The Quality of Elephant Ginger Dried by Using Modified Hohenheim Dryer under Tropical Climate

R. Khathir¹, R. Agustina¹, B. S. Putra¹ and Rahmadi¹

1 Department of Agricultural Engineering, Faculty of Agriculture, University of Syiah Kuala
rkhathir@unsyiah.ac.id

Abstract. The objective of the study was to determine the quality of elephant ginger (Zingiber officinale) dried by using a modified Hohenheim dryer designed based on the Hohenheim type tunnel dryer at University of Kassel, Germany. Drying is the oldest method used to extend the shelf-life of the product, and the thickness of the material is one of the factors that will influence the drying process. The study was conducted under the tropical climate, in Banda Aceh, Indonesia. The elephants ginger were sliced at different thickness of 3, 4 and 5 mm. Research parameters included solar irradiation, temperature, relative humidity (RH), drying time, drying rate, moisture content, ash content, yield, and colour. To assess the consumer acceptance to the dried ginger, a consumer test was also run to 25 respondents by using hedonic scale on the colour and flavour properties. The study showed that the drying of elephant ginger by using a modified Hohenheim dryer was promising to apply at slice thickness of 3 mm under the tropical climate. The average daily solar irradiation was 403.2 W/m² and the average temperature of drying chamber was 49.5°C, and the total drying time was 7h. The drying curve of ginger did not follow the ideal drying rate curve; therefore, the modification of the dryer is still needed to improve its performance. However, the quality of dried ginger was good since it had met the export standard for moisture. Nevertheless, the ash content should be reduced to meet this standard by piling the tuber. According to the sensory analysis, the respondents preferred the colour of ginger dried at slice thickness 3 mm to 4 and 5 mm, but they preferred the flavour of both slice thickness 3 and 4 mm to 5 mm. The colour properties at slice thickness of 3 mm were R-value by 204, G-value by 187, B-value by 119, L-value by 76, a-value by -3 and b-value by 36 and the colour properties among different slice thickness of dried ginger were strongly explained by b-value.

Keywords: Elephant Ginger, Slice Thickness, and Hohenheim Dryer.

1. Introduction
Elephant ginger (Zingiber officinale) is one of the potential agricultural products in Aceh, Indonesia. It has been consumed as food as well as medicine long time ago since the plants contains a lot of beneficial ingredients for human health. Some reports showed that ginger was effective for pregnancy-induced and postoperative nausea and vomiting [1], for gastrointestinal problems and for prevention the symptoms of travel sickness [2]. The ingredients of ginger are vitamin A, B, C, oil, protein, organic compounds, gingerin, and some volatile compounds [3]. Its strong aroma is the result of pungent ketones including gingerol [1].

Ginger can be used as a fresh or dried product [1,2], and the most important commercial form is dried ginger [4]. Therefore, the drying process has an important role to apply the diversifications of ginger products. Commonly, sun-drying is the oldest method used for the drying agricultural products by Indonesian farmers. Recent efforts to improve the sun drying have led to the development of solar dryer. The main parts of this dryer are solar collector, food dryer compartment, and the airflow system.
The objective of using a dryer is to shorten the drying time and to reduce the risks of food spoilage or mold growth [6]. Hereby, Hohenheim type solar dryer is a tunnel dryer designed for low-cost dryer in Germany [7,8]. The Hohenheim type dryer results in faster drying and higher quality than traditional open-air methods [5]. Although the dryer was first developed in Germany under subtropical climate, it is expected that the dryer will work much better in Indonesia and then could be used to improve the drying technology for farmers. Therefore, the objective of this study was to observe the quality of elephant ginger dried by using a modified Hohenheim type dryer the under tropical climate.

2. Methodology
The study was conducted at Field Laboratory of Postharvest Technology, the Department of Agricultural Engineering, Faculty of Agriculture, the University of Syiah Kuala, Banda Aceh, Indonesia, in March 2018. The instruments used were a modified Hohenheim type dryer (Figure 1), a pyranometer RK 200-03, thermometers, humidity meter, and a digital balance.

