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Evaluation of Drying Temperature on Water Removal and Physicochemical Quality of Onion Slice

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Drying is one of the most important steps in preserving bioactive compounds or other ingredients in onions. This study evaluated the moisture removal and physicochemical quality of red onion slices with various air temperatures. The harvested onion with a moisture content of around 82.6% was sliced about 4 and 6 mm thick and dried in the convective dryer from 40°C to 120°C. The moisture content, rehydration ratio, color, quercetin content, and antioxidant activity were evaluated. Results showed that the moisture removal from onion at the higher temperature was faster, and the onion still had the antioxidant ability. However, at operational temperatures upper 80°C, the structure of onion tissue and its organic substances deteriorated, which degraded the appearance, rehydration ratio, and quercetin content. Therefore, the drying temperature of 80°C or below is recommended to retain the physicochemical quality of onion.

1. Introduction

Red onion is one of the most important agricultural products commonly used as a seasoning, condiments, and spices, which is highly commercial in the food industry. The world production of red onion is 55 million tons per year and is increasing annually (Yan et al., 2015). The onion product contains a complex compounds such as essential oil, volatiles, bioactives (phenolic and flavonoid), anti-oxidant and the others that contribute to specific aroma and flavor (Marlin et al., 2019). The commodity has also become a therapeutic agent in traditional medicine (Kothari et al., 2020). The beneficial compounds such as quercetin allicin and their derivatives or flavonoid glycosides are in onions (Yan et al., 2015). Quercetin is also the major dietary flavonoid in vegetables. Those compounds have potential benefits for human health that can be used as functional food or raw materials for the pharmaceutical industry, such as cardio-protective, anti-microbial activities, anti-inflammatory, and anti-cancer. The antioxidant properties can prevent cardiovascular diseases (Hashmi et al., 2015).

Even though the red onion is rich in bioactive compounds, its quality can degrade during the post-harvest treatment using heat such as drying. The drying is used to remove moisture in onion to prolong storage life. In the drying, heat and moisture transfer occur simultaneously, changing the physical structure/appearance and chemical compositions. With low air relative humidity and/or high temperature, the moisture removal can be faster, which speeds up the drying time for onions (Asiah et al., 2017; Djaeni & Perdanianti, 2019). However, in high temperature drying, the physical structure of the onion's matrix changes, and some bioactive substances are losses (Minatel et al, 2017). Djaeni et al, (2017) reported that under an operational drying temperature 60°C for 2 h, the thiamine content loss was about 74%. In addition, vitamin C and vitamin D in the onion slices are also reduced with the increase of air temperature (Olalusi, 2014). Free-drying is another option to dehydrate red onion with better bioactive preservation (Thuy et al., 2020). However, the current freeze-drying is in-efficient in terms of energy usage, and it is also a high investment and operational cost (Barbosa et al., 2016)

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This study evaluated red onion slices' moisture removal and physicochemical quality under various air drying temperatures. As responses, the moisture content, color, rehydration ratio, quercetin content, and antioxidant ability were evaluated. The results can be used to consider the suitable condition for onion drying and treatment.

2. Materials and Methods

2.1 Materials

Bulb Red Onions (harvested from Sukomoro, East Java) were selected by similar size (diameter between 25–30 mm) and color without any visible disorder. The onions were peeled and sliced with thicknesses of 4 mm ±1, 6 mm measured by a digital vernier caliper with an accuracy of 0.001 mm. The initial moisture content (x_0) in onion was about 82.6% analyzed by gravimetric method.

2.2 Methods

2.2.1 Convective Drying

A convective drying was used to dry the onion slices. The dryer can work up to an operational temperature of 150°C. In the study, the sliced onion was dried at 40, 60, 80, 100, and 120°C. Temperatures of 100°C and 120°C were applied, referring to the basic concept of drying temperature that can be conducted from below the triple point to above the liquid critical point (Jangam et al., 2010). Before the commencement of each drying experiment, the oven (Memmert 110 Schwabatch, Germany) was run for 15 min to stabilize the operational temperature (suppose 80°C). After that, the six Petri dishes containing 30–35 grams of onion slices were put on the tray. The moisture content in the onion was observed every 30 min for 180 min by gravimetric methods assisted by a top-pan electronic balance (CX made in China, resolution ±0.01 g). After completing the process, the dried onion quality regarding to the rehydration ratio, color, and quercetin content was analyzed. The procedures were repeated for drying temperatures 40, 60, 100 and 120°C.

