH is a free radical that has a maximum absorbance at 517 nm in methanol. The scavenging of DPPH by the addition of antioxidants is indicated by the change in solvent's colour from purple to yellow (Sayed *et al*., 2015). The ability of *Etlingera* flowers to scavenge DPPH free radicals tended to increase along with increasing drying temperature (Figure 5). In addition, the drying process of *Etlingera* flowers using the rotary dryer with temperatures ranging from 60-90^{o}C for 4 hrs did not significantly change its DPPH scavenging activity, which indicated the ability of the rotary drying method to effectively maintain both total phenolic content and antioxidant activity of *Etlingera* flowers. On the contrary, different results from Liaotrakoon and Liaotrakoon (2018) revealed a decrease in the antioxidant activity of mushrooms after being subjected to the oven drying process.

Furthermore, no correlation was found between the antioxidant activity and the total phenolic content of *Etlingera* flowers. The coefficient determination of less than 0.95 (R^2 = 0.3318) indicated an increase in total phenolic content was not closely related to an increase in the DPPH free radical scavenging activity. This result was not in line with Piluzza and Bullitta (2011) where the DPPH and ABTS free radicals scavenging activity were positively correlated with total phenolic content with R^2 = 0.9152 and R^2 = 0.889, respectively. Gan *et al.* (2017) also noted total phenolic content was linearly correlated with antioxidant activity (iron ion reducing power, hydroxyl free radical scavenging activity and lipid oxidation inhibition activity). Khiya *et al.* (2021) added a high positive correlation between phenolic compounds and antioxidant activity (R^2 = 0.932), showing the phenolic compounds may have contributed to the antioxidant activity of *Salvia offi*cinalis leaves. This absence of correlation in this study depicted the possibility of other phytochemical compounds influencing the antioxidant activity of *Etlingera* flowers. Naufalin *et al*. (2005) and Setiawati (2018) showed that the phytochemical compounds that comprise *Etlingera* flowers are alkaloids, glycosides, phenolics, terpenoids, steroids, saponins, and flavonoids, with alkaloids as the dominant compound. Alkaloids and phenolic compounds are very important as antioxidants, with alkaloids possessing a stronger antioxidant activity. Quezada *et al.* (2004) showed the presence of alkaloids and flavonoids exhibited high antioxidant potency of Boldo (*Peumus boldus* Molina) extract. Benabdesselam *et al.* (2007) also found that total quinolizidine alkaloid contents of *Fumaria capreolata* (426 mg/100 g) and *Fumaria bastardii* (521 mg/100 g) extracts exhibited a strong total antioxidant activity.

4. Conclusion

The time required for drying *Etlingera* flowers using a rotary dryer did not much differ among the temperatures of 70°C, 80°C, and 90°C and was shorter compared to 60°C. A rapid decrease in drying rate was experienced by *Etlingera* flowers before 200 min of drying process under 70°C, 80°C, and 90°C, while longer time (380 mins) occurred when using a drying temperature of 60°C. Drying with a rotary dryer was found to effectively maintain the total phenolic content of *Etlingera* flowers, although the drying process was performed under a quite high temperature for 4 hrs. In addition, drying with rotary drying at 60 – 90°C for 4 hrs did not change the DPPH free radical scavenging activity. Accordingly, the rotary drying method was very effective in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Conflict of interest

The authors declare no conflict of interest in this research.

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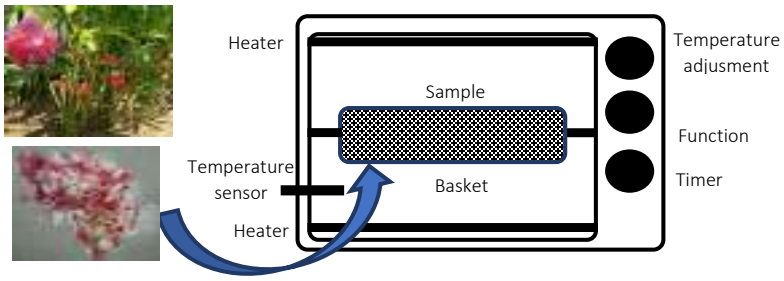

(a) (b)

Figure 1. *Etlingera elatior* Jack (a) and Rotary dryer lab-scale (b)

Figure 2. The moisture content of *Etlingera elatior* Jack flowers at various drying temperatures.

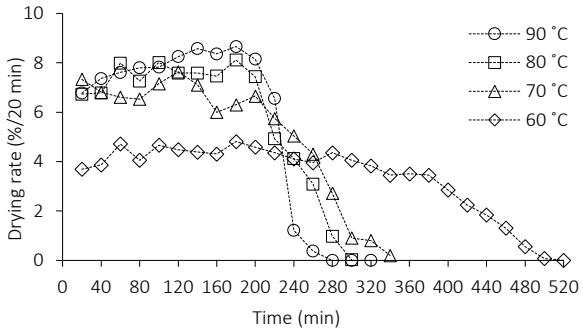

Figure 3. The drying rate of *Etlingera elatior* Jack flowers at various drying temperatures.

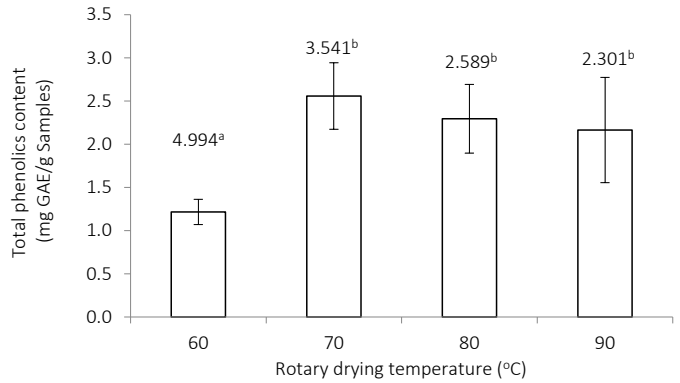

Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures. The results were presented as SD of the means that were gotten by six replicates. Means with different superscripts (alphabets) in the histogram were significantly different, $p<0.05$.

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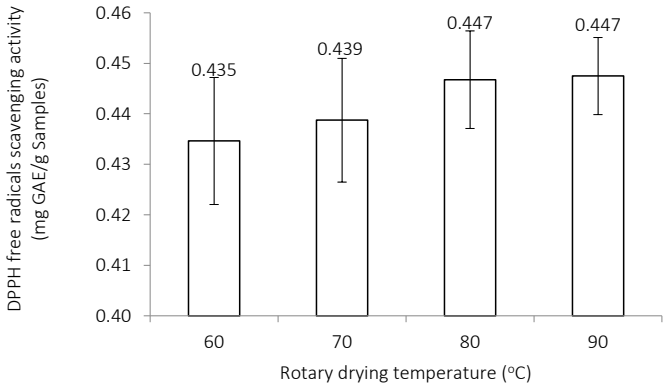

Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying temperatures.

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The effect of rotary drying temperature on drying characteristic and antioxidant activity of *Etlingera elatior* Jack

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Abstract

The study was conducted to investigate the effect of drying temperature on a rotary type of dryer for drying characteristics and antioxidant activity of *Etlingera elatior* flower. This study used a lab-scale rotary dryer which was a modification of the commercial oven heater from the market. The research design was a Randomized Block Design (RCBD) with one factor, i.e. the drying temperature, which consisted of four temperature levels, 60°C, 70°C, 80°C and 90°C. All experiments were repeated six times. The results showed that the drying of *Etlingera elatior* flowers at three different temperatures (70°C, 80°C and 90°C) required a shorter drying time than that of 60°C. The drying rate of the samples at 70°C, 80°C and 90°C was drastically decreased before the 200th min, while 60°C took a long time to 380 mins. The drying rate pattern with the drying temperature of 60°C showed a significantly lower total phenolic content of *Etlingera* flowers compared to 70°C, 80°C and 90°C, while there was no significant

difference in total phenolic content among 70°C, 80°C and 90°C. In addition, different drying temperatures did not give a significant effect on the antioxidant activity based on the DPPH (2,2-diphenyl-1-picrylhydrazyl radical) method. This study proposed the effectiveness of drying using a rotary dryer in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Keywords: *Etlingera*, Rotary drying, Drying characteristics, Antioxidant

1. Introduction

Etlingera elatior Jack (ginger red/torch ginger) is a spice plant that is included in the *Zingiberaceae* family that is quite widespread in Indonesia. This herb plant can be found in several regions in Southeast Asia (Wijekoon *et al*., 2010; Nor *et al*., 2020) with different names, such as *Kincung* in Medan, Rias in North Tapanuli, *Sambuang* in Minangkabau, *Kecicang* in Bali, *Siantan* in Malaya and *Daalaa* in Thailand (Health Research and Development Agency of Indonesia, 2000; Lacumy *et al*., 2010; Nor *et al*., 2020). *Etlingera elatior* flower is potential as a food flavouring (seasoning) in cooked, sauteed, or heated (Noweg *et al*., 2003, Juwita *et al*., 2018) as in fish processing (*pepes* fish, grilled fish, and fried). Fish cooked with *Etlingera* will taste better and the fishy aroma will be reduced (Sukandar *et al*., 2011). In addition, this plant is efficacious in deodorizing body odour and bad breath (Health Research and Development Agency of Indonesia, 2000; Aldi *et al*., 2020), natural cosmetic ingredients (Chan *et al*., 2007). The profile of *E. elatior* Jack is shown in Figure 1a.

