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DRYING ONION SLICES USING A FOOD DEHYDRATOR

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ABSTRACT

Shallots are one of the mainstay products of Demak Regency which are continuously being developed. However, the Demak Shallot Cluster faces a major obstacle, namely drying technology, which is the main cause of the decline in competitiveness, and farmers suffer huge losses. Therefore, in this study, a study of the drying of sliced shallots using a food dehydrator will be carried out. The research analysis includes (1) Drying Characteristics, (2) Drying Rate Analysis, (3) Application of Thin Layer Drying Model, (4) Rehydration Ratio Analysis, (5) Color Analysis, (6) Flavonoid and Total Phenolic Analysis, (7) Antioxidant Activity Analysis. The quality parameters of shallot products in general will follow SNI 3159-2013, this standard stipulates provisions regarding the quality, size and hygiene of shallots (Allium cepa varascalonicum) of the Alliaceae family for consumption, plus the strength of onion bulbs, identification and quantification of flavonoid compounds, and anthocyanin levels. The results showed that the moisture ratio value in equilibrium was 9.34% with the fastest drying occurring at a temperature of 60 oC , which was 0.938 g/minute. The three thin layer drying models were analyzed to determine the appropriate thin layer drying model. The Page model was chosen because it has an R value of 2 the highest is 0.9353 and the lowest RMSE and x 2 values are 0.04354 and 0.0025 3. Changes in color and bioactive compounds in the dried onion slices are caused by heat which causes damage to bioactive compounds. Based on the parameters that have been determined, a temperature of 50 o C indicates the optimum temperature for drying shallot slices.

KEYWORDS Shallots, Solar Dryer, Hybrid

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INTRODUCTION

Shallots (Allium ascalonicum L.) is one of the horticultural crop commodities that are widely consumed by the public as a mixture of cooking spices after chili(Suswadi & Prasetyo, 2022). Apart from being a mixture of cooking spices, red onions are also sold in processed forms such as onion extract, powder, essential oil, fried onions and even as a medicinal ingredient to lower cholesterol levels, blood sugar, prevent blood clots, lower blood pressure and improve blood flow. As a horticultural commodity that is widely consumed by the public, the potential for the development of shallots is still wide open not only for domestic needs but also for foreign countries (Sativa, Harianto, & Suryana, 2017).

Horticulture is a combination of Latin, hortus which means garden and culture which means farming. Horticulture can be defined as a way of cultivating plants in gardens and yards (Lang, 2014).

Shallots contain minerals such as calcium, phosphorus, iron, magnesium, potassium and zinc and nitrogen, also contain vitamins such as vitamin A, vitamin C, thiamine, riboflavin, niacin, pyridoxine, and folic acid (Stephen & Suresh, 2015). Vitamins catalyze reactions in the body, are essential for many body functions, are effective in small but necessary amounts.

Shallots are known for their potassium content. 100 g of shallots provide 180 mg of potassium(Stephen & Suresh, 2015). Potassium helps maintain osmotic pressure in cells. Catalysts carry out several energy reactions and help maintain blood pressure.

In the last decade, the need for shallots in Indonesia from year to year for both domestic consumption and seeds has increased by 5%. This is in line with the increase in the number of residents which also increases every year. The Central Statistics Agency (BPS, 2016) stated that the production of shallots in Indonesia from 2011 to 2015 was 893,124 tons, 964,195 tons, 1,010,773 tons, 1,233,984 tons, 1,229,184 tons. In 2015 the national shallot production decreased compared to 2014 which was 0.39%. According to the Director General of Horticulture (2016), the area of shallot harvested in Indonesia in 2011-2015 was 93,667 Ha, 99,519 Ha, 98,937 Ha, 120,704 Ha, and 122.126 Ha. The national harvested area of shallots in 2015 only grew by 1.18% compared to 2014. To meet domestic needs, the government adopted a policy of importing shallots from abroad although this would result in less desirable domestic production (Dewi, 2012). Thus, the productivity and quality of shallots need to be increased to meet domestic demand.

In Indonesia, shallot is one of the horticultural crops that many people cultivate. Shallots are called horticultural crops because they are a type of vegetable crop, namely the area of plants that are harvested at once / exhausted / unloaded and the area of plants that have been harvested many times (more than once) / has not been exhausted. Plants that are harvested all at once/exploited/unloaded are plants that are immediately dismantled/uprooted after harvesting, consisting of shallots, garlic, leeks, potatoes, cabbage/cabbage, cauliflower, Chinese cabbage/mustard, carrots, radishes and red beans.

According to the 2015 Agricultural Data and Information System Center, in the 2010-2014 period (the last five years), the average growth of shallot harvested area in Indonesia increased by 3.70% per year. Meanwhile, the average growth of shallot harvested area in Java, in the period 1980-2014, was 4.29% per year.

The four shallot center provinces (Central Java, East Java, West Java, and West Nusa Tenggara) contributed 86.24% to the average Indonesian shallot production. Central

Java province gave the largest contribution, namely 42.70% with an average production of 439,851 tons.

Meanwhile, in 2016, Central Java was able to produce 5,466,846 quintal shallots with a harvested area of 53,331 ha. Besides Brebes Regency, Demak, Pati and Kendal Regencies are also the highest shallot-producing areas in Central Java.

In 2016, Demak Regency had a harvested area of 6,218 ha, a production of 599,053 quintals, and a productivity of 96.34 ku/ha. Mijen District is a sub-district that is included in the Demak Regency area, and is the highest shallot-producing sub-district in the last 3 years. As for the shallot production data in Demak Regency, in the last three consecutive years period 2014-2016, shallot production in Mijen District has increased in the 3 years period. In 2014 shallot production was 160,926 (Ha/Kw), for 2015 shallot production increased to 281,111 (Ha/Kw) and in 2016 shallot production increased even more with total production of 317,755 (Ha/Kw). The data on the amount of production was obtained from the Department of Agriculture of the Demak Regency in 2016.

