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by Paini Sri Widyawati

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

[1]Simanjuntak, M.E., [2]Ristiarini, S. and [2,*]Widyawati, P.S.

[1]*Mechanical Engineering Department, Medan State Polytechnic, Medan, Indonesia*
[2]*Food Technology Department, Widya Mandala Surabaya Catholic University, Surabaya, Indonesia*

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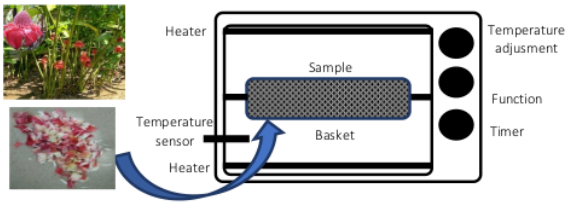
Abstract

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).

*Corresponding author.
Email: *paini@ukwms.ac.id*

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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,

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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.

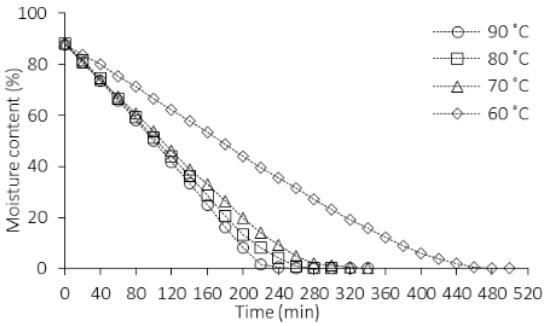

Figure 2. The moisture content of *Etlingera elatior* Jack flowers at various drying temperatures.

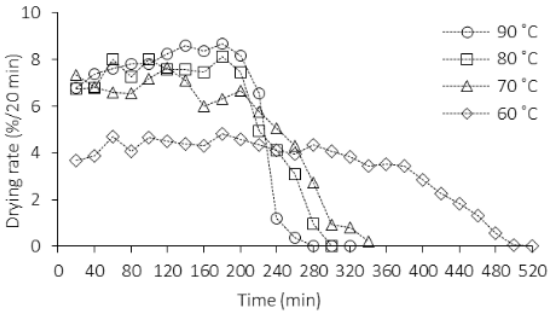

Figure 3. The drying rate of *Etlingera elatior* Jack flowers at various drying temperatures.

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.

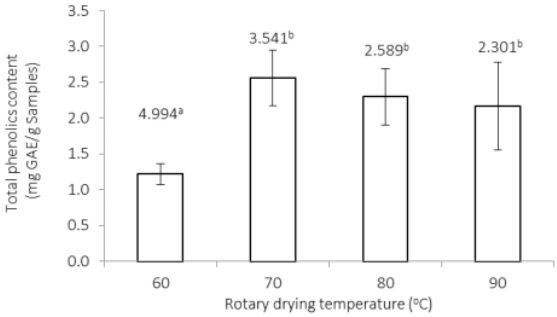

Figure 4. Total phenolics content of *Etlingera elatior* Jack flowers at various drying temperatures. Values are presented as means of six replicates. Values with different superscripts are significantly different, $p<0.05$.

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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°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.

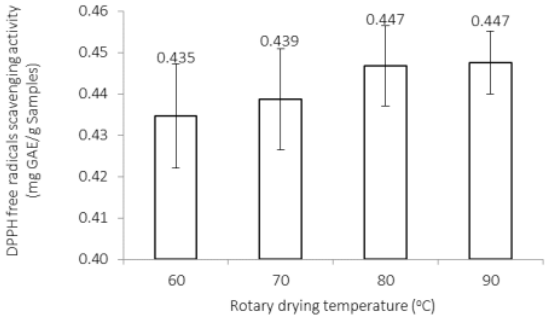

Figure 5. DPPH Free Radical scavenging activity of *Etlingera elatior* Jack flowers at various drying temperatures.

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°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 the 200th 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.

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