The benefits offered by *Etlingera* flower are correlated to phytochemical compounds, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides (Naufalin *et al*., 2005; Setiawati, 2018). A previous study showed that flavonoids, terpenoids, saponins, tannins, and carbohydrate compounds from *etlingera* flowers can be extracted using 80% methanol as the solvent (Lachumy *et al*., 2010). Furthermore, *E. elatior* has been described to exhibit many biological activities (Lachumy *et al*., 2010; Chan *et al*., 2009; Puttarak *et al*., 2014; Juwita *et al*., 2018; Nor *et al*., 2020; Putri, 2021).

Several investigations revealed that the phytochemical compounds of the *Etlingera* flowers have the potential of becoming a source of antioxidants. The methanolic and ethanolic extracts of them have been proven to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical (Chan *et al*., 2007). The inhibition of DPPH radical was successfully performed by *Etlingera* flowers' methanolic extract at the concentration of 9.14 mg/mL (Lachumy *et al*., 2010) as well as its aqueous extracts at the concentration

of 76.4% (Gasemzadeh *et al*., 2015). Naufalin and Rukmini (2011) also found that the *Etlingera* flower has a higher potential antioxidant activity (61.61-83.17%) than its leaf (40.64-60.40%) and stem (57.42-84.65%).

In general, fresh *etlingera* flower usually has moisture contents of more than 80%, so it is a very perishable commodity (Sagar and Kumar, 2010). The shelf life of *Etlingera* flower can be extended by reducing its moisture content using drying methods. Several drying methods, such as air-, freeze-, microwave-, vacuum-, oven- and sun-drying, have different effects on the quality of dried material. Variation of drying temperature using a specific drying method can also influence the losses or preservation of antioxidant compounds (Kamiloglu *et al*., 2016). Can *et al*. (2009) studied the effect of various drying types, such as oven drying, microwave, oven, sun drying, and freeze-drying on the antioxidant properties of *E. elatior* leaves. The total phenolic content of *E. elatior* leaves subjected to freeze-drying was found to be higher compared to other drying methods. Another study by Rohkyani and Suryani (2015) showed drying using an oven at 65^{o}C resulted in the highest DPPH scavenging activity (66.43%) of *Etlingera* flowers compared to 85^{o}C (56.76%).

Rotary drying is another drying method that has not been widely applied in the drying of food commodities. Delele *et al.* (2015) informed that rotary dryers are capable of processing a variety of agricultural products with a wide range of thermo-physical and flow properties, and improve the efficiency of the drying process. To the best of our knowledge, there is still few information regarding the antioxidant characteristics of *E. elatior* flowers dried using a rotary dryer.

Several studies utilized the rotary drying method to preserve food material. Kaleemullah (2005) used rotary drying to 10.5 kg chilli with an initial moisture content of 330% (dry basis) in the temperature range of 50 – 65^{o}C. The study showed that the moisture content is reduced to 10.0% (dry basis) after being dried for 32 hrs, 27 hrs, 23 hrsand 20 hrs at 50°C, 55°C, 60°C and 65°C, respectively. Tarhana (2010) examined the drying of 15 kg peppermint using a rotary dryer for 15 - 18 hrs and 12 – 15 hrs. Drying can cause the leaves to darken, but the essential oil content is not much different from 2.08 - 2.7 mL/100 g dry matter. The specific energy consumption values have ranged from 7.88 to 15.08 MJ/kg of moisture removed). Daily fluctuations in ambient air conditions directly affected the specific energy consumption of a rotary dryer. Ademiluyi *et al*. (2010) also uses a rotary dryer to dry fermented cassava with parameter tests, including dry air inlet temperature, dry air inlet velocity, relative humidity, feed rate, drum rotational per min and feeding. The results showed that the dry air inlet temperature, the dry air inlet velocity, and the feed rate give a significant effect on the specific heat transfer coefficient and heat load on the material.

This study aimed to investigate the effect of rotary drying temperature on drying characteristics and antioxidant activity of *E. elatior* flowers that including moisture content, drying rate, total phenol, and DPPH free radical scavenging activity. Antioxidant activity analysis was carried out to determine the potential antioxidant activity of *Etlingera* flowers dried under different drying temperatures (60°C, 70°C, 80°C and 90°C) using a rotary dryer. The antioxidant activity was obtained by comparing the antioxidant activity of water extract of *Etlingera* flower petal powder at various drying temperatures with gallic acid and calculating its ability to reduce DPPH free radicals based on the percentage of inhibition (% inhibition). This study used a lab-scale rotary dryer made from a modified commercial oven heater.

2. Materials and methods

Fresh *E. elatior* flowers were obtained from the traditional market around Medan city, Indonesia. All chemicals used were of analytical grade. The DPPH (2,2-diphenyl-1-picrylhidrazyl free radical) was purchased from Sigma Aldrich Chemicals (St. Louis, Missouri, United States), gallic acid, Folin-ciocalteu phenol, sodium carbonate, methanol was obtained from Merck and Co. Pharmaceutical Company (New Jersey, United States), and aquadest was bought from PT. Surabaya Aqua Industry, Indonesia.

The petals of fresh *E. elatior* flowers were collected and the knobs were discarded. The fresh flower petals were chopped to a size of about 1 cm. For each experiment, around 400±0.1 g (Ohaus PA 224) of fresh petals was inserted into the drying basket and filled about 50% volume of the basket. Commercial electric oven (Oxone type OX-8830, 30 L in volume) with modification was pre-heated to the set temperature until a steady condition was achieved, followed by inserting the drying basket containing samples into the oven. The drying air temperatures used were 60°C, 70°C, 80°C and 90°C while the basket rotates at around 3 rpm. The experimental setup was shown in Figure 1b. The experimental setup is shown in Figure 1b. During the drying process, the samples were taken out, immediately weighed, and put back into the oven. The process was done periodically every 20 min until the samples reached a constant weight and the drying process was terminated. The moisture content was calculated based on a wet basis with Equation 1:

$$\mathrm{MC}\ (\%) = \frac{\mathrm{M_{H2O}}}{\mathrm{M_{total}}} \times 100\% \quad (1)$$

Where MC = moisture content (%), M_{H2O} = mass of moisture (g) and M_{total} = mass of solid + mass of moisture (g)

The drying rate was calculated from the Equation 2:

$$\mathrm{DR}\ (\%/\mathrm{min}) = \frac{\mathrm{MC_{t0}} - \mathrm{MC_{t1}}}{\Delta t} \quad (2)$$

Where DR = drying rate (%/min), MC_{t0} = moisture content at time t (g), MC_{t1} = moisture content at t + 20 min (g) and Δt = time interval (min)

The two transfer processes simultaneously occur in thermal drying: i.e. heat or energy transfer and mass transfer. Energy transfer occurs from the environment to vaporize moisture present on the surface of a material/product. Convection heat transfer takes place due to temperature differences between the surface of the material and the dry air. Vaporization is the evaporation of moisture located on the surface of the material. When heat moves from the outside to the inside of the material, moisture that is located inside the material will diffuse out to the material's surface due to differences in moisture content.

2.1 Extraction of samples

The samples were extracted by the soxhlet extraction method (Widyawati *et al*., 2014). As much as 3 g of fresh *E. elatior* petals were wrapped in a filter paper and put into a soxhlet tube (timbre) that had been filled with 50 mL of water as the solvent. The extraction was carried out at its boiling point for 4 hrs until the solvent's colour in the timbre became colourless. The obtained extract was evaporated by a rotary evaporator under a vacuum at a temperature of 65-80°C, a pressure of 250 - 300 mbar, and a rotational speed of 40 rpm. The evaporation was run for 10 mins to obtain 2.5 mL of a concentrated extract. The concentrated extract was placed in vials and stored in the freezer until further analysis.

2.2 Total phenolic content analysis

Analysis of total phenolic content was based on the oxidation reaction of phenol compounds to produce a blue solution from reducing yellow hetero polyphosphoric molybdate tungstate anions (Muntana and Prasong, 2010). In brief, 20 µL of *Etlingera* flower extract was added to 1 mL of 10% Folin Ciocalteau reagent in a 10 mL flask bottle. The mixture was shaken and left for 5 mins Then, 2.0 mL of 7.5% Na_2CO_3 and distilled water were subsequently added to the mixture until a volume of 10 mL was achieved. The mixture was allowed to stand for 30 mins and the absorbance of the samples was measured at λ 760 nm (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples) (Siddiqui *et al.*, 2017).

2.3. DPPH free radical scavenging activity analysis

The assay of DPPH free radical scavenging activity was based on Sompong *et al.* (2011) with some modifications. As much as 3 mL of DPPH solution (4 mg/100 mL in methanol) was added to 20 µL of the extract and methanol until the volume reached 10 mL in a 10 mL flask bottle. The samples were incubated for 30 mins in a dark chamber. The absorbance of each sample was measured at λ 517 nm by a spectrophotometer (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples).

3. Results and discussion

3.1. Moisture content and drying rate

The initial moisture content of each sample for temperatures 60°C, 70°C, 80°C and 90°C was 87.53%, 88.03%, 88.1% and 87.53% (w/w). During the drying process, the changes in moisture content occurred as shown in Figure 3 and these changes in moisture content are proportional. As for the temperature of 60°C, the change is much slower. For each drying temperature of 90°C, 80°C, 70°C and 60°C, the moisture content will approach 0% after 240, 260, 320 and 480 mins, respectively. The decrease in moisture content follows a straight line until the moisture content approaches 0%. The decrease indicates that the process of moisture evaporation takes place constantly for each period of measurement. The moisture content for each experiment calculated based on Equation 1 is shown in Figure 2.