One of the main obstacles faced by these farmers is the need for onion drying technology. At the main harvest with abundant onion production, the selling price received by farmers is very low, sometimes it is not even balanced with the production costs that must be incurred, among others, for harvesters. Shallots are one of the perishable agricultural commodities.

Decrease in the quality of onion after Harvesting that often occurs in shallots is the growth of shoots, softening of tubers, growth of roots and rot and the emergence of a dark mass due to high water content, activity of microorganisms, and molds. This damage results in decreased shelf life and quality of shallots. The critical point of failure in post-harvest handling of shallots, especially when harvesting occurs during the rainy season, is at the stage of leaf drying or withering and tuber drying.

Failure of the leaf withering process can lead to bacterial infection of putrefactive bacteria, while failure to dry the tubers can cause low shelf life, tubers rot quickly, sprout and root out. Yield loss due to this damage can reach 20 – 40%. So far, the drying technique used by farmers is drying in the sun which takes between 7-9 days. Drying with this technique is of course very dependent on the weather conditions at the time of drying. When the weather is sunny, drying can take place well, but on the other hand, when the weather is cloudy or even rainy, drying cannot be done at all so that the onion bulbs rot quickly.

With closed sun drying technology, the limitations of open sun drying technology can be eliminated. Therefore, in this research, the technology of drying shallots slices will be applied using a forced convection drying method with a food dehydrator for drying shallot slices. The function of the dryer is very useful in the process of drying shallot slices and in maintaining the quality of the dried shallot slices.

Some of the advantages of using a food dehydrator as a drying device include the temperature can be adjusted according to the desired conditions, having a ventilator and cover so that it can avoid the entry of dust, dirt, insects and other contaminants that can cause a decrease in the quality of the sliced shallots to be dried. Another advantage is that the drying process of red onion slices does not take a long time, compared to drying directly in the sun and also a food dehydrator can dry onion slices in greater numbers with a multilevel rack system, in one rack it can be filled with 50-100 sliced shallots, with the initial weight of the onion that has not been peeled and sliced, which is 100 gr.

The specific objective of the study was to obtain technical data on the drying process of shallot slices, including 1) Drying Characteristics, (2) Drying Rate Analysis, (3) Application of the Thin Layer Drying Model, (4) Rehydration Ratio Analysis, (5) Color Analysis, (6) Analysis of Flavonoid and Total Phenolic, (7) Analysis of Antioxidant Activity. Through the forced convection drying method using a food dehydrator machine or tool so as to speed up drying time, improve product quality, increase product yield, reduce product damage, and perform scale-up.

RESEARCH METHOD

Determination of Research Variables

The variables in this study are using two variables, the first is a fixed variable consisting of the weight of whole onions that have not been sliced weighing 100 grams and sliced red onions that have been peeled and cleaned with a thickness of 2 mm.

Figure 1 The initial weight of the onion before being peeled and sliced with a weight of 100 gr

Furthermore, the second variable is the variable that changes, including the drying temperature with variations in temperature of 40 ^{0}C, 50 ^{0}C, and 60 ^{0}C, the method used with a stacked rack system, and the drying of sliced shallots at each temperature (40 ^{0}C, 50 ^{0}C, and 60 ^{0}C) until it reaches a moisture content of ± 10% or the dry weight of sliced shallots reaches a constant weight and for a drying time at a temperature of 40 ^{0}C with a drying time of 8 hours, a temperature of 50 ^{0}C with a drying time of 5 hours 50 minutes, and a temperature of 60 ^{0}C with a drying time of 2 hours 30 minutes.

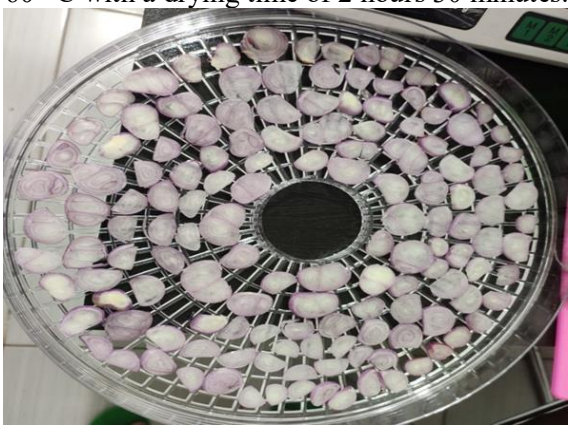

Figure 2 Sliced onion to be dried

Materials and Tools Used

The raw materials used in this study include shallots from Demak, for the materials used in the sample testing (dried shallots with a thickness of 2 mm) carried out in the

laboratory include standard phenolic determinations of gallic acid, Folin Cpa, Na2CO3 0.2 mM, Aquades, standard flavonoid determination material quercetin, 5% NaNO2, 10% Al2Cl3, 1 M NaOH, filter paper, antioxidant determination material Methanol pa, DPPH 0.2 mM (Dissolve as much as 0.078 g in methanol pa to a volume of 1000 ml), the material for determining the moisture content of silica gel, the material for determining the color of the dried shallot slices with a thickness of 2 mm.

The drying equipment used is the Food Dehydrator ARD-PM88, weighing phenolic determination tool, measuring pipette, suction cup, beaker, measuring flask, vortex, centrifuge, vaccum filter, test tube, cuvette, uv vis spectrophotometer, weighing flavonoid determination tool, pipette measuring tape, suction cup, measuring flask, centrifuge, glass funnel, erlenmeyer separating funnel, test tube, cuvette, spectrophotometer. instrument for determining antioxidant activity of scales, mortar hammer, measuring pipette, suction cup, measuring flask, funnel glass, erlenmeyer, beaker, test tube, cuvette, spectrophotometer, instrument for determining water content (oven method) weighing bottle, oven, desiccator, analytical balance , the tool for determining the color of the color reader used is the Minolta color reader.

Figure 3 Drying process with a food dehydrator

Trial Procedure

Material Preparation

For the preparation of the material to be dried, namely whole shallots weighing 100 grams, peeled, after that they were sliced with a thickness of 2 mm. With an initial moisture content of 81.057% shallots were measured in an oven and calculated from the mass lost at a temperature of 90-100 ^{0}C until a constant weight was obtained.