A modified Hohenheim dryer was designed based on the solar tunnel dryer built at University of Kassel, in Germany. The length of the dryer is 6m and the width is 2m, and the height above the ground is approximately 0.8m. The total drying and absorber (black painted surface) area is 6m², respectively. About 3 fans of 12V 0.2A DC by diameter of 12cm were installed to flow fresh air at rate 2 m/s during the drying process. A 50WP solar panel was installed to generate electricity.

Figure 1. The modified Hohenheim dryer

About 9 kg of elephant ginger was bought from the local market. The ginger was washed, cleaned, sorted, air dried, and sliced at 3 different thicknesses of 3, 4, and 5 mm. Then, the sliced ginger was distributed on the drying chamber in three columns. The drying process was run during the day for 8h from 9.00 to 17.00. During the drying process, the parameters observed were solar irradiation, temperature, relative humidity, and weight loss. The solar irradiation of local was measured by using a pyranometer. Temperatures and relative humidity observed were at the environment (Te, RHe), and the drying chamber temperature at three points i.e. at the distance of 50 cm from absorber (T1, RH1), at the distance of 150 cm from absorber (T2, RH2), and at the distance of 250 cm (T3, RH3). Finally, the quality of dried ginger was evaluated based on its drying characteristics such as drying rate, final moisture content, ash content, yield, and colour. A consumer test was also run to 25 respondents by using hedonic scale on the colour and flavour properties. The moisture content was analyzed following AOAC air oven method [9], while the ash content procedure was adopted from TDRI standard 1984.
[10]. The colour was analyzed by image colour summarizer 0.76 [11]. The drying rate was calculated by using Eq. 1 according to the moisture content in the dry basis [12].

\[
\frac{dM}{dt} = \frac{M_i - M_f}{t} \times 100 \tag{Eq. 1}
\]

3. Results and Discussion

3.1. The Characteristics of Drying Process

Because the main source of energy used by the modified Hohenheim dryer was solar irradiation, the first parameter to discuss is the solar irradiation trend. The average solar irradiation was 403.2 W/m²; the data were displayed in Figure 2. The trend of solar irradiation was following the polynomial equation with R-square value about 88.1%. According the graph in Figure 2, the total solar irradiation during the day was about 3,677.361 W/m² or 3.7 kWh/m². However, this value is lower than the average solar irradiation in Indonesia, which was reported about 4.8 kWh/m² [13]. This can be explained by the large standard deviation value of solar irradiation distribution among the observation days. In this experiment, the standard deviation value was approximately 182 W/m²; it was doubled than the standard deviation in the previous study by 66 W/m² [13]. The phenomenon has explained that there is high fluctuation of solar irradiation during the day. Nevertheless, the solar irradiation is still potential enough for the drying process.

![Figure 2. Solar irradiation during the experiment in Banda Aceh](image)

From Figure 3, it can be learnt that the average environment temperature was about 32.67°C. In fact, the temperature inside the drying chamber was always higher than the environment temperature recognized by the yellowish to reddish colour. It explained that the drying process was potential to conduct from 10.00 to 17.00 as the solar irradiation was above 200 W/m² and it had increased the drying chamber temperature above 37°C. The green colour represents the colder area whereas the red colour shows the hotter region. Of course, since the source of energy for this dryer was from the sunlight, the temperature development inside the drying chamber had followed the trend of solar irradiation in Figure 2. The average temperature at 50 and 150cm was 51°C, while the average temperature at 250cm from absorber was 46.3°C. Overall, the average temperature inside the drying chamber was 49.5°C.

It can be said that the drying process by using the Hohenheim dryer is promising for agricultural products. Previously study in August 2015 had shown the same condition where by the average
environment temperature of 35°C, the average drying chamber temperature was about 55°C [14]. The difference between environment and drying chamber temperature in the previous study had reached about 20°C. Supporting this finding, the result of this study showed that the temperature inside the drying chamber was also higher than the environment temperature by 16.85°C.