The drying rate during the experiment calculated using Equation 2 is shown in Figure 3. The constant drying rate looks long enough for all types of temperatures. The constant drying period of around 220 mins was nearly the same for drying temperatures of 70°C, 80°C and 90°C. During this period, the drying rate is around 1.25 – 30 g/min of measurement. At 60°C, the drying rate is around 0.75 g/min and lasts for about 380 mins. The duration of this constant rate period is due to the high moisture content contained in fresh *E. elatior* flowers. Moisture content for all samples was around 90% and a large amount of moisture content is present on the surface of the sample. The low thickness of the sample also allows the moisture on the inside or middle to evaporate to the surface with minimum difficulty. The fall rate period was shorter than the constant rate period, which was around 40 to 100 mins for experiments with temperatures of 90 °C, 80 °C, and 70°C. As for the drying temperature of 60°C, the time was around 240 mins.

The second falling rate period has a shorter time than the previous period. A shorter time indicates that after experiencing a critical condition, the moisture content of *E. elatior* flowers will then be low. During the second falling rate period, the drying rate would be controlled by the diffusion rate of moisture from the inner surface of the sample. This process was conducted until it reached an equilibrium state or until the moisture content has completely evaporated (Nurafifah *et al*., 2018). Data in Figure 3 showed a constant drying rate lasting up to 20% of moisture content. After that, the drying rate will decrease rapidly. Moisture content in this range is a critical condition where the drying rate will be significantly influenced by the rate of moisture transportation from the centre to the surface.

3.2 Antioxidant activity

The total phenolic content describes the amount of phenol compounds present in a sample. Phenol compounds can facilitate redox reactions, thus can act as antioxidants (Johari and Khong, 2019). The total phenolic content of *Etlingera* flower powder produced using various temperatures of rotary dryer is shown in Figure 4. The results showed total phenolic content of *Etlingera* flower powder produced under the temperature of 60°C (1.216±0.146 mg gallic acid equivalent/g samples) was statistically lower from that of 70°C, 80°C, and 90°C (2.558±0.385 - 2.165±0.609 mg gallic acid equivalent/g samples). The trend of increasing total phenolic content was observed when the drying temperature increased to 70°C, followed by a decrease after the heating temperature was elevated to 90°C. However, no significant difference in total phenolic content was found from the drying temperatures of 70°C, 80°C, 90°C. The obtained results revealed that the phenolic compounds in *E. elatior* flowers were thermostable and could be maximally extracted under the drying temperature of 70°C. Zlotek *et al.* (2019) also discovered the thermostability of phenolic compounds derived from white quinoa after being subjected to drying using a single convection dryer under various drying temperatures (30°C, 40°C, 60°C). Generally, the secondary metabolites contained in plants are in the form of free metabolites or bonded to other metabolites. Vanic acid possesses a thermostable characteristic at various dry temperatures, which is similar to p-hydroxybenzoic acid, p-coumaric acid, salicylic acid, and ferulic acid. Naufalin *et al.* (2005) reported *etlingera* flowers contained phytochemical components, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. In contrast, Liaotrakoon and Liaotrakoon (2018) observed a decrease in the total phenolic content and antioxidant activity of mushrooms after being dried using an oven under the temperatures of 40°C, 50°C, and 60°C with an extended drying time. Therefore,

it can be concluded that drying using the rotary dryer with a higher temperature and longer time up to 4 hrs could maintain the total phenolic content of a material.

DPPH is a free radical that has a maximum absorbance at 517 nm in methanol. The scavenging of DPPH by the addition of antioxidants is indicated by the change in solvent's colour from purple to yellow (Sayed *et al*., 2015). The ability of *Etlingera* flowers to scavenge DPPH free radicals tended to increase along with increasing drying temperature (Figure 5). In addition, the drying process of *Etlingera* flowers using the rotary dryer with temperatures ranging from 60-90^{o}C for 4 hrs did not significantly change its DPPH scavenging activity, which indicated the ability of the rotary drying method to effectively maintain both total phenolic content and antioxidant activity of *Etlingera* flowers. On the contrary, different results from Liaotrakoon and Liaotrakoon (2018) revealed a decrease in the antioxidant activity of mushrooms after being subjected to the oven drying process.

Furthermore, no correlation was found between the antioxidant activity and the total phenolic content of *Etlingera* flowers. The coefficient determination of less than 0.95 (R^2 = 0.3318) indicated an increase in total phenolic content was not closely related to an increase in the DPPH free radical scavenging activity. This result was not in line with Piluzza and Bullitta (2011) where the DPPH and ABTS free radicals scavenging activity were positively correlated with total phenolic content with R^2 = 0.9152 and R^2 = 0.889, respectively. Gan *et al.* (2017) also noted total phenolic content was linearly correlated with antioxidant activity (iron ion reducing power, hydroxyl free radical scavenging activity and lipid oxidation inhibition activity). Khiya *et al.* (2021) added a high positive correlation between phenolic compounds and antioxidant activity (R^2 = 0.932), showing the phenolic compounds may have contributed to the antioxidant activity of *Salvia offi*cinalis leaves. This absence of correlation in this study depicted the possibility of other phytochemical compounds influencing the antioxidant activity of *Etlingera* flowers. Naufalin *et al*. (2005) and Setiawati (2018) showed that the phytochemical compounds that comprise *Etlingera* flowers are alkaloids, glycosides, phenolics, terpenoids, steroids, saponins, and flavonoids, with alkaloids as the dominant compound. Alkaloids and phenolic compounds are very important as antioxidants, with alkaloids possessing a stronger antioxidant activity. Quezada *et al.* (2004) showed the presence of alkaloids and flavonoids exhibited high antioxidant potency of Boldo (*Peumus boldus* Molina) extract. Benabdesselam *et al.* (2007) also found that total quinolizidine alkaloid contents of *Fumaria capreolata* (426 mg/100 g) and *Fumaria bastardii* (521 mg/100 g) extracts exhibited a strong total antioxidant activity.

4. Conclusion

The time required for drying *Etlingera* flowers using a rotary dryer did not much differ among the temperatures of 70°C, 80°C, and 90°C and was shorter compared to 60°C. A rapid decrease in drying rate was experienced by *Etlingera* flowers before 200 min of drying process under 70°C, 80°C, and 90°C, while longer time (380 mins) occurred when using a drying temperature of 60°C. Drying with a rotary dryer was found to effectively maintain the total phenolic content of *Etlingera* flowers, although the drying process was performed under a quite high temperature for 4 hrs. In addition, drying with rotary drying at 60 – 90°C for 4 hrs did not change the DPPH free radical scavenging activity. Accordingly, the rotary drying method was very effective in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Conflict of interest

The authors declare no conflict of interest in this research.

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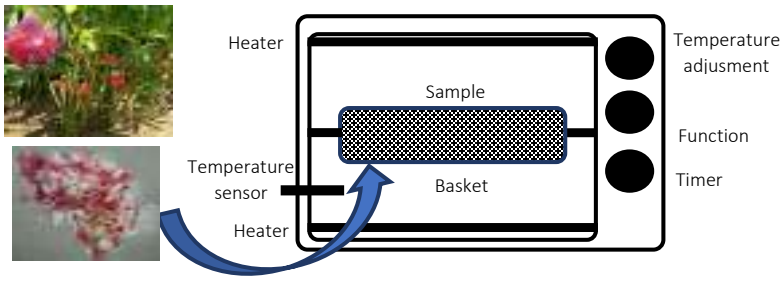

(a) (b)

Figure 1. *Etlingera elatior* Jack (a) and Rotary dryer lab-scale (b)

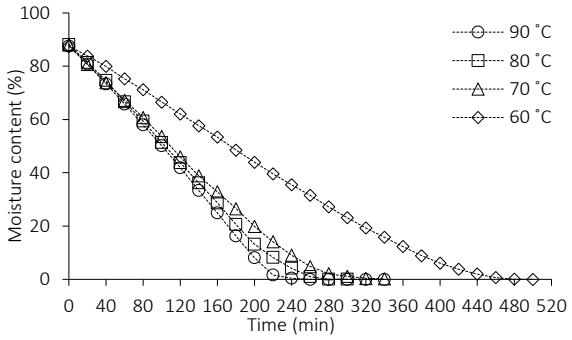

Figure 2. The moisture content of *Etlingera elatior* Jack flowers at various drying temperatures.

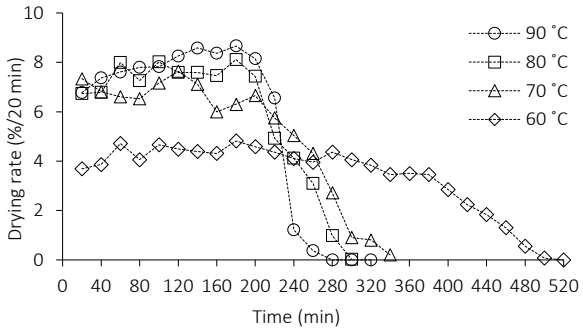

Figure 3. The drying rate of *Etlingera elatior* Jack flowers at various drying temperatures.

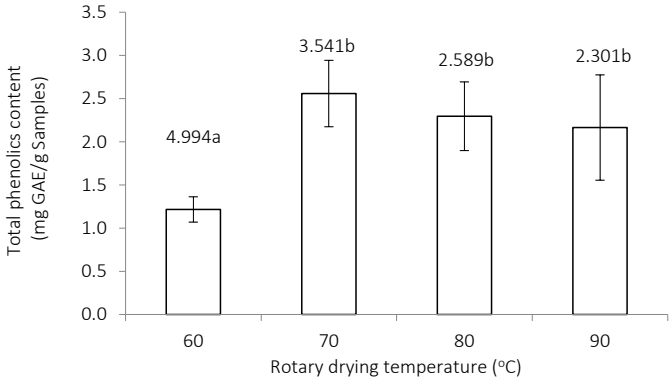

Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures.