Drying Stage

Prepare sliced shallots with a thickness of 2 mm and a weight of 100 g at each operating temperature variable, namely 40 ^{0}C, 50 ^{0}C, 60 ^{0}C. Pressing the Power button of the dryer then placing the shallot slices by arranging them on the rack in the drying device. solar food dehydrator, then records the change in the weight of the shallot slices every 10 minutes, each temperature of 40 ^{0}C, 50 ^{0}C, 60 ^{0}C. After the drying stage of the shallot slices is complete, the dried shallot slices will be tested in the lab for determine phenolic, flavonoid, antioxidant, color, and % water content.

The steps in determining phenolics, flavonoids, antioxidants, color and moisture content % namely Determination of Phenolics (Folin C Spectrophotometer Method) with the procedure: 1. Preparation of standards used is gallic acid standard concentration made (mg/l) is 0, 2, 5, 10, 25, 50 solutions can be used for further processes, 2 Sample

preparation: for solid samples, the samples were crushed and then weighed as much as 0.5 - 2 g, then dissolved in methanol pa to 25 ml in a measuring flask, then homogenized and allowed to stand for about 30 minutes, then filtered and if necessary centrifuged at 3000 rpm for 10 minutes and the supernatant was taken. The solution can be used for further processing for liquid samples, take as much as 1 ml of the sample, add 5 ml of methanol pa, place it in a test tube, homogenize using a vortex for 5 minutes. Filter the solution with a vacuum filter, take the filtrate. The filtrate solution can be used for further processes, 3. Determination of phenolics: 1 ml of sample or standard added 0.2 ml of folin c, 0.6 ml of 0.2 mM Na2CO3 homogenized by vortex for 5 minutes and allowed to stand for 120 minutes. Measure the absorbance at 765 nm.

Determination of flavonoids with the following procedures: 1. Preparation of Standards: the standard used is quercetin, the concentration of the standard made (mg/L) is 0; 0.5; 1; 25; 50; 100, standard (100 mg/l) was prepared by dissolving 10 mg of quercetin in distilled water to 100 ml. For other concentrations, it can be done by dilution from a concentration of 100 mg/l, the solution can be used for the next process, 2. Sample and Standard Preparation: a. For solid samples, the samples were mashed and then weighed as much as 1 g, then dissolved in methanol pa to 10 ml in a measuring flask, then homogenized and allowed to stand for about 30 minutes, then filtered with a vacuum filter and if necessary centrifuged at 3000 rpm for 10 minutes and taken supernatant, b. For liquid samples, take 1 ml of sample, add 5 ml of methanol pa, place in a test tube, homogenize using a vortex for 5 minutes, filter the solution with a vacuum filter, take the filtrate. The filtrate solution can be used for further processing. c. The solution can be used for the next process, 3. Determination of flavonoids: take 0.1 ml of sample or standard solution, add 0.1 ml of 2% Al2Cl3, homogenize with a vortex, let stand for 60 minutes at room temperature then add distilled water to 1 ml volume a red solution will be formed if there are flavonoids, after that the absorbance is measured with a spectrophotometer at 420 nm.

Determination of antioxidants by the procedure: 1. Sample preparation: a. Solid sample, mashed sample then weighed as much as 2.5 g, then dissolved in methanol pa to 25 ml in a measuring flask, so that a 10% sample solution was obtained, b. Homogenization and allowed to stand for about 30 minutes, then filtered and if necessary centrifuged at 3000 rpm for 10 minutes and the supernatant was taken, c. For liquid samples, samples were taken dissolved in methanol pa up to 25 ml in a measuring flask, until a 10% sample solution was obtained, d. Homogenization and allowed to stand for about 30 minutes, then filtered and if necessary centrifuged at 3000 rpm for 10 minutes and the supernatant was taken. 2. Determination of Antioxidant Activity: a. A total of 1.5 ml of sample solution was added with 3 ml of 0.2 mM DPPH solution, b. Homogenization and allowed to stand for 30 minutes, then the absorbance was measured at 516 nm, c. Perform the above procedure on a blank that is 1.5 ml of methanol pa

Determination of Color (Minolta Color Reader Method) with the following procedures: 1. The color reader tool used is the Minolta color reader, 2. Change the on-off button to the on position to turn on the tool, 3. Adjust the position so that the sensor is in contact with the sample to be tested. the color level is measured, 4. The sample must be placed in a transparent container (glass or plastic), 5. Press the target button, which will be followed by a beep sound, indicating the reading is complete, 6. Record the numbers L, a, and b on the monitor screen of the instrument. color reader, 7. Press reset for the next measurement, 8. Turn the on-off button to off to turn off the instrument, 9. Store the instrument in a dry place away from sunlight.

Figure 4 Color Reader Minolta CR-10
(Reference: Konica Minolta, 1996. Color Reader CR-10. Konica Minolta Inc.)

Determination of Moisture Content (oven method) with the following procedures: 1. Wash the weighing bottle or beaker to be used as a sample holder, 2. Dry the weighing bottle by heating it in the oven and then cooling it in a desiccator, 3. Weigh the weighing bottle and record (a), don't forget to label, 4. Carefully weigh the sample as much as 1-2 grams (b) depending on the moisture content of the material and place it in a weighing bottle, 5. Oven the sample along with the weighing bottle at a temperature of 100 ° C for 5 hours, then cool in desiccator, then oven again for 1 hour at the same temperature, cool in a desiccator and then weigh, repeat the process until a constant weight is achieved (c). 6. Heating can also be carried out for 24 hours at a temperature of 90 - 100 ° C, usually on heating in this way a constant weight can be obtained.