At the beginning of the drying process, the temperature at 50 cm from absorber was higher than that of at 150 cm from absorber. After 2h, the temperatures at these points were almost equal. However, the temperature at 250 cm from absorber had reached the lowest value since the location was close to the air outlet. Hereby, the temperature distribution inside the drying chamber needs to be improved by modification design, for example by increasing the airflow.

Another characteristic of the drying process can be explained by analyzing the correlation between temperature and relative humidity. There is a strong correlation between temperature and relative humidity (RH) determined by the $R$-value above 0.8 (Table 1). The $R$-value at environment, 50cm from absorber, 150cm from absorber, and 250cm from absorber were 0.93, 0.84, 0.83, and 0.96, respectively. The slopes of the equations are negative; it is explained that the increase of temperature will decrease the relative humidity (RH). At environment, the increase of temperature by 1°C will cause the decrease of RH by 5.4%. However, inside the drying chamber the increase of temperature by 1°C will result the decrease of RH in range of 1.4 to 1.9%; the RH in drying chamber was relatively high above 60%. Therefore, in order to increase the slope of RH changes inside the drying chamber, the size and the number of fans should be increased.

**Table 1.**The correlation between temperature and relative humidity at the environment and inside the drying chamber

| No | Position | Equation | R-square | R     |
|----|----------|----------|----------|-------|
|    |          |          |          |       |

**Figure 3.** The temperature profile inside the drying chamber at 50 cm from absorber (T1), at 150 cm from absorber (T2), at 250 cm from absorber (T3), and at environment (Te) during the experiment

![Figure 3](image-url)
1. Environment  
   \[ \text{RHe} = 235.6 - 5.416T_e \]  
   0.86  
   0.93
2. 50cm from absorber  
   \[ \text{RH}_1 = 163.4 - 1.976T_1 \]  
   0.707  
   0.84
3. 150cm from absorber  
   \[ \text{RH}_2 = 130.1 - 1.377T_2 \]  
   0.696  
   0.83
4. 250cm from absorber  
   \[ \text{RH}_3 = 126.0 - 1.423T_3 \]  
   0.928  
   0.96

From Figure 4, it shows that the drying time at the thickness of 3mm was higher and faster (7h) than that of at the thickness of 4 and 5mm (8h). Lastly, the drying rate of elephant ginger is fluctuated along the drying process as can be seen in Figure 5. It showed that the drying curve of elephant ginger did not follow the drying curve theory (the bold black curve). Following the drying curve theory [15], the first step of drying rate was the increased rate from A to B. The next step was the constant rate from B to C until the free moisture was evaporated. The third step was the sharp decrease of drying rate from C to D, and the last step was the slight decrease of drying rate from D to E. Therefore, the deviation between the theory and elephant ginger drying curve should be solved by the next modification of the modified Hohenheim dryer.

![Figure 4](image-url)  
Figure 4. The loss of moisture content (db) of elephant ginger during the drying process
Figure 5. The comparison between the theory and elephant ginger drying curve

3.2. The Quality of Dried Elephant Ginger

The initial moisture content of elephant ginger was about 488.2% (dry basis) or 83% (wet basis). At the end of the drying process, the final moisture of elephant ginger at the thickness of 3 mm was about 6.49%(wb), whereas at the thickness of 4 and 5 mm the final moisture was 10.95%(wb) and 11.2%(wb), respectively. As can be seen from Table 2, the final moisture content of dried elephant ginger was lower than 12% representing that the dried ginger was safe for storage and met the export standard [16]. The lowest moisture was obtained at thickness 3 mm. The previous study [17] had found that under the slice thickness variations of 2.5, 5, 7.5 and 10 mm, the slice thickness of 2.5 mm had performed the best quality of dried elephant ginger, i.e. the fastest drying time (36 h), the lowest moisture (5.53%), and the highest oil content (3.77%). They also confirmed that under the sun-drying method, the drying time took about 6 days with effective drying time per day about 6 h. The drying time absolutely influence the quality of dried product; a long drying time would invite the growth of mold [7]. Hence, the short drying time about 7 h by using Hohenheim type dryer is promising for drying elephant ginger at the slice thickness of 3 mm. By using Hohenheim type dryer it is possible to reduce the drying time and improve the quality as well as protect the product from the rain significantly compared to the traditional drying methods [8].