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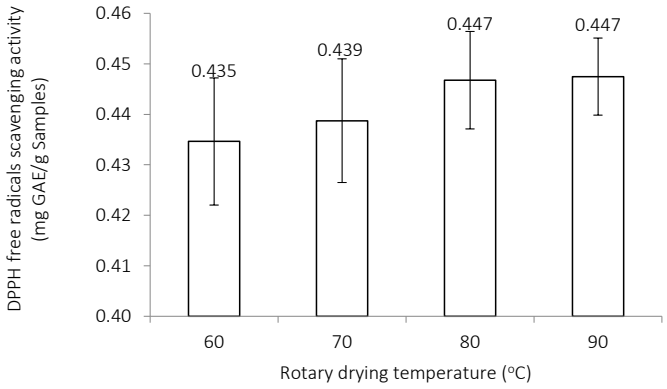

Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying temperatures.

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The effect of rotary drying temperature on drying characteristic and antioxidant activity of *Etlingera elatior* Jack

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Abstract

The study was conducted to investigate the effect of drying temperature on a rotary type of dryer for drying characteristics and antioxidant activity of *Etlingera elatior* flower. This study used a lab-scale rotary dryer which was a modification of the commercial oven heater from the market. The research design was a Randomized Block Design (RCBD) with one factor, i.e. the drying temperature, which consisted of four temperature levels, 60°C, 70°C, 80°C and 90°C. All experiments were repeated six times. The results showed that the drying of *Etlingera elatior* flowers at three different temperatures (70°C, 80°C and 90°C) required a shorter drying time than that of 60°C. The drying rate of the samples at 70°C, 80°C and 90°C was drastically decreased before the 200th min, while 60°C took a long time to 380 mins. The drying rate pattern with the drying temperature of 60°C showed a significantly lower total phenolic content of *Etlingera* flowers compared to 70°C, 80°C and 90°C, while there was no significant

difference in total phenolic content among 70°C, 80°C and 90°C. In addition, different drying temperatures did not give a significant effect on the antioxidant activity based on the DPPH (2,2-diphenyl-1-picrylhydrazyl radical) method. This study proposed the effectiveness of drying using a rotary dryer in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Keywords: *Etlingera*, Rotary drying, Drying characteristics, Antioxidant

1. Introduction

Etlingera elatior Jack (ginger red/torch ginger) is a spice plant that is included in the *Zingiberaceae* family that is quite widespread in Indonesia. This herb plant can be found in several regions in Southeast Asia (Wijekoon *et al*., 2010; Nor *et al*., 2020) with different names, such as *Kincung* in Medan, Rias in North Tapanuli, *Sambuang* in Minangkabau, *Kecicang* in Bali, *Siantan* in Malaya and *Daalaa* in Thailand (Health Research and Development Agency of Indonesia, 2000; Lacumy *et al*., 2010; Nor *et al*., 2020). *Etlingera elatior* flower is potential as a food flavouring (seasoning) in cooked, sauteed, or heated (Noweg *et al*., 2003, Juwita *et al*., 2018) as in fish processing (*pepes* fish, grilled fish, and fried). Fish cooked with *Etlingera* will taste better and the fishy aroma will be reduced (Sukandar *et al*., 2011). In addition, this plant is efficacious in deodorizing body odour and bad breath (Health Research and Development Agency of Indonesia, 2000; Aldi *et al*., 2020), natural cosmetic ingredients (Chan *et al*., 2007). The profile of *E. elatior* Jack is shown in Figure 1a.

The benefits offered by *Etlingera* flower are correlated to phytochemical compounds, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides (Naufalin *et al*., 2005; Setiawati, 2018). A previous study showed that flavonoids, terpenoids, saponins, tannins, and carbohydrate compounds from *etlingera* flowers can be extracted using 80% methanol as the solvent (Lachumy *et al*., 2010). Furthermore, *E. elatior* has been described to exhibit many biological activities (Lachumy *et al*., 2010; Chan *et al*., 2009; Puttarak *et al*., 2014; Juwita *et al*., 2018; Nor *et al*., 2020; Putri, 2021).

Several investigations revealed that the phytochemical compounds of the *Etlingera* flowers have the potential of becoming a source of antioxidants. The methanolic and ethanolic extracts of them have been proven to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical (Chan *et al*., 2007). The inhibition of DPPH radical was successfully performed by *Etlingera* flowers' methanolic extract at the concentration of 9.14 mg/mL (Lachumy *et al*., 2010) as well as its aqueous extracts at the concentration

of 76.4% (Gasemzadeh *et al*., 2015). Naufalin and Rukmini (2011) also found that the *Etlingera* flower has a higher potential antioxidant activity (61.61-83.17%) than its leaf (40.64-60.40%) and stem (57.42-84.65%).

In general, fresh *etlingera* flower usually has moisture contents of more than 80%, so it is a very perishable commodity (Sagar and Kumar, 2010). The shelf life of *Etlingera* flower can be extended by reducing its moisture content using drying methods. Several drying methods, such as air-, freeze-, microwave-, vacuum-, oven- and sun-drying, have different effects on the quality of dried material. Variation of drying temperature using a specific drying method can also influence the losses or preservation of antioxidant compounds (Kamiloglu *et al*., 2016). Can *et al*. (2009) studied the effect of various drying types, such as oven drying, microwave, oven, sun drying, and freeze-drying on the antioxidant properties of *E. elatior* leaves. The total phenolic content of *E. elatior* leaves subjected to freeze-drying was found to be higher compared to other drying methods. Another study by Rohkyani and Suryani (2015) showed drying using an oven at 65°C resulted in the highest DPPH scavenging activity (66.43%) of *Etlingera* flowers compared to 85°C (56.76%).

Rotary drying is another drying method that has not been widely applied in the drying of food commodities. Delele *et al.* (2015) informed that rotary dryers are capable of processing a variety of agricultural products with a wide range of thermo-physical and flow properties, and improve the efficiency of the drying process. To the best of our knowledge, there is still few information regarding the antioxidant characteristics of *E. elatior* flowers dried using a rotary dryer.

Several studies utilized the rotary drying method to preserve food material. Kaleemullah (2005) used rotary drying to 10.5 kg chilli with an initial moisture content of 330% (dry basis) in the temperature range of 50 – 65°C. The study showed that the moisture content is reduced to 10.0% (dry basis) after being dried for 32 hrs, 27 hrs, 23 hrs, and 20 hrs at 50°C, 55°C, 60°C and 65°C, respectively. Tarhana (2010) examined the drying of 15 kg peppermint using a rotary dryer for 15 - 18 hrs and 12 – 15 hrs. Drying can cause the leaves to darken, but the essential oil content is not much different from 2.08 - 2.7 mL/100 g dry matter. The specific energy consumption values have ranged from 7.88 to 15.08 MJ/kg of moisture removed). Daily fluctuations in ambient air conditions directly affected the specific energy consumption of a rotary dryer. Ademiluyi *et al*. (2010) also uses a rotary dryer to dry fermented cassava with parameter tests, including dry air inlet temperature, dry air inlet velocity, relative humidity, feed rate, drum rotational per min and feeding. The results showed that the dry air inlet temperature, the dry air inlet velocity, and the feed rate give a significant effect on the specific heat transfer coefficient and heat load on the material.

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This study aimed to investigate the effect of rotary drying temperature on drying characteristics and antioxidant activity of *E. elatior* flowers that including moisture content, drying rate, total phenol, and DPPH free radical scavenging activity. Antioxidant activity analysis was carried out to determine the potential antioxidant activity of *Etlingera* flowers dried under different drying temperatures (60°C, 70°C, 80°C and 90ºC) using a rotary dryer. The antioxidant activity was obtained by comparing the antioxidant activity of water extract of *Etlingera* flower petal powder at various drying temperatures with gallic acid and calculating its ability to reduce DPPH free radicals based on the percentage of inhibition (% inhibition). This study used a lab-scale rotary dryer made from a modified commercial oven heater.

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2. Materials and methods

Fresh *E. elatior* flowers were obtained from the traditional market around Medan city, Indonesia. All chemicals used were of analytical grade. The DPPH (2,2-diphenyl-1-picrylhidrazyl free radical) was purchased from Sigma Aldrich Chemicals (St. Louis, Missouri, United States), gallic acid, Folin-ciocalteu phenol, sodium carbonate, methanol was obtained from Merck and Co. Pharmaceutical Company (New Jersey, United States), and aquadest was bought from PT. Surabaya Aqua Industry, Indonesia.