Drying Data Analysis

Phenolic Analysis

The standard phenolic absorbance results that have been obtained are processed with the help of a statistical program to determine a simple linear regression equation y = a + b(x), where y = absorbance and x = phenolic concentration. The phenolic content was determined with the help of the standard regression equation by taking into account the weight of the sample used and the dilutions carried out. *(Oluwaseun R. Alara, 2018.).*

Flavonoid Analysis

The standard flavonoid absorbance results that have been obtained are processed with the help of a statistical program to determine a simple linear regression equation y = a + b(x), where y = absorbance and x = flavonoid concentration. The flavonoid content was determined with the help of the standard regression equation by taking into account the weight of the sample used and the dilutions carried out. *(Oluwaseun R. Alara, 2018.).*

Antioxidant Analysis

Antioxidant activity (%) =(1-s/b)×100%, where b is the absorbance of the blank and s is the absorbance of the sample.

Moisture content calculation

To calculate the moisture content, dry and wet weight data is needed. (Nidhi, 2015):

$$\text{Mc (wet basis)} = \frac{(Mi-Md)}{Mi}\ x100 \qquad (3.1)$$

$$\text{Mc(dry basis)} = \frac{(Mi-Md)}{Md}\ x100 \qquad (3.2)$$

$$X_n = \frac{W_n - Mbk}{W_n} \times 100\% \qquad (3.3)$$

Information :
Xn = Moisture Content
Wn = Initial Mass (grams)
Mbk = Dry Base Mass (grams)

Drying rate calculation

To get the drying rate, data on sample weight reduction is needed for each (Nindhi, 2015) :

$$DR = \frac{M_i(gram) - M_d(gram)}{t\,(menit)} \quad (3.4)$$

Information:
DR = *drying rate* (g/s)
Mi = initial mass (g)
Md = final mass (g)
t = drying time (minutes)

Product Quality Analysis
Chemical content

Fresh onions were measured soluble solids content (%), pH, and titrated acidity (g citric acid / L) was measured. Ash content and moisture were also analyzed on fresh onions and dried onions.

Bioactive compounds: total soluble phenolic content (TSP), flavonoids (F) and antioxidant activity (AA).

Onion extract. Methanol extracts from fresh and dried shallot samples were prepared according to the methodology described by Siddiq et al. Onions are ground in a coffee grinder and mixed to obtain a homogeneous product. Samples were weighed (ca. 5.0 g fresh or dry material), and extracted by sonication (40 kHz, 45 min, 25 C, ultrasound bath model TB02TACA, TESTLAB SRL, Buenos Aires, Argentina) using 20 ml methanol:water (80:20). , MeOH:H2O). The homogenate was then centrifuged at 10,000 g for 10 min using the Biofuge 28RS Heraeus Sepatech Centrifuge (Heraeus Instruments, Hanau, Germany) and filtered. Each homogenate was extracted twice and the combined fraction was diluted to a final volume of 40 ml and used for further analysis.

Total soluble phenolic content (TSP) was determined by the FolinCiocalteu method, using linear regression of calibration plots constructed using gallic acid. The results were expressed as mg gallic acid equivalent (GAE) per 100 g shallots at fresh weight (fw) (mg GAE/100 g fw) and at dry weight (dw) expressed (mg GAE/100 g dw). The flavonoid content (F) was determined using the AlCl3 method according to the modified methodology proposed by Ismail et al. The F content was calculated by linear regression of the calibration curve construction using quercetin. The results are expressed as mg quercetin equivalent (QE) per 100 g of onions on fresh weight (fw) (mg QE/100 g fw) and on dry weight (dw) (mg QE/100 g dw). Antioxidant activity (AA) was determined using the FRAP assay as described by Oyaizu. Trolox (0–50 M) was used as the standard antioxidant and AA of the extract was expressed as microMolar equivalent of Trolox (µMol TE) per g onion based on dry weight (dw) (µMol TE/g dw). The free radical scavenging effect was assessed according to the procedure described by Brand-Williams et al. with minor modifications to reduce testing time. Quercetin equivalent was used as the reference compound. The concentration of the extract giving 50% radical scavenging activity (EC50) was calculated. Absorbance measurements were carried out at 25°C, using a Multiscan FC spectrometer (Thermo Fisher Scientific Corporation). All measurements were made in triplicate.

Rehydration ratio

After the drying process, the rehydration was evaluated to observe the possible structural changes produced by the drying process. Rehydration was carried out at 25 ± 1 C. The dry sample (3 slices dried at each temperature) was put into 50 ml of distilled water in a Petri dish for 3 hours (until the weight was constant). The sample is removed from the water and then, its surface is covered with a piece of filter paper to soak up the excess water. The rehydrated shallot slices were then weighed using an electronic scale (Taff-Ware brand, type I – 2000, Max resolution 1000 g, d = 0.1 g). All experiments were carried out 3 times and the average value of the rehydration ratio (RR) was taken. The rehydration ratio can be calculated by the following formula:

$$RR = \frac{Berat\ sampel\ setelah\ rehidrasi\ (gr)}{Berat\ sampel\ sebelum\ rehidrasi\ (gr)}$$

Color Measurement

The color of the shallot slices was measured with a Minolta Chroma meter CR 400 color meter (Minolta Co., Osaka, Japan) before and after drying. The color meter is calibrated against a standard calibration plate from a white surface and set to CIE Standard Illuminant C. Values L*, a*, b* are the average of ten readings. The L* color brightness coordinate measures the whiteness of a color and ranges from black at 0 to white at 100. The a* chromaticity coordinates measure red when positive and green when negative, and b* chromaticity coordinates measure yellow when positive and blue when negative (Doymaz, 2003). Tugrul, & Pala, 2006).

RESULT AND DISCUSSION

Drying Characteristics

The process of drying thin layers of sliced onions using a *food dehydrator* at temperatures of 40 °C, 50 °C, and 60 °C starting at a moisture content of 85% was carried out for 8 hours and stopped when the weight of the sliced shallots has reached a constant or has reached equilibrium. . Connection drying time to *moisture ratio* on the drying of sliced shallots is presented in Figure 4.1.