Another study on drying ginger [18] had indicated that the drying process by using solar dryer under temperature 36.3-45.6°C produced dried ginger at moisture 11.8%. The drying temperature for ginger could be applied in the range of 40-70°C with no significant yield of ginger oil by supercritical fluid extraction technique, but it could reduce the drying time from 22 h to 4 h [9]. Therefore, the drying temperature inside the modified Hohenheim dryer was well enough for drying ginger. However, it is very important to shorten the drying time of ginger since long processing for ginger candy had caused the loss of 6-gingerol compound [19].

| No  | Slice Thickness | Moisture (%) | Ash content (%) | Yield (%) |
|-----|-----------------|--------------|-----------------|----------|
| 1.  | 3mm             | 6.49         | 10.22           | 18.0     |
| 2.  | 4mm             | 8.10         | 10.95           | 18.5     |
| 3.  | 5mm             | 8.59         | 11.20           | 19.3     |
| 4.  | Export standard [16] | <12   | 8               | -        |
The yield of dried elephant ginger in this study was approximately 18%. The yield of dried ginger was also reported about 15.7%[18]. This difference could be caused by the different type of ginger used i.e. small white ginger. The ash content of dried elephant ginger in this study ranges from 10.22 to 11.2%. This result was in contrast to previous study [18], while the ash content was lower than Indonesian standard i.e. 8%. Since there is no possibility of contamination during the drying process, the high content of ash probably was influenced by the preparation of sample in this study without pilling the tuber.

The colour quality was observed by using the RGB and Lab values. According to Table 3, the colour of dried ginger was influenced by the b-value. The increase of slice thickness had led to the decrease of b-values. The colours at slice thickness 3, 4 and 5mm were winter hazel, tahuana sands and miso, respectively. The different value of B was recognized clearly. However, the values of R, G, and L of dried ginger at slice thickness 4 and 5mm were almost equal. Furthermore, there is no difference for a-value among all samples. Trials on solar tunnel and greenhouse type dryer show not only massive fuel savings but also great worth addition due to improved quality of dried product in terms of colour, aroma and taste [8]. About 25 consumers liked the colour of dried ginger at slice thickness of 3mm, but they preferred both the flavour of dried ginger at slice thickness of 3 and 4mm to 5mm.

Table 3. The colour properties of dried elephant ginger

| No | Slice Thickness | R   | G   | B   | L   | a   | b   |
|----|----------------|-----|-----|-----|-----|-----|-----|
| 1  | 3mm            | 204 | 187 | 119 | 76  | -3  | 36  |
| 2  | 4mm            | 219 | 205 | 154 | 82  | -3  | 27  |
| 3  | 5mm            | 218 | 204 | 168 | 83  | -3  | 19  |

4. Conclusion

The study showed that the drying of elephant ginger by using a modified Hohenheim type dryer was promising to apply at slice thickness of 3mm under tropical climate. The average drying temperature was 49.5°C and the drying time needed was about 7h. The drying rate curve of ginger did not follow the ideal drying rate curve; therefore the modification of the dryer is needed to improve its performance. The quality of dried elephant ginger was good since it met the export standard for moisture content about 6.49%. However the ash content was still higher than allowed by the export standard. According to sensory analysis, the respondents preferred the colour of dried ginger at slice thickness 3mm to 4 and 5 mm, but they preferred the flavour of both slice thickness 3 and 4 mm to 5 mm. The colour properties at slice thickness 3mm were R-value by 204, G-value by 187, B-value by 119, L-value by 76, a-value by -3 and b-value by 36 and the colour properties among different slice thickness of dried ginger were strongly explained by b-value.