The petals of fresh *E. elatior* flowers were collected and the knobs were discarded. The fresh flower petals were chopped to a size of about 1 cm. For each experiment, around 400±0.1 g (Ohaus PA 224) of fresh petals was inserted into the drying basket and filled about 50% volume of the basket. Commercial electric oven (Oxone type OX-8830, 30 L in volume) with modification was pre-heated to the set temperature until a steady condition was achieved, followed by inserting the drying basket containing samples into the oven. The drying air temperatures used were 60°C, 70°C, 80°C, and 90ºC while the basket rotates at around 3 rpm. The experimental setup was shown in Figure 1b. The experimental setup is shown in Figure 1b. During the drying process, the samples were taken out, immediately weighed, and put back into the oven. The process was done periodically every 20 min until the samples reached a constant weight and the drying process was terminated. The moisture content was calculated based on a wet basis with Equation 1:

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$$\mathrm{MC}\ (\%) = \frac{\mathrm{M_{H2O}}}{\mathrm{M_{total}}} \times 100\% \quad (1)$$

Where MC = moisture content (%), M_{H2O} = mass of moisture (g) and M_{total} = mass of solid + mass of moisture (g)

The drying rate was calculated from the Equation 2:

$$\mathrm{DR}\ (\%/\mathrm{min}) = \frac{\mathrm{MC_{t0}} - \mathrm{MC_{t1}}}{\Delta t} \quad (2)$$

Where DR = drying rate (%/min), MC_{t0} = moisture content at time t (g), MC_{t1} = moisture content at t + 20 min (g) and Δt = time interval (min)

The two transfer processes simultaneously occur in thermal drying: i.e. heat or energy transfer and mass transfer. Energy transfer occurs from the environment to vaporize moisture present on the surface of a material/product. Convection heat transfer takes place due to temperature differences between the surface of the material and the dry air. Vaporization is the evaporation of moisture located on the surface of the material. When heat moves from the outside to the inside of the material, moisture that is located inside the material will diffuse out to the material's surface due to differences in moisture content.

2.1 Extraction of samples

The samples were extracted by the soxhlet extraction method (Widyawati *et al*., 2014). As much as 3 g of fresh *E. elatior* petals were wrapped in a filter paper and put into a soxhlet tube (timbre) that had been filled with 50 mL of water as the solvent. The extraction was carried out at its boiling point for 4 hrs until the solvent's colour in the timbre became colourless. The obtained extract was evaporated by a rotary evaporator under a vacuum at a temperature of 65-80°C, a pressure of 250 - 300 mbar, and a rotational speed of 40 rpm. The evaporation was run for 10 mins to obtain 2.5 mL of a concentrated extract. The concentrated extract was placed in vials and stored in the freezer until further analysis.

2.2 Total phenolic content analysis

Analysis of total phenolic content was based on the oxidation reaction of phenol compounds to produce a blue solution from reducing yellow hetero polyphosphoric molybdate tungstate anions (Muntana and Prasong, 2010). In brief, 20 µL of *Etlingera* flower extract was added to 1 mL of 10% Folin Ciocalteau reagent in a 10 mL flask bottle. The mixture was shaken and left for 5 mins Then, 2.0 mL of 7.5% Na_2CO_3 and distilled water were subsequently added to the mixture until a volume of 10 mL was achieved. The mixture was allowed to stand for 30 mins and the absorbance of the samples was measured at λ 760 nm (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples) (Siddiqui *et al.*, 2017).

2.3. DPPH free radical scavenging activity analysis

The assay of DPPH free radical scavenging activity was based on Sompong *et al.* (2011) with some modifications. As much as 3 mL of DPPH solution (4 mg/100 mL in methanol) was added to 20 µL of the extract and methanol until the volume reached 10 mL in a 10 mL flask bottle. The samples were incubated for 30 mins in a dark chamber. The absorbance of each sample was measured at λ 517 nm by a spectrophotometer (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples).

3. Results and discussion

3.1. Moisture content and drying rate

The initial moisture content of each sample for temperatures 60°C, 70°C, 80°C, and 90°C was 87.53%, 88.03%, 88.1%, and 87.53% (w/w). During the drying process, the changes in moisture content occurred as shown in Figure 3 and these changes in moisture content are proportional. As for the temperature of 60°C, the change is much slower. For each drying temperature of 90°C, 80°C, 70°C, and 60°C, the moisture content will approach 0% after 240, 260, 320, and 480 mins, respectively. The decrease in moisture content follows a straight line until the moisture content approaches 0%. The decrease indicates that the process of moisture evaporation takes place constantly for each period of measurement. The moisture content for each experiment calculated based on Equation 1 is shown in Figure 2.

The drying rate during the experiment calculated using Equation 2 is shown in Figure 3. The constant drying rate looks long enough for all types of temperatures. The constant drying period of around 220 mins was nearly the same for drying temperatures of 70°C, 80°C, and 90°C. During this period, the drying rate is around 1.25 – 30 g/min of measurement. At 60°C, the drying rate is around 0.75 g/min and lasts for about 380 mins. The duration of this constant rate period is due to the high moisture content contained in fresh *E. elatior* flowers. Moisture content for all samples was around 90% and a large amount of moisture content is present on the surface of the sample. The low thickness of the sample also allows the moisture on the inside or middle to evaporate to the surface with minimum difficulty. The fall rate period was shorter than the constant rate period, which was around 40 to 100 mins for experiments with temperatures of 90°C, 80°C, and 70°C. As for the drying temperature of 60°C, the time was around 240 mins.

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The second falling rate period has a shorter time than the previous period. A shorter time indicates that after experiencing a critical condition, the moisture content of *E. elatior* flowers will then be low. During the second falling rate period, the drying rate would be controlled by the diffusion rate of moisture from the inner surface of the sample. This process was conducted until it reached an equilibrium state or until the moisture content has completely evaporated (Nurafifah *et al*., 2018). Data in Figure 3 showed a constant drying rate lasting up to 20% of moisture content. After that, the drying rate will decrease rapidly. Moisture content in this range is a critical condition where the drying rate will be significantly influenced by the rate of moisture transportation from the centre to the surface.

3.2 Antioxidant activity

The total phenolic content describes the amount of phenol compounds present in a sample. Phenol compounds can facilitate redox reactions, thus can act as antioxidants (Johari and Khong, 2019). The total phenolic content of *Etlingera* flower powder produced using various temperatures of rotary dryer is shown in Figure 4. The results showed total phenolic content of *Etlingera* flower powder produced under the temperature of 60°C (1.216±0.146 mg gallic acid equivalent/g samples) was statistically lower from that of 70°C, 80°C, and 90°C (2.558±0.385 - 2.165±0.609 mg gallic acid equivalent/g samples). The trend of increasing total phenolic content was observed when the drying temperature increased to 70°C, followed by a decrease after the heating temperature was elevated to 90°C. However, no significant difference in total phenolic content was found from the drying temperatures of 70°C, 80°C, 90°C. The obtained results revealed that the phenolic compounds in *E. elatior* flowers were thermostable and could be maximally extracted under the drying temperature of 70°C. Zlotek *et al.* (2019) also discovered the thermostability of phenolic compounds derived from white quinoa after being subjected to drying using a single convection dryer under various drying temperatures (30°C, 40°C, 60°C). Generally, the secondary metabolites contained in plants are in the form of free metabolites or bonded to other metabolites. Vanic acid possesses a thermostable characteristic at various dry temperatures, which is similar to p-hydroxybenzoic acid, p-coumaric acid, salicylic acid, and ferulic acid. Naufalin *et al.* (2005) reported *etlingera* flowers contained phytochemical components, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. In contrast, Liaotrakoon and Liaotrakoon (2018) observed a decrease in the total phenolic content and antioxidant activity of mushrooms after being dried using an oven under the temperatures of 40°C, 50°C, and 60°C with an extended drying time. Therefore,

it can be concluded that drying using the rotary dryer with a higher temperature and longer time up to 4 hrs could maintain the total phenolic content of a material.

DPPH is a free radical that has a maximum absorbance at 517 nm in methanol. The scavenging of DPPH by the addition of antioxidants is indicated by the change in solvent's colour from purple to yellow (Sayed *et al*., 2015). The ability of *Etlingera* flowers to scavenge DPPH free radicals tended to increase along with increasing drying temperature (Figure 5). In addition, the drying process of *Etlingera* flowers using the rotary dryer with temperatures ranging from 60-90^{o}C for 4 hrs did not significantly change its DPPH scavenging activity, which indicated the ability of the rotary drying method to effectively maintain both total phenolic content and antioxidant activity of *Etlingera* flowers. On the contrary, different results from Liaotrakoon and Liaotrakoon (2018) revealed a decrease in the antioxidant activity of mushrooms after being subjected to the oven drying process.

Furthermore, no correlation was found between the antioxidant activity and the total phenolic content of *Etlingera* flowers. The coefficient determination of less than 0.95 (R^2 = 0.3318) indicated an increase in total phenolic content was not closely related to an increase in the DPPH free radical scavenging activity. This result was not in line with Piluzza and Bullitta (2011) where the DPPH and ABTS free radicals scavenging activity were positively correlated with total phenolic content with R^2 = 0.9152 and R^2 = 0.889, respectively. Gan *et al.* (2017) also noted total phenolic content was linearly correlated with antioxidant activity (iron ion reducing power, hydroxyl free radical scavenging activity and lipid oxidation inhibition activity). Khiya *et al.* (2021) added a high positive correlation between phenolic compounds and antioxidant activity (R^2 = 0.932), showing the phenolic compounds may have contributed to the antioxidant activity of *Salvia offi*cinalis leaves. This absence of correlation in this study depicted the possibility of other phytochemical compounds influencing the antioxidant activity of *Etlingera* flowers. Naufalin *et al*. (2005) and Setiawati (2018) showed that the phytochemical compounds that comprise *Etlingera* flowers are alkaloids, glycosides, phenolics, terpenoids, steroids, saponins, and flavonoids, with alkaloids as the dominant compound. Alkaloids and phenolic compounds are very important as antioxidants, with alkaloids possessing a stronger antioxidant activity. Quezada *et al.* (2004) showed the presence of alkaloids and flavonoids exhibited high antioxidant potency of Boldo (*Peumus boldus* Molina) extract. Benabdesselam *et al.* (2007) also found that total quinolizidine alkaloid contents of *Fumaria capreolata* (426 mg/100 g) and *Fumaria bastardii* (521 mg/100 g) extracts exhibited a strong total antioxidant activity.