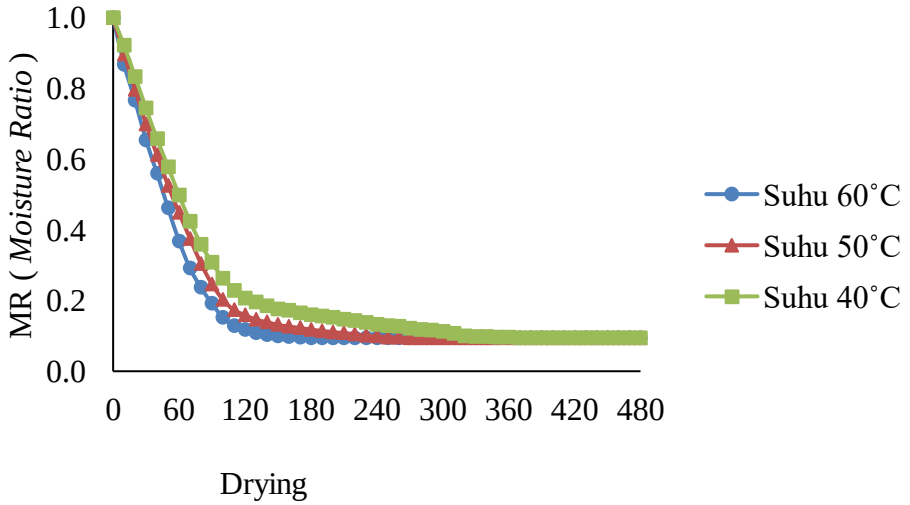

Figure 5 Relationship of drying time to *moisture ratio*

Figure 5 shows a decrease in the value of the *moisture ratio* with increasing drying time. The time required for drying shallot slices using a temperature of 40 °C to reach an equilibrium weight of 9.34% is 7 hours. The drying time is slower than the drying of sliced shallots using a temperature of 50 °C and 60 °C, namely for 3 hours and 5 hours.

The decrease in the value of the *moisture ratio* during the drying period is due to the reduced moisture content of the material due to the mass transfer of water from the material to the air (Sahoo et al., 2016). The difference in temperature used also affects the high decrease in the value of the *moisture ratio* so that it affects the drying time used to achieve the equilibrium weight of sliced shallots. This phenomenon can be caused by the use of higher temperatures in the drying process which causes the heat transfer to be greater. As a result, the process of transferring water mass from the material to the air is faster so that the drying time used is also faster (Salamatullah, Uslu, Özcan, Alkaltham, & Hayat, 2021). Research conducted by Hendrawan *et al* . (2018) on the drying of sliced shallots shows that the value of the *moisture ratio* at equilibrium is 9.99%. The difference in the *moisture ratio value* obtained can be caused by the initial moisture content of the material and the thickness of the material used (Olubi, Oniya, & Owolabi, 2021).

Drying Rate Analysis

The drying rate data analysis showed that the drying of shallot slices occurred in the *falling rate period* . Drying rate can be defined as the rate of evaporation of water from the material into the air per unit time. The value of the drying rate of sliced shallots using a *food dehydrator* at temperatures of 40 °C, 50 °C, and 60 °C is presented in Figure 4.2.

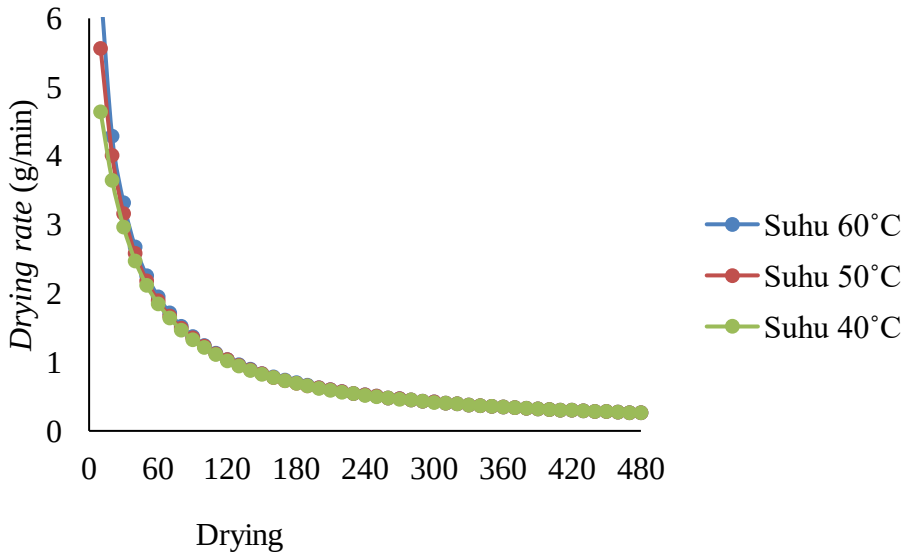

Figure 6 Curve of drying rate

Figure 6 shows the drying rate at temperatures of 40 °C, 50 °C, and 60 °C decreased with increasing drying time due to a decrease in water content with increasing time. The average drying rate of sliced shallots at each temperature of 40 °C, 50 °C, and 60 °C were 0.865 g/minute, 0.904 g/minute, and 0.938 g/minute. Figure 4.2 also shows that the higher the drying temperature used, the faster the drying rate that occurs.

The use of higher temperatures in the drying process can accelerate the drying rate because the rate of evaporation of water from the material to the air also increases with increasing temperature (Davodi-Boroujerd, Abasi, Arani, & Aslzaker, 2022). Then, the drying rate decreases with increasing time. The drying rate that occurs at the beginning of

drying is still relatively high because the free water content on the surface of the material is still quite high. The free water content is easy to evaporate because it fills the cell cavities and intercellular spaces (Kaveh, Abbaspour-Gilandeh, & Nowacka, 2021). Furthermore, there is a decrease in the drying rate with increasing time because the remaining water content in the material is water bound to the cells and tissues of the material making it difficult to get out of the material. The bound water content is difficult to evaporate because it is hygroscopically attached to the cell wall which in the end the drying rate of the shallot slices becomes constant (Misha, Mat, Ruslan, Sopian, & Salleh, 2013).

Application of the Thin Layer Drying Model

The three thin layer drying models are used to predict the drying characteristics of sliced shallots so that the drying process can be controlled according to the desired results. *Moisture Ratio (MR)* data obtained from the experiment was plotted into three drying models, namely Newton, Page, and Henderson & Pabis. The results of the constant values for each tested model are presented in Table 1.