5. References

[1] White B 2007 Ginger: An Overview Am. Fam. Physician 75 1689–91
[2] Langner E, Greifenberg S and Gruenwald J 1998 Ginger: History and Use. Adv. Ther. 15 25–44
[3] Setyaningrum H D and Saparinto C 2013 Jahe (Jakarta: Penebar Swadaya Grup)
[4] Simonyan K J, Ehiem J C, Eke A B, Adama J C and Okpara D A 2013 Some Physical Properties of Ginger Varieties J. Appl. Agric. Res. 5 73–39
[5] Green M G and Schwarz D 2001 Solar Drying Equipment: Notes on Three Driers Infogate 1–6
[6] Ahmed N, Singh J, Chauhan H and Anjum P G A 2013 Different Drying Methods: Their Applications and Recent Advances Int. J. Food Nutr. Saf. 4 34–42
[7] Patil R and Gawande R 2016 A review on solar tunnel greenhouse drying system Renew. Sustain. Energy Rev. 56 196–214
[8] Eissen W, Mühlbauer W and Kutzbach H D 1985 Solar Drying of Grapes Dry. Technol. 3 63–
74

[9] Chen H-H, Chung C-C, Wang H-Y and Huang T-C 2011 Application of Taguchi Method to Optimize Extracted Ginger Oil in Different Drying Conditions International Conference on Food Engineering and Biotechnology IPCBEE vol 9 (Singapore: IACSIT Press) pp 310–6

[10] Brenndorfer B, Kennedy L, Bateman C O O, Trim D S, Mrema .C. and Wereko-Brobby C 1987 Solar Dryers: Their Role in Post-harvest Processing (London: The Commonwealth Secretariat)

[11] Krzywinski M 2019 Image Color Summarizer

[12] Fauziah Sulaiman, Abdullah N and Aliasak Z 2013 Solar drying system for drying Empty Fruit Bunches J. Phys. Sci. 24 75–93

[13] Pranoto B, Cendrawati D G, Hesty N W and Kusriadie E 2018 Evaluasi Pemetaan Potensi Energi Surya Berbasis Model WRF Di Desa Palihan Dan Desa Aikangkung J. Sains Dirgant. 15 63

[14] Khathir R, Agustina R and Ratna 2015 Karakteristik alat pengering tipe Hohenheim pada pengeriningan Pliek-U Seminar Nasional Hasil Riset dan Standardisasi Industri V (Banda Aceh: Balai Riset dan Standardisasi Industri Banda Aceh) pp 308–13

[15] Berk Z 2009 Dehydration Food Process Engineering and Technology ed Z Berk (San Diego: Academic Press) pp 459–510

[16] Rukmana R 2000 Usaha tani jahe (Jakarta: Kanisius)

[17] Julianti E, Ridwansyah and Nurminah M 2010 Pengerining Kemoreaksi Dengan Kapur Api (CaO) Untuk Mencegah Kehilangan Minyak Atsiri Pada Jahe J. Teknol. Dan Ind. Pangan 21 51

[18] Rusli S and Rahmawan D 2017 Pengaruh Cara Pengiris dan Tipe Pengeriningan Terhadap Mutu Jahe Kering Bul. Penelit. Tanam. Rempah Dan Obat 3 80–3

[19] Fitriani S, Ali A and Widiasutti D 2013 Pengaruh Suhu dan Lama Pengeriningan terhadap Mutu Manisan Kering Jahe dan Kandungan Antioksidannya SAGU 12 1–8

6. Acknowledgments
We highly acknowledge the Ministry of Research, Technology and Education for financing the work through Product Technology Disseminated to Community Program (PPTDM) granted in year 2019.