4. Conclusion

The time required for drying *Etlingera* flowers using a rotary dryer did not much differ among the temperatures of 70°C, 80°C, and 90°C and was shorter compared to 60°C. A rapid decrease in drying rate was experienced by *Etlingera* flowers before 200 min of drying process under 70°C, 80°C, and 90°C, while longer time (380 mins) occurred when using a drying temperature of 60°C. Drying with a rotary dryer was found to effectively maintain the total phenolic content of *Etlingera* flowers, although the drying process was performed under a quite high temperature for 4 hrs. In addition, drying with rotary drying at 60 – 90°C for 4 hrs did not change the DPPH free radical scavenging activity. Accordingly, the rotary drying method was very effective in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Conflict of interest

The authors declare no conflict of interest in this research.

Acknowledgement

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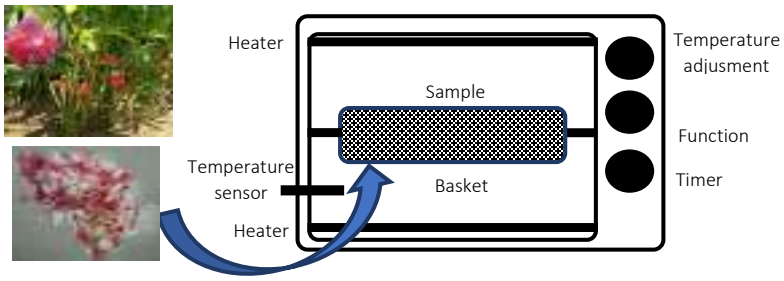

(a) (b)

Figure 1. *Etlingera elatior* Jack (a) and Rotary dryer lab-scale (b)

Figure 2. The moisture content of *Etlingera elatior* Jack flowers at various drying temperatures.

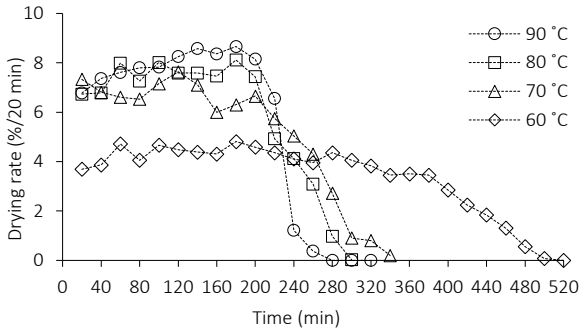

Figure 3. The drying rate of *Etlingera elatior* Jack flowers at various drying temperatures.

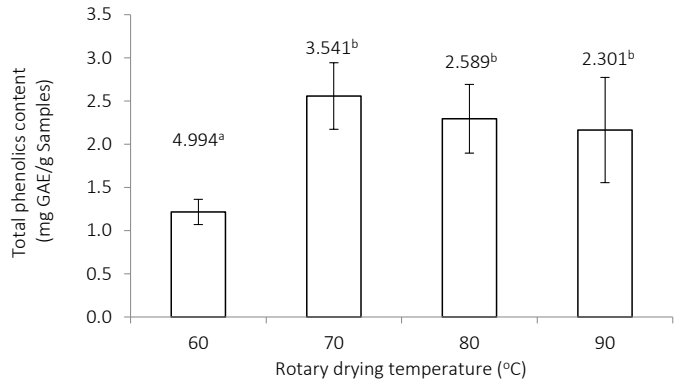

Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures. The results were presented as SD of the means that were gotten by six replicates. Means with different superscripts (alphabets) in the histogram were significantly different, $p<0.05$.

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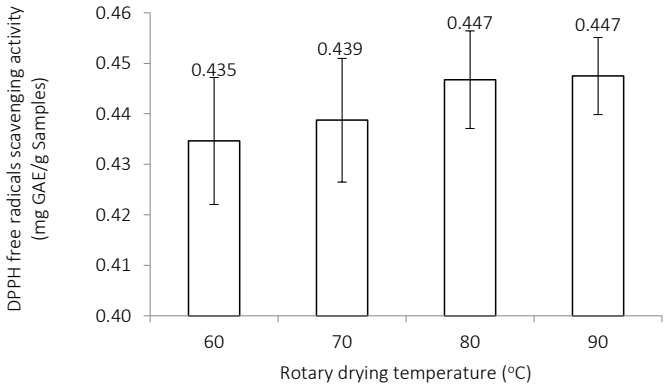

Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying temperatures.

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FULL PAPER

The effect of rotary drying temperature on drying characteristic and antioxidant activity of *Etlingera elatior* Jack

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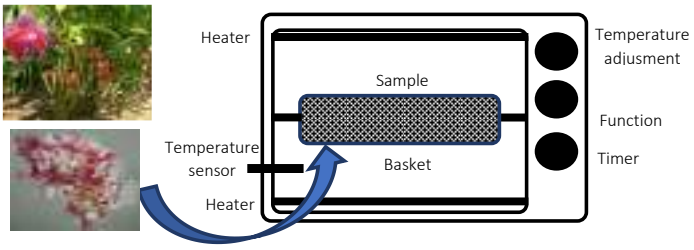
Abstract

The study was conducted to investigate the effect of drying temperature on a rotary type of dryer for drying characteristics and antioxidant activity of *Etlingera elatior* flower. This study used a lab-scale rotary dryer which was a modification of the commercial oven heater from the market. The research design was a Randomized Block Design (RCBD) with one factor, i.e. the drying temperature, which consisted of four temperature levels, 60°C, 70°C, 80°C and 90°C. All experiments were repeated six times. The results showed that the drying of *Etlingera elatior* flowers at three different temperatures (70°C, 80°C and 90°C) required a shorter drying time than that of 60°C. The drying rate of the samples at 70°C, 80°C and 90°C was drastically decreased before the 200th min, while 60°C took a long time to 380 mins. The drying rate pattern with the drying temperature of 60°C showed a significantly lower total phenolic content of *Etlingera* flowers compared to 70°C, 80°C and 90°C, while there was no significant difference in total phenolic content among 70°C, 80°C and 90°C. In addition, different drying temperatures did not give a significant effect on the antioxidant activity based on the DPPH (2,2-diphenyl-1-picrylhydrazyl radical) method. This study proposed the effectiveness of drying using a rotary dryer in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

1. Introduction

Etlingera elatior Jack (ginger red/torch ginger) is a spice plant that is included in the *Zingiberaceae* family that is quite widespread in Indonesia. This herb plant can be found in several regions in Southeast Asia (Wijekoon *et al*., 2010; Nor *et al*., 2020) with different names, such as *Kincung* in Medan, Rias in North Tapanuli, *Sambuang* in Minangkabau, *Kecicang* in Bali, *Siantan* in Malaya and *Daalaa* in Thailand (Health Research and Development Agency of Indonesia, 2000; Lacumy *et al*., 2010; Nor *et al*., 2020). *Etlingera elatior* flower is potential as a food flavouring (seasoning) in cooked, sauteed, or heated (Noweg *et al*., 2003, Juwita *et al*., 2018) as in fish processing (*pepes* fish, grilled fish, and fried). Fish cooked with *Etlingera* will taste better and the fishy aroma will be reduced (Sukandar *et al*., 2011). In addition, this plant is efficacious in deodorizing body odour and bad breath (Health Research and Development Agency of Indonesia, 2000; Aldi *et al*., 2020), natural cosmetic ingredients (Chan *et al*., 2007). The profile of *E. elatior* Jack is shown in Figure 1a.



(a) (b)

Figure 1. *Etlingera elatior* Jack (a) and Rotary dryer lab-scale (b)

The benefits offered by *Etlingera* flower are correlated to phytochemical compounds, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides (Naufalin *et al*., 2005; Setiawati, 2018). A previous study showed that flavonoids, terpenoids, saponins, tannins, and carbohydrate compounds from *etlingera* flowers can be extracted using 80% methanol as the solvent (Lachumy *et al*., 2010). Furthermore, *E. elatior* has been described to exhibit many biological activities (Lachumy *et al*., 2010; Chan *et al*., 2009; Puttarak *et al*., 2014; Juwita *et al*., 2018; Nor *et al*., 2020; Putri, 2021).

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Several investigations revealed that the phytochemical compounds of the *Etlingera* flowers have the potential of becoming a source of antioxidants. The methanolic and ethanolic extracts of them have been proven to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical (Chan *et al*., 2007). The inhibition of DPPH radical was successfully performed by *Etlingera* flowers' methanolic extract at the concentration of 9.14 mg/mL (Lachumy *et al*., 2010) as well as its aqueous extracts at the concentration of 76.4% (Gasemzadeh *et al*., 2015). Naufalin and Rukmini (2011) also found that the *Etlingera* flower has a higher potential antioxidant activity (61.61-83.17%) than its leaf (40.64-60.40%) and stem (57.42-84.65%).

In general, fresh *etlingera* flower usually has moisture contents of more than 80%, so it is a very perishable commodity (Sagar and Kumar, 2010). The shelf life of *Etlingera* flower can be extended by reducing its moisture content using drying methods. Several drying methods, such as air-, freeze-, microwave -, vacuum-, oven- and sun-drying, have different effects on the quality of dried material. Variation of drying temperature using a specific drying method can also influence the losses or preservation of antioxidant compounds (Kamiloglu *et al*., 2016). Can *et al*. (2009) studied the effect of various drying types, such as oven drying, microwave, oven, sun drying, and freeze-drying on the antioxidant properties of *E. elatior* leaves. The total phenolic content of *E. elatior* leaves subjected to freeze-drying was found to be higher compared to other drying methods. Another study by Rohkyani and Suryani (2015) showed drying using an oven at 65^{o}C resulted in the highest DPPH scavenging activity (66.43%) of *Etlingera* flowers compared to 85^{o}C (56.76%).