Table 1 Analysis results from thin layer drying model

Drying Model	T (^{o} C)	k	a	n	R2 -	RMSE	x^2
Newton	40	0.0064			0.9334	0.12280	0.01939
	50	0.0067			0.9006	0.14177	0.03618
	60	0.0068			0.8699	0.16687	0.08354
Page	40	0.0928		0.549	0.9353	0.04354	0.00253
	50	0.1559		0.469	0.9032	0.05111	0.00522
	60	0.3159		0.350	0.8859	0.04921	0.00969
Henderson - Pabis	40	0.0039	0.538		0.8007	0.16415	0.03464
	50	0.0043	0.446		0.6791	0.19536	0.06870
	60	0.0046	0.370		0.5679	0.21825	0.14290

Table 1 shows the results of the constant value analysis of each model equation. The drying model shows that Page's model has the highest R2 value between $^{0.8859}$ to 0.9353 and the lowest RMSE and x2 values $^{\text{between}}$ 0.04354 to 0.05111 and 0.00254 to 0.00969. This indicates that Page's model is the most accurate model in describing the drying characteristics of sliced shallots based on the resulting constant values.

The analysis of the R2 value $^{\text{is}}$ a test of a statistical model that describes how well the variance of the model is with a series of observations. These measurements usually summarize the difference between the observed value and the expected value in the model. The closer the R2 value is to ^{1}, the more the model explains the observed variation, the more perfect it is. Analysis of the value of x^2 is a statistical test used to determine whether two variables have a significant difference between the observed and the expected. RMSE value analysis is a measurement for the error rate based on the difference between the two corresponding variables, the smaller the RMSE value, the more accurate a predictive model is (Siami-Namini, Tavakoli, & Namin, 2018).

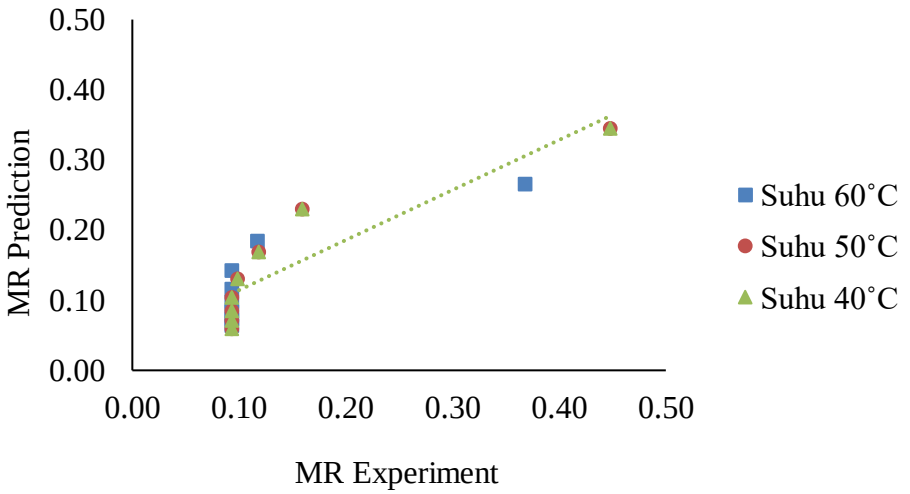

Figure 7 The relationship between predicted MR and experimental MR in the Page . model

Figure 7 shows the predicted MR and experimental MR at temperatures of 40 °C, 50 °C, and 60 °C using Page's model. The results of the relationship between prediction MR and experimental MR show that the Page model is a drying model used to predict the water content of sliced shallots at various temperatures so that the drying process can be controlled according to the desired results (Santoso et al., 2018).

Most of the drying of agricultural products occurs in the falling rate period and the movement of water during this period is controlled by internal diffusion. Analysis in this period was carried out to understand the drying kinetics by determining the effective diffusivity (*Deff*) (*Afifah* et al., 2017). The results of the calculation of the $D_{eff\ value}$ for all treatments are presented in table 8.

Table 2 Effective diffusivity (Deff) value of_{drying} shallot slices at various temperatures

Drying Temperature (°C)	Effective Diffusivity (m^2/s)
40	1.58×10^{-9}
50	$1,744 \times 10^{-9}$
60	1.866×10^{-9}

Based on Table 2, the value of the effective diffusivity (*Deff*) for_{drying} sliced shallots at temperatures of 40 °C, 50 °C, and 60 °C is 1.58×10^{-9} m^2/s, 1.74×10^{-9} m^2/s, and 1.86 10^{-9} m^2/s. This value is considered acceptable for most agricultural products. The higher the drying temperature, the higher the product temperature, which encourages the movement of water in the product through diffusion and then evaporates into the air (Herlina & Suherman, 2020). Several other studies have shown that the Deff value in sliced garlic on drying using an oven dryer at a temperature of 60 °C and 70 °C is 8.11×10^{-11} m^2/s and 1.22×10^{-10} m^2/s (Roman et al. , 2019). The difference in effective diffusivity values between agricultural commodities is possible due to differences in the structure of the dried material including differences in material thickness (Widowati et al., 2017).

Rehydration Ratio Analysis

The rehydration ratio is one of the important parameters of the quality of a drying product. Rehydration properties are the ability of drying products to absorb water so that they are close to their fresh condition. The results of the study for the effect of drying

temperature on the rehydration ratio of sliced shallots are presented in Table 3.