2.2.2 Moisture Content Observation

The gravimetric method analyzed the moisture content in triplicate at every sampling time. The calculation was based on the onion weight difference at incremental sampling time, as can be seen in equation 1.

$$X_t = \frac{W_t - W_d}{W_d} \qquad (1)$$

$$W_d = W_0 * (100\% - x_0) \qquad (2)$$

Where, X_t is the moisture content dry basis (gram moisture/gram dry product) at sampling time (t), x_0 is the percentage of moisture in fresh onion before drying (%), W_t is the weight of onion at sampling time (gram), W_d is the dry weight of onion (gram), and W_0 is the initial weight of onion (gram), and t is sampling time (minute).
In this step, Fick's model is also used to estimate the effective moisture diffusivity (*De,* in square meters per second) for a thin layer with a thickness L (m) and at drying time t (s) (Maskan et al., 2002):

$$\mathrm{MR} = \frac{8}{\pi^2} exp\left(\frac{-\pi^2 D_e t}{L^2}\right) \qquad (3)$$

Where MR is moisture ratio. It was calculated using equation 4:

$$\mathrm{MR} = \left(\frac{M_t - M_e}{M_0 - M_e}\right) \qquad (4)$$

Here, M_t is moisture content at t, M_0 is initial moisture content. Since the value of M_e is very small compared to M_t and M_0, the value of M_e (moisture content equilibrium) is neglected.

2.2.3 Rehydration Ratio (RR)

Rehydration ratio (RR) is used to measure a dried onion's water absorption by the osmotic process. 5 g of dried onion slice was soaked in 100 ml of water at 80°C for 30 min. After that, the onion slices were wiped with tissue to remove the droplet of water on the surface (Kumar et al., 2021). It was then weighted using a top-pan electronic balance (CX made in China, resolution ±0.01 g). All the experiments were performed in triplicate, and average values were reported. The RR was calculated with equation 5, as follows:

$$RR = \frac{weight\ of\ rehydrated\ onion\ (g)}{Weight\ of\ onion\ before\ rehydrated\ (g)} \qquad (5)$$

2.2.4 Color Measurement

Color of onion slices were measured by using a handheld colorimeter (NR20XE, Shenzhen 3nh Technology Co. Ltd., China) on the basis of three color values in terms of L (Lightness), a* (redness and greenness), b* (yellowness and blueness), and the total color change were calculated as equation 6.

$$\Delta E = \sqrt{(L_0^* - L_t^*)^2 + (a_0^* - a_t^*)^2 + (b_0^* - b_t^*)^2} \qquad (6)$$

Where, L_0^*, a_0^*, b_0^* and L_t^*, a_t^*, b_t^* are the color values of the fresh onion and dried onion slice, respectively. The colorimeter was calibrated with a standard white reference before measurements. The dried onion was placed below the light source and covered by thin transparent plastic, then captured by the colorimeter. All the values (L*, a*, b*) was recorded and worked in three times repetitions.

2.2.5. Total Flavonoid (Quercetin Analysis)

The quantitative analysis of quercetin was determined by high-performance liquid chromatography (model: LC-10AT vp plus, Shimadzu, Japan). The dried onion was extracted by Ultrasound-assisted extraction (UEA) before analysis. The 5 g of the ground onion was extracted with 50 mL of methanol 97% in 60 mL glass bottle under 40 Hz and 100% power at room temperature for 10 min (Oancea et al., 2020). The liquid extract was separated as a sample for quercetin analysis.

2.2.6 Anti-oxidant activity (AA)

The AA was represented by 1, 1-Diphenyl-2-picryl-hydrazyl (DPPH) analysis determined by high-performance liquid chromatography (model: LC-10AT vp plus, Shimadzu, Japan). The result is presented in DPPH radical scavenging activity (%), %RSA. The dried onion was extracted by Ultrasound-assisted extraction (UEA) before analysis. The 5 g of the ground onion was extracted with 50 mL of methanol 97% in 60 mL glass bottle under 40 Hz and 100% power at room temperature for 10 min (Oancea et al., 2020). The liquid extract was separated for DPPH analysis.

3. Results and Discussions

3.1 Moisture Content Evaluations

The moisture content reduction in the red onion slices at different drying temperatures was presented in Figure 1. For all cases, the increase of drying temperature, the moisture removal was faster since higher drying temperature speeds up the water diffusion from the inside solid to the surface (Kouchakzadeh, 2014). For each drying temperature, effective moisture diffusivity (De) was calculated using Fick's model (Eq. 3). The data at Table 1 shows that the effective moisture diffusivity value increases with the increase of temperature. The other result on onion slices drying observation, found the same phenomena with this experiment (Mitra et al., 2011). Based on Figure 1 (a), the moisture content reduced drastically at the first 90 min. This is due to the excessive availability of free moisture content in the onion tissue. Thus, the driving force for moisture transfer from onion to the air as a drying medium was high. After 90 min, the moisture content reduction tends to be declivous as the driving force decreases. Drying temperature affects the relative humidity of the air, whereas, at high temperatures, the relative humidity of air is lowered in, which enhances the driving force for drying. As a result, the water removal was faster, which shortened the drying time (Revaskar et al., 2014). Meanwhile, the increase in onion slice thickness caused more water resistance for diffusion (Russo et al., 2019). As consequence, the water removal became slower.