Rotary drying is another drying method that has not been widely applied in the drying of food commodities. Delele *et al.* (2015) informed that rotary dryers are capable of processing a variety of agricultural products with a wide range of thermo-physical and flow properties, and improve the efficiency of the drying process. To the best of our knowledge, there is still few information regarding the antioxidant characteristics of *E. elatior* flowers dried using a rotary dryer.

Several studies utilized the rotary drying method to preserve food material. Kaleemullah (2005) used rotary drying to 10.5 kg chilli with an initial moisture content of 330% (dry basis) in the temperature range of 50 – 65^{o}C. The study showed that the moisture content is reduced to 10.0% (dry basis) after being dried for 32 hrs, 27 hrs, 23 hrs, and 20 hrs at 50°C, 55°C, 60°C and 65°C, respectively. Tarhana (2010) examined the drying of 15 kg peppermint using a rotary dryer for 15 - 18 hrs and 12 – 15 hrs. Drying can cause the leaves to darken, but the essential oil content is not much different from 2.08 - 2.7 mL/100 g dry matter. The specific energy consumption values have ranged from 7.88 to 15.08 MJ/kg of moisture removed). Daily fluctuations in ambient air conditions directly affected the specific energy consumption of a rotary dryer. Ademiluyi *et al*. (2010) also uses a rotary dryer to dry fermented cassava with parameter tests, including dry air inlet temperature, dry air inlet velocity, relative humidity, feed rate, drum rotational per min and feeding. The results showed that the dry air inlet temperature, the dry air inlet velocity, and the feed rate give a significant effect on the specific heat transfer coefficient and heat load on the material.

This study aimed to investigate the effect of rotary drying temperature on drying characteristics and antioxidant activity of *E. elatior* flowers that including moisture content, drying rate, total phenol, and DPPH free radical scavenging activity. Antioxidant activity analysis was carried out to determine the potential antioxidant activity of *Etlingera* flowers dried under different drying temperatures (60°C, 70°C, 80°C and 90^{o}C) using a rotary dryer. The antioxidant activity was obtained by comparing the antioxidant activity of water extract of *Etlingera* flower petal powder at various drying temperatures with gallic acid and calculating its ability to reduce DPPH free radicals based on the percentage of inhibition (% inhibition). This study used a lab-scale rotary dryer made from a modified commercial oven heater.

2. Materials and methods

Fresh *E. elatior* flowers were obtained from the traditional market around Medan city, Indonesia. All chemicals used were of analytical grade. The DPPH (2,2-diphenyl-1-picrylhidrazyl free radical) was purchased from Sigma Aldrich Chemicals (St. Louis, Missouri, United States), gallic acid, Folin-ciocalteu phenol, sodium carbonate, methanol was obtained from Merck and Co. Pharmaceutical Company (New Jersey, United States), and aquadest was bought from PT. Surabaya Aqua Industry, Indonesia.

The petals of fresh *E. elatior* flowers were collected and the knobs were discarded. The fresh flower petals were chopped to a size of about 1 cm. For each experiment, around 400±0.1 g (Ohaus PA 224) of fresh petals was inserted into the drying basket and filled about 50% volume of the basket. Commercial electric oven (Oxone type OX-8830, 30 L in volume) with modification was pre-heated to the set temperature until a steady condition was achieved, followed by inserting the drying basket containing samples into the oven. The drying air temperatures used were 60°C, 70°C, 80°C,

and 90°C while the basket rotates at around 3 rpm. The experimental setup was shown in Figure 1b. The experimental setup is shown in Figure 1b. During the drying process, the samples were taken out, immediately weighed, and put back into the oven. The process was done periodically every 20 min until the samples reached a constant weight and the drying process was terminated. The moisture content was calculated based on a wet basis with Equation 1:

$$MC\ (\%) = \frac{M_{H2O}}{M_{total}} \times 100\% \quad (1)$$

Where MC = moisture content (%), M_{H2O} = mass of moisture (g) and M_{total} = mass of solid + mass of moisture (g)

The drying rate was calculated from the Equation 2:

$$DR\ (\%/min) = \frac{MC_{t0} - MC_{t1}}{\Delta t} \quad (2)$$

Where DR = drying rate (%/min), MC_{t0} = moisture content at time t (g), MC_{t1} = moisture content at t + 20 min (g) and Δt = time interval (min).

The two transfer processes simultaneously occur in thermal drying: i.e. heat or energy transfer and mass transfer. Energy transfer occurs from the environment to vaporize moisture present on the surface of a material/ product. Convection heat transfer takes place due to temperature differences between the surface of the material and the dry air. Vaporization is the evaporation of moisture located on the surface of the material. When heat moves from the outside to the inside of the material, moisture that is located inside the material will diffuse out to the material's surface due to differences in moisture content.

2.1 Extraction of samples

The samples were extracted by the soxhlet extraction method (Widyawati *et al*., 2014). As much as 3 g of fresh *E. elatior* petals were wrapped in a filter paper and put into a soxhlet tube (timbre) that had been filled with 50 mL of water as the solvent. The extraction was carried out at its boiling point for 4 hrs until the solvent's colour in the timbre became colourless. The obtained extract was evaporated by a rotary evaporator under a vacuum at a temperature of 65-80°C, a pressure of 250 - 300 mbar, and a rotational speed of 40 rpm. The evaporation was run for 10 mins to obtain 2.5 mL of a concentrated extract. The concentrated extract was placed in vials and stored in the freezer until further analysis.

2.2 Total phenolic content analysis

Analysis of total phenolic content was based on the oxidation reaction of phenol compounds to produce a blue solution from reducing yellow hetero polyphosphoric molybdate tungstate anions (Muntana and Prasong, 2010). In brief, 20 µL of *Etlingera* flower extract was added to 1 mL of 10% Folin Ciocalteau reagent in a 10 mL flask bottle. The mixture was shaken and left for 5 mins Then, 2.0 mL of 7.5% Na_2CO_3 and distilled water were subsequently added to the mixture until a volume of 10 mL was achieved. The mixture was allowed to stand for 30 mins and the absorbance of the samples was measured at λ 760 nm (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples) (Siddiqui *et al.*, 2017).

2.3. DPPH free radical scavenging activity analysis

The assay of DPPH free radical scavenging activity was based on Sompong *et al.* (2011) with some modifications. As much as 3 mL of DPPH solution (4 mg/100 mL in methanol) was added to 20 µL of the extract and methanol until the volume reached 10 mL in a 10 mL flask bottle. The samples were incubated for 30 mins in a dark chamber. The absorbance of each sample was measured at λ 517 nm by a spectrophotometer (UV-Vis spectrophotometer, Shimadzu 1800). Data were analysed against gallic acid as a standard solution (mg GAE/g samples).

3. Results and discussion

3.1 Moisture content and drying rate

The initial moisture content of each sample for temperatures 60°C, 70°C, 80°C, and 90°C was 87.53%, 88.03%, 88.1%, and 87.53% (w/w). During the drying process, the changes in moisture content occurred as shown in Figure 3 and these changes in moisture content are proportional. As for the temperature of 60°C, the change is much slower. For each drying temperature of 90°C, 80°C, 70°C, and 60°C, the moisture content will approach 0% after 240, 260, 320, and 480 mins, respectively. The decrease in moisture content follows a straight line until the moisture content approaches 0%. The decrease indicates that the process of moisture evaporation takes place constantly for each period of measurement. The moisture content for each experiment calculated based on Equation 1 is shown in Figure 2.

The drying rate during the experiment calculated using Equation 2 is shown in Figure 3. The constant drying rate looks long enough for all types of temperatures. The constant drying period of around 220 mins was nearly the same for drying temperatures of 70° C, 80°C, and 90°C. During this period, the drying rate is around 1.25 – 30 g/min of measurement. At 60°C, the drying rate is around 0.75 g/min and lasts for about 380

mins. The duration of this constant rate period is due to the high moisture content contained in fresh *E. elatior* flowers. Moisture content for all samples was around 90% and a large amount of moisture content is present on the surface of the sample. The low thickness of the sample also allows the moisture on the inside or middle to evaporate to the surface with minimum difficulty. The fall rate period was shorter than the constant rate period, which was around 40 to 100 mins for experiments with temperatures of 90°C, 80°C, and 70°C. As for the drying temperature of 60°C, the time was around 240 mins.

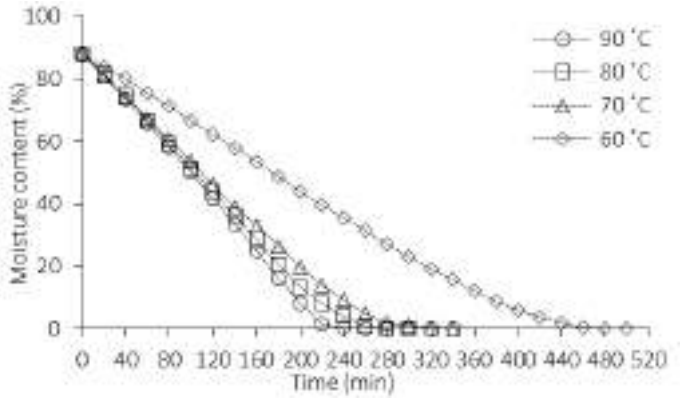

Figure 2. The moisture content of *Etlingera elatior* Jack flowers at various drying temperatures.