Table 3 Value of rehydration ratio of drying products at various temperatures

Drying Temperature (°C)	Rehydration Ratio
40	5.28
50	4.92
60	4.64

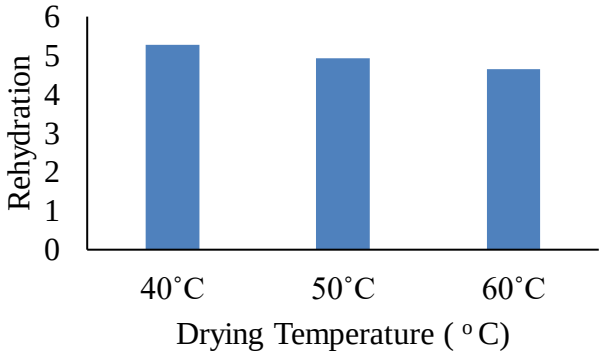

Figure 8 Effect of drying temperature on product rehydration ratio

Figure 8 shows the value of the rehydration ratio obtained from the comparison of the mass of sliced shallots after being rehydrated to the mass of dried shallots slices. The results showed that the rehydration ratio of sliced shallots for temperatures of 40 °C, 50 °C, and 60 °C was 5.28; 4.92; 4.64. The higher the drying temperature used, the lower the value of the rehydration ratio. This can be due to the red onion slices which are very sensitive to temperature so that the tissue is easily damaged if dried at too high a temperature (Ali Asgar, 2013).

Widyasanti et al. (2018) stated that the higher the rehydration ratio value, the higher the ability of drying products to absorb water, and the better the elasticity of the cell walls and vice versa. A high value of the rehydration ratio is needed in drying products because it shows that the product is close to its original shape which means it has good physical quality.

Color Analysis

The appearance of a product, especially its color, is very important in influencing the preferences and decisions of a buyer. Therefore, the color of the dried shallot slices is an important parameter to measure. The results of the analysis of the effect of drying temperature on the values of *L, a,* and *b* shallot slices are presented in Figure 9

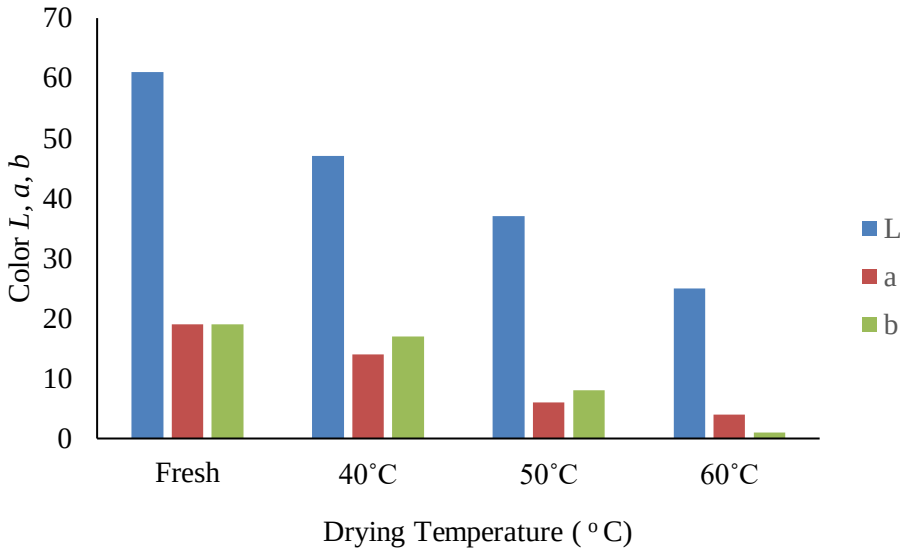

Figure 9 Effect of drying temperature on the values of *L, a,* and *b* shallot slices

The results showed that the drying temperature had a very large effect on the color of sliced shallots. Both the values of *L* (brightness level), *a* (red intensity), and *b* (yellow color intensity) decreased with increasing drying temperature used. Sliced shallots in *fresh condition* had the highest *L, a,* and *b values* of 61, 19, and 19. Meanwhile, sliced shallots dried at 60 ^{oC} had the lowest *L, a,* and *b values of 25,* 4, 1.

The lower *L value in the dried product indicates the darker the color of the product.* The decrease in the brightness of the shallot slices at higher drying temperatures can be caused by the high protein content in the shallot slices. In addition, the decrease in the brightness of the shallot slices can be caused by the *Maillard reaction* during the drying process. The *Maillard* reaction is a reaction between reducing glucose and primary amino acid groups which can produce brown or melodic nitrogen polymers . The decrease in the value of *L* was also followed by a decrease in the values of *a* and *b* which could be due to the intensity of the red and yellow colors being very sensitive to heat. This is also supported by the research of Wijaya and Wahyono (2018) which states that the presence of drying temperature and *blanching time* gives a decrease in the values of *a* and *b* .

Analysis of Flavonoids and Total Phenolic

According to Tiho *et al* . (2017), polyphenols are a large group of phytochemical compounds in onions. Polyphenols also have aromatic ring components, which include flavonoids and phenols. The results of the study for the effect of drying temperature using a *food dehydrator* on flavonoids and total phenolics in sliced shallots are presented in Figure 10.