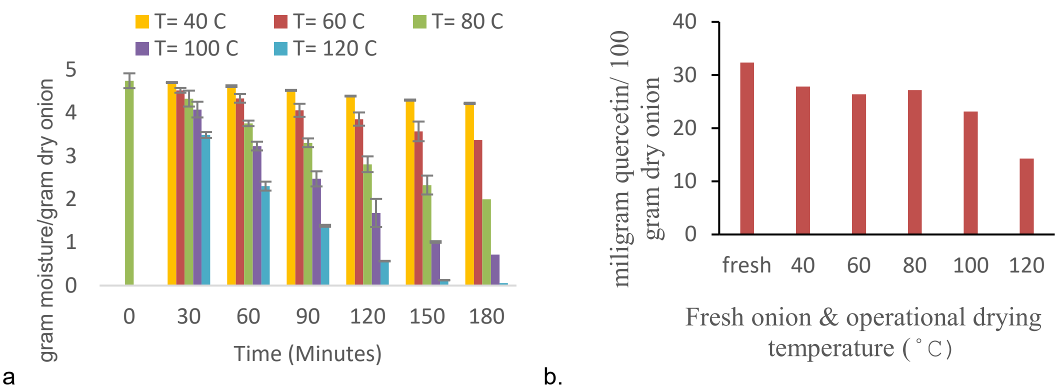


Figure 1: (a) The observation of moisture in onion slices versus time at different drying temperatures. (b) Effects of Different Drying Temperature on Total Quercetin Contents

3.2 Rehydration Ratio (RR) Characteristics

Most dry products such as onions are usually rehydrated during usage. The RR was used for identifying the structure of a dried onion. The result of RR for 4 mm of onion slice in various temperatures is shown in Table 1.

Most of the moisture content was released at higher temperatures. Therefore, some water can be potentially re-adsorbed to fulfill the empty hole in onion's tissue. However, part of the onion tissue structure deteriorated at higher temperatures and became shrinkage. It can reduce the affinity to the water and hamper the rehydration rate. As a result, the part of tissue void cannot be fulfilled by water. For example at 120°C, the RR was 0.63 gram moisture per gram dry onion with the total moisture loaded rounded 0.75 gram moisture per gram dry onion, only. The total moisture loaded in fresh onion was 4.75 grams of moisture per gram of onion (Table 1). Therefore, the capability of dried onion to hold water is reduced up to 84.2% from fresh conditions.
In general, after the high temperature drying, the water capacity can be lower. Due to the decreasing hydrophilic properties, the dried material give lower values of RR and unable to adsorb sufficient water, leaving pores unfilled (Krokida & Marinos-Kouris, 2003). The rehydration degree also depend on the degree of cellular and structural disruption generally. The cellular or tissue rupture is irreversible and the dissociation during drying process results in loss of integrity (Jayaraman et al., 1990). Thus, after soaked in hot water, the affinity of dry onion to hold water was limited.

Table 1. Rehydration ratio (RR) of onion slice with thickness 4 mm in various drying temperature

Parameter (gram moisture/gram dry onion)	**Fresh onion**	**Drying Temperature (°C)**				
		40	**60**	**80**	**100**	**120**
Initial Moisture Content	4.75	4.23	3.53	1.8	0.7	0.13
Rehydration Ratio (RR)	NA	0.32	1.2	1.24	0.76	0.62
Total moisture loaded	4.75	4.55	4.73	3.04	1.46	0.75
De 10^{-11}, m^2/s		2.16	5.95	14.06	31.10	68.97

3.3 Color Measurement

The appearance of dried onion can be noticed as a parameter in deciding on the drying process. The dehydrated product color undergoes change during the drying process depending on the severity of operation conditions. During commercial dehydration of red onion flakes, pink discoloration often adversely affects the quality of dried onion flakes. Control of pink discoloration is very important to attract the consumer and also to compete in the market. Higher L* values show the brightness of the samples of fresh onion slices, and onion slices dried at temperatures 40, 60, 80, 100, and 120°C. The data shows that L* values of fresh onion (± 69.89) is greater than dried onion slice (ranging from 63–43) and the increase of drying temperature caused a lower value of L*. All dried onion slices showed significant ($p < 0.001$) values of L*. The dried onion slices had the highest a* (±10.4) value which means higher redness, while the fresh onion slice had the lowest value (±3.35) (Pott et al., 2005). The value a* of dried onion slice is not significantly different ($p > 0.05$). A higher b* represents the increase of bluish/yellowish level. As depicted in Table 2, the redness and bluish of dried onion increase corresponding to the increase of operational drying temperature. All the dried onion slices showed a significant ($p < 0.05$) value b*. Upper 80°C, the color of onion tends to dark due to the deterioration of ingredients or the other organic substances.