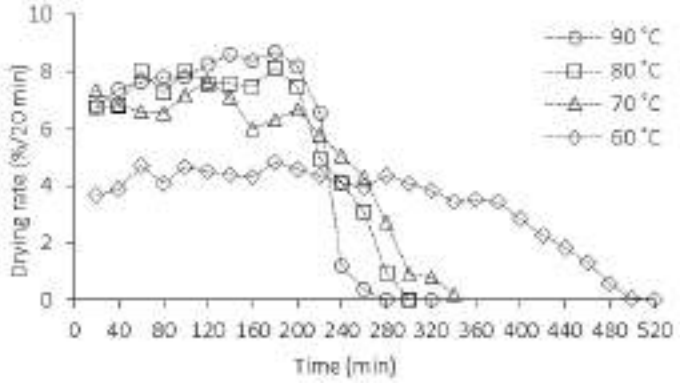

Figure 3. The drying rate of *Etlingera elatior* Jack flowers at various drying temperatures.

The second falling rate period has a shorter time than the previous period. A shorter time indicates that after experiencing a critical condition, the moisture content of *E. elatior* flowers will then be low. During the second falling rate period, the drying rate would be controlled by the diffusion rate of moisture from the inner surface of the sample. This process was conducted until it reached an equilibrium state or until the moisture content has completely evaporated (Nurafifah *et al*., 2018). Data in Figure 3 showed a constant drying rate lasting up to 20% of moisture content. After that, the drying rate will decrease rapidly. Moisture content in this range is a critical condition where the drying rate will be significantly influenced by the rate of moisture transportation from the centre to the surface.

3.2 Antioxidant activity

The total phenolic content describes the amount of phenol compounds present in a sample. Phenol compounds can facilitate redox reactions, thus can act as antioxidants (Johari and Khong, 2019). The total phenolic content of *Etlingera* flower powder produced using various temperatures of rotary dryer is shown in Figure 4. The results showed total phenolic content of *Etlingera* flower powder produced under the temperature of 60°C (1.216±0.146 mg gallic acid equivalent/g samples) was statistically lower from that of 70°C, 80°C, and 90°C (2.558±0.385 - 2.165±0.609 mg gallic acid equivalent/g samples). The trend of increasing total phenolic content was observed when the drying temperature increased to 70°C, followed by a decrease after the heating temperature was elevated to 90°C. However, no significant difference in total phenolic content was found from the drying temperatures of 70°C, 80°C, 90°C. The obtained results revealed that the phenolic compounds in *E. elatior* flowers were thermostable and could be maximally extracted under the drying temperature of 70°C. Złotek *et al.* (2019) also discovered the thermostability of phenolic compounds derived from white quinoa after being subjected to drying using a single convection dryer under various drying temperatures (30°C, 40°C, 60°C). Generally, the secondary metabolites contained in plants are in the form of free metabolites or bonded to other metabolites. Vanic acid possesses a thermostable characteristic at various dry temperatures, which is similar to p- hydroxybenzoic acid, p-coumaric acid, salicylic acid, and ferulic acid. Naufalin *et al.* (2005) reported *etlingera* flowers contained phytochemical components, such as alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, steroids, and glycosides. In contrast, Liaotrakoon and Liaotrakoon (2018) observed a decrease in the total phenolic content and antioxidant activity of mushrooms after being dried using an oven under the temperatures of 40°C, 50°C, and 60°C with an extended drying time.

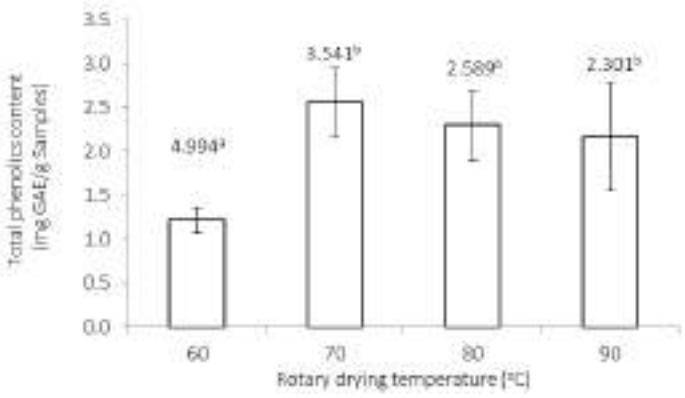

Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures. Values are presented as means of six replicates. Values with different superscripts are significantly different, $p<0.05$.

Therefore, it can be concluded that drying using the rotary dryer with a higher temperature and longer time up to 4 hrs could maintain the total phenolic content of a material.

DPPH is a free radical that has a maximum absorbance at 517 nm in methanol. The scavenging of DPPH by the addition of antioxidants is indicated by the change in solvent's colour from purple to yellow (Sayed *et al*., 2015). The ability of *Etlingera* flowers to scavenge DPPH free radicals tended to increase along with increasing drying temperature (Figure 5). In addition, the drying process of *Etlingera* flowers using the rotary dryer with temperatures ranging from 60-90^{o}C for 4 hrs did not significantly change its DPPH scavenging activity, which indicated the ability of the rotary drying method to effectively maintain both total phenolic content and antioxidant activity of *Etlingera* flowers. On the contrary, different results from Liaotrakoon and Liaotrakoon (2018) revealed a decrease in the antioxidant activity of mushrooms after being subjected to the oven drying process.

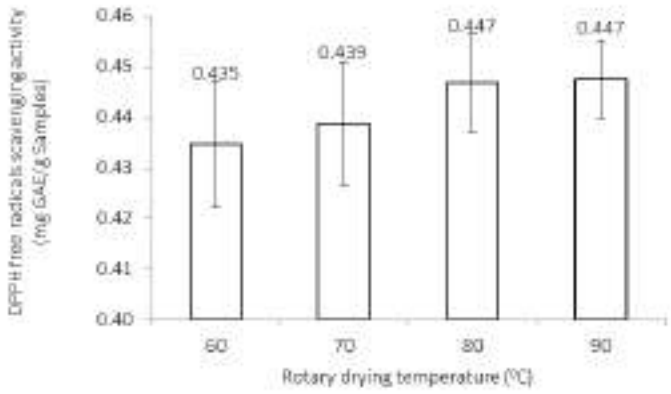

Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying temperatures.

Furthermore, no correlation was found between the antioxidant activity and the total phenolic content of *Etlingera* flowers. The coefficient determination of less than 0.95 (R^2 = 0.3318) indicated an increase in total phenolic content was not closely related to an increase in the DPPH free radical scavenging activity. This result was not in line with Piluzza and Bullitta (2011) where the DPPH and ABTS free radicals scavenging activity were positively correlated with total phenolic content with R^2 = 0.9152 and R^2 = 0.889, respectively. Gan *et al.* (2017) also noted total phenolic content was linearly correlated with antioxidant activity (iron ion reducing power, hydroxyl free radical scavenging activity and lipid oxidation inhibition activity). Khiya *et al.* (2021) added a high positive correlation between phenolic compounds and antioxidant activity (R^2 = 0.932), showing the phenolic compounds may have contributed to the antioxidant activity of *Salvia offi*cinalis leaves. This absence of correlation in this study depicted the possibility of other phytochemical compounds influencing the antioxidant activity of *Etlingera* flowers. Naufalin *et al*. (2005) and Setiawati (2018) showed that the phytochemical compounds that comprise *Etlingera* flowers are alkaloids, glycosides, phenolics, terpenoids, steroids, saponins, and flavonoids, with alkaloids as the dominant compound. Alkaloids and phenolic compounds are very important as antioxidants, with alkaloids possessing a stronger antioxidant activity. Quezada *et al.* (2004) showed the presence of alkaloids and flavonoids exhibited high antioxidant potency of Boldo (*Peumus boldus* Molina) extract. Benabdesselam *et al.* (2007) also found that total quinolizidine alkaloid contents of *Fumaria capreolata* (426 mg/100 g) and *Fumaria bastardii* (521 mg/100 g) extracts exhibited a strong total antioxidant activity.

4. Conclusion

The time required for drying *Etlingera* flowers using a rotary dryer did not much differ among the temperatures of 70^{o}C, 80^{o}C, and 90^{o}C and was shorter compared to 60^{o}C. A rapid decrease in drying rate was experienced by *Etlingera* flowers before the 200th min of drying process under 70^{o}C, 80^{o}C, and 90^{o}C, while longer time (380 mins) occurred when using a drying temperature of 60^{o}C. Drying with a rotary dryer was found to effectively maintain the total phenolic content of *Etlingera* flowers, although the drying process was performed under a quite high temperature for 4 hrs. In addition, drying with rotary drying at 60 – 90^{o}C for 4 hrs did not change the DPPH free radical scavenging activity. Accordingly, the rotary drying method was very effective in maintaining the total phenolic content and antioxidant activity of *Etlingera* flowers.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgement

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Dr Widyawati, P.S.
Food Technology Department,
Agricultural Technology Faculty,
Widya Mandala Surabaya Catholic University
Dinoyo Street Number 42-44,
Surabaya, East Java, Indonesia 60265

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Food Research <foodresearch.my@outlook.com> Sun, May 22, 2022 at 3:08 PM
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Dear Dr Widyawati

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From: Food Research <foodresearch.my@outlook.com>
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On Tue, May 17, 2022 at 10:57 AM Food Research <foodresearch.my@outlook.com> wrote:

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On Sun, May 15, 2022 at 10:26 AM Food Research <foodresearch.my@outlook.com> wrote:

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On Fri, May 13, 2022 at 9:52 AM Food Research <foodresearch.my@outlook.com> wrote:

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> Dear Dr. Vivian New
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Subject: Re: Give me Information

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>
> Thanks for information
>
> The best regards
>
> Paini Sri Widyawati