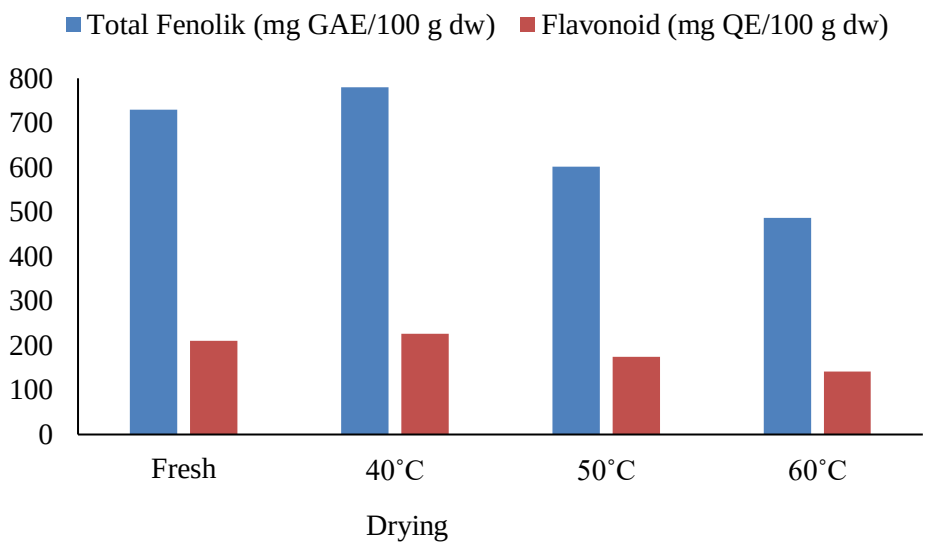

Figure 10 Effect of drying temperature on flavonoids and total phenolic

The results showed that the drying temperature had a big effect on the flavonoid content and total phenolic in the sliced shallots. The content of flavonoids and total phenolic increased from fresh sliced shallots to dried shallot slices. The highest value of flavonoid content and total phenolic content of sliced shallots was obtained at a temperature of 40ºC, namely 226 mg QE/100 g and 730 mg GAE/100 g, while the lowest flavonoid and total phenolic content of sliced shallots was obtained at a drying temperature of 60ºC, namely 141 mg QE. /100 mg and 486 mg GAE/100 g.

The increase in the flavonoid content and total phenolic content of fresh shallot slices against dried shallot slices could be due to the inactivation of the polyphenol oxidase enzyme (Khatulistiwa *et al.,* 2020). In addition, the increase in the flavonoid content and total phenolic content of shallot slices due to drying can also be caused by the release of polyphenolic compounds during the drying process (Roman *et al* ., 2020). According to Lisanti *et al* . (2015), drying accelerates the release of bound polyphenolic compounds during the breakdown of cellular constituents. Meanwhile, in the drying of sliced shallots after a temperature of 40 ° C the content of phenolic compounds decreased which could be caused by damage to bioactive components such as polyphenol compounds due to excessive heat (Oniya *et al.,* 2021).

Antioxidant Activity Analysis

Antioxidants are compounds that are able to inhibit or prevent cell damage due to oxidation by free radicals (Artanti and Lisnasari , 2018). The results of the study for the effect of drying temperature using a *food dehydrator* on the antioxidant activity of sliced shallots are presented in Figure 11.

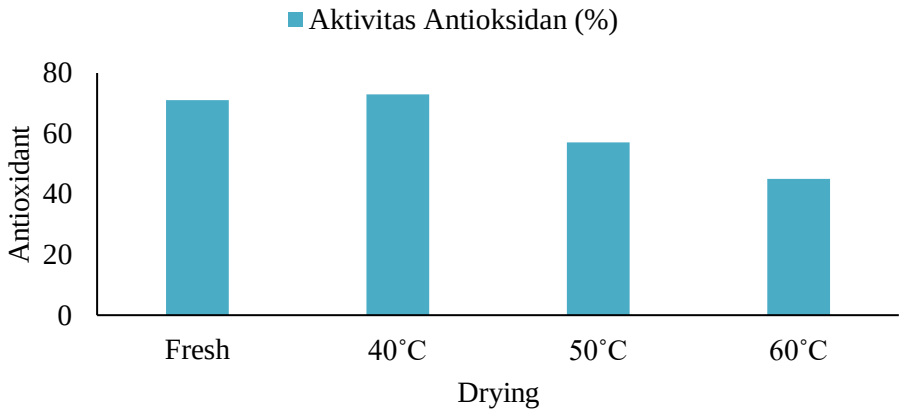

Figure 11 Effect of drying temperature on antioxidant activity

The results showed that the drying temperature had a very large effect on the activity of sliced shallots. The antioxidant activity increased from fresh sliced shallots to dried shallot slices. The highest antioxidant activity of sliced shallots was obtained at a drying temperature of 40ºC, which was 73%, while the lowest antioxidant activity of sliced shallots was obtained at a drying temperature of 60ºC, which was 45%.

Flavonoids and total phenolic compounds are compounds that have the ability as antioxidants. According to Molaveisi *et al* . (2018), flavonoids and total phenolics can act as antioxidants because of their ability to donate hydrogen atoms to free radicals, and as metal binders. The increase in antioxidant activity of fresh shallot slices against dried shallot slices could be caused by the release of polyphenolic compounds (flavonoids and total phenolic) during the drying process (Roman *et al* ., 2020). According to Lisanti *et al* . (2015), drying accelerates the release of bound polyphenolic compounds during the breakdown of cellular constituents. Meanwhile, in the drying of sliced shallots after a temperature of 40 ° C, the antioxidant activity decreased which could be caused by the higher heating temperature resulting in secondary metabolite compounds that act as antioxidants (polyphenol compounds) being damaged (Molaveisi *et al* ., 2018).

CONCLUSION

The decrease in *moisture ratio* is influenced by an increase in temperature, due to a decrease in air humidity so that heat and mass transfer also increase, and the moisture content of the material will decrease more quickly. Meanwhile, the drying rate on a *food dehydrator with* variable temperatures of 40 °, 50 °, and 60 o as well as traditional drying were 0.865 g/minute, 0.904 g/minute, and 0.938 g/minute, respectively . The fastest drying rate occurs in the drying process at a variable temperature of 60 ° C. Then the drying rate will decrease with increasing drying time, because the moisture content of the material also decreases.

The mathematical model of thin layer drying that is suitable for drying shallot slices using a *food dehydrator* is the Page model because it has the highest R2 value of 0.9353 and the lowest RMSE and x2 values $^{\text{are } 0.04354}$ and 0.00253. The content of total phenolic, flavonoid, and antioxidant activity found in sliced shallots before drying was 730 mg GAE/100 g, 210 mg QE/100 g, and 71%, respectively. Meanwhile, the total phenolic, flavonoid, and aa content found in sliced shallots dried at 60 ^{oC} were 486 mg GAE/100 g,

141 mg QE/100 mg, and 45%, respectively. The decrease in bioactive compounds on drying at higher temperatures was caused by the destruction of bioactive components such as polyphenol compounds due to too high heat. The use of a higher temperature also reduces the color degrees of *L*, *a*, and *b* so that the color of the dried red onion slices becomes darker. The rehydration ratio was determined to determine the parameters of good physical quality of the drying product. The highest rehydration ratio value was obtained at a drying temperature of 40 °C.

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