Table 2. Color parameters observatio during convective drying

Temperature (°C)	Thickness (mm)	**L***	**a***	**b***	**ΔE**
Fresh		69.81	3.35	2.85	0
40	4	57.52	7.92	13.11	17.19
40	6	58.76	8.67	11.48	15.55
60	4	51.72	7.67	7.58	19.75
60	6	49.74	10.15	2.86	21.73
80	4	47.52	7.81	8.28	24.13
80	6	43.745	9.67	7.56	27.64
100	4	53.965	8.09	13.67	20.89
100	6	53.105	9.44	9.425	20.42
120	4	52.225	10.405	15.955	23.308
120	6	53.54	9.02	16.215	23.251

The onion color depends on the presence of anthocyanin. Anthocyanin are water-soluble compounds and contribute to the color of plants (leaves, stems, roots, flowers, and fruits) (Fossen et al., 1996). The anthocyanin level in red onion decreased at a higher drying temperature or longer drying time (Djaeni et al., 2020). The introduction of heat in drying plays a role in destabilizing the molecular structure of anthocyanins. The increasing temperature damages anthocyanins, as reported by Stintzing et al. (2002) and Dyrby et al. (2001). The degradation of anthocyanins was associated with a reduction in the appearance of onion.

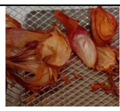
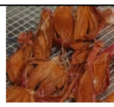
3.4 Quercetin in Dried Onion Slice

Figure 1 (b) shows the total quercetin content of fresh and dried onion slices at various temperatures for 180 min. The quercetin concentration goes down with the increasing of drying temperature. The higher temperature, the less quercetin was retained. Here at a drying temperature of 120°C, the quercetin retention was about 44%, only. Drying at high temperatures with long drying leads to the loss of vitamins, colorants, and antioxidants of the fruits and vegetables (Calín-Sánchez et al., 2014). Quercetin reduction in the form of phenolic compound of onion was also detected after drying at 150° C for 20 min (Çubukçu et al., 2019). Nevertheless, drying at a low temperature did not significantly affect quercetin change (Djaeni & Arifin, 2017). In this study, for drying temperatures (40, 60 and 80°C) the quercetin content was also still comparable with previous study (Djaeni & Arifin, 2017). Above 80°C, the quercetin content decreases significantly. Above 80°C, the quercetin content decreases significantly. Quercetin at high temperature are degraded (130°C, 2 h) and changed into 2-(3,4-dihydroxyphenyl)-2-oxoacetic acid), (2,4,6-trihydroxybenzoic acid), and two other undefined compounds (Chaaban et al., 2017) .Therefore, quercetin is popular with its high sensitivity to temperature .

3.5 Anti-oxidant activity (AA)

One of the special tastes of onion is spices caused by the presence of phenolic compounds. The antioxidant substances must be kept high in onions to make the onion consumption more meaningful on health effects. The AA was represented by the percentage of radical scavenging activity (% RSA). Table 3 shows that AA increased with the decrease of moisture content in onion at higher drying temperatures. The pure solid onion sample for antioxidant analysis was heavier with lower moisture content. So, the number of phenolic compounds and the other active substances related to AA became more concentrated. Moreover, at higher drying temperatures, the remaining flavonoid, quercetin, and phenolic compound still have an antioxidant ability (Chaaban et al., 2017). However, above 80°C, the carbonation of organic substances occurred as indicated in the darkness of onion appearance (Table 2 and Table 3). Hence, these drying temperatures were not recommended.

Table 3. Anti-oxidant activity (AA) in onion slice before and after drying

Parameter	Fresh	40 C	60 C	80 C	100 C	120 C
						
RSA (%)	21.1	10.4	11.5	21.5	24.9	39.7
MC_{db}	4.75	4.23	3.53	1.8	0.7	0.13

4. Conclusions

The moisture removal and physicochemical properties of onion were observed at different drying temperatures. Results showed that at higher temperatures, the moisture removal was faster. However, at higher temperatures, the RR, color, as well as quercetin content declined significantly. The RR of onion decreased with the increase of temperature due to the structural change in onion tissue. Hence, the capability to load water was lower. Meanwhile, the color and appearance of onion were affected by anthocyanin's presence, which becomes unstable at higher temperatures. So, the appearance and color of onions tend to darken, especially at temperatures above 80°C. Moreover, at this temperature, some of the active component having flavonoid groups, such as quercetin, has changed. Even at operational drying temperatures of 120°C, the retention of quercetin is only 44%. With this trade-off, the medium operational temperatures 80°C or below are still recommended for resulting in reasonable physicochemical quality of the onion.

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