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The Effect of Different Storage Temperatures and Internal Analysis of Onions with X-Ray CT on The Respiration Rate of Onions

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Abstract. Onion is an agricultural product that will continue to respirate after harvesting. Internal factors affecting the respiration rate are shelf life, onion type, and water levels external factors derived from the affected environment are temperature and RH. This study aimed to determine the difference in the rate of onion respiration with different storage temperatures. The samples used are local onion batu ijo. The onions for each sample are weighed 300 grams, then put in a sealed respiratory jar and stored at 27 ± 2°C and 7 ± 2°C temperature. The change in O_2 and CO_2 levels is measured using an analytical gas at a time interval of 1 hour in the first 12 hours, then every 8 hours in the following 60 hours, every 12 to 144 hours, and every 24 to 432 hours. The O_2 consumption and CO_2 production respiration rate equations perform the analysis. The results showed that temperature affected the onion respiration rate. Then, a non-destructive analysis of the internal damage of onions during storage in modified air conditions using X-Ray CT is also carried out. This analysis was performed to determine whether non-destructive analysis using X-Ray CT could be applied to see the damage to onions internally.

1 Introduction

The onion (*Allium cepa* L.) is essential to Indonesian culinary seasoning. The production of onions in Indonesia in 2020 reached 1.82 million tons, based on data from the *Badan Pusat Statistik*[1]. Onions are included in horticultural commodities that are easily damaged. One of the causes of this damage is the post-harvest treatment that has not been optimal. The loss of post-panned onions is 25%[2]. The inappropriate postmenstrual treatment causes the metabolism of onions to increase.

Onions are one of the surviving agricultural commodities after harvesting, characterized by a still metabolic process in onions after harvesting. One of the metabolic processes that occur is respiration. Respiration is the process of dissolving a complex molecule of carbohydrates ($C_6H_{12}O_6$) with the help of oxygen (O_2), resulting in simpler compounds of carbon dioxide (CO_2) and water (H_2O) accompanied by energy[5]. Respiration that occurs in onions will decrease the quality of onions, where the shelf life of onions cannot last long[5]. Because of

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this, the continuous and even availability of onions with good quality is still a difficult challenge to date. Therefore, onion storage is done to suppress damage and extend the shelf life of onions.

One of the storage techniques developed today is storage with Modified Atmosphere Storage (MAS). Storage with MAS is a storage technique with air conditioning, where O_2 gas concentration is lowered, CO_2 gas is raised, and ambient temperature is lowered[7]. The purpose of MAS storage is to lower or inhibit the respiration rate in onions so that the shelf life of onions becomes longer. In Indonesia, the storage of onions with MAS has begun. However, storage has not been optimally performed because scientific research has yet to be conducted on the optimum air conditions (O_2 and CO_2 concentrations) for onion storage. As an initial step to find out the optimal air condition, a test compares the respiration rate of onions with different storage temperatures (environment and refrigerator condition). With no difference in the respiration rate of onions with different storage temperatures, it can be used to reference whether they can be stored in the same MAS room. Optimum storage conditions can be predicted.

After knowing the appropriate storage temperature conditions, an analysis of internal damage during storage is carried out. Analysis of the quality of onions previously carried out by sampling and destructively was assessed as not being able to represent the entire product. Therefore, in this study, a non-destructive analysis of onion internals was carried out using X-Ray CT to determine whether analysis using X-Ray CT could be applied to see internal damage to onions.

2 Material and Methods

2.1 Materials

The onion (*Allium cepa* L.) used in this study is an onion with a variety of batu ijo from Batu City, East Java. Onions are obtained from onion suppliers at the Beringharjo Market in Yogyakarta. The onions used are onions with a growing age of 60 days and one week after harvest and are in the condition of being stolen. The amount of batu ijo onions used is 1.8 kg for good quality. While onions were stored in modified air for as much as 1.5 kg for each treatment.

2.2 Experiment design and treatment

This research was conducted at the Post-harvest Engineering Laboratory, Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Gadjah Mada University. The study was conducted from January to February 2023. X-Ray CT scanning images were taken at PT Cairnhill Serviech Inti located at Delta Commercial Park, St. Kenari Jaya, Blk. B5-B6, Jayamukti, Central Cikarang, Bekasi Regency, West Java, on January 19 and February 28, 2023.

This study used the Complete Randomized Design (RAL) method, with each variety using three repeats. The study used ta variety of onion, namely the Batu Ijo. The respiration data capture process was carried out for 432 hours with temperatures 7 ± 2ºC and 27 ± 2ºC where the data were taken with a time range of 1 hour at the first 12 hours and then every 8 hours for 60 hours, every 12 hours until 144 hours, and 24 hours with a time remaining after that.

The research phase began by weighing the onion varieties of batu ijo, weighing 300 grams for each sample. Then, the onion is placed in a sealed glass jar that has been set up. Data were collected using a 902D Dual Tank-type gas analyzer. Storage is performed at two different temperatures: environment and refrigerator. Space temperature storage is at 27 ± 2ºC, and

relative humidity is 85%, while at cooling temperatures, it ranges from 7 ± 2ºC in relative humidity to 70%.
The internal damage test of onions using X-Ray CT is performed twice, before and after onions are stored. Scanning images is done using a tube-type X-Ray CT under the Phoenix v |tome| x m microfocus CT brand. The resolution is 65 microns. The number of onions scanned is 3 for each repeat. After the onions are scanned, then the onions are stored on MAS storage. Storage in MAS was carried out under conditions of 5% O_2 and 2% CO_2[2] at temperatures of 7 ± 2ºC and 27 ± 2ºC[11]. Air conditioning was carried out every day, and measurements of weight loss were carried out every ten days for a total of 30 days of storage. After that, the onion is removed and rescanned to find out the difference in the internal structure of the onion before and after storage.

2.3 Respiration rate

Respiration is a biological mechanism by which the complex material of carbohydrates is broken down into simpler compounds of CO_2 and H_2O using O_2[5]. In the process of respiration, it also produces energy. The respiration rate affects the speed at which onions are broken. The faster the respiration rate, the faster the onions are to be broken. The rate of respiration can be calculated using the following two equations:
The speed at which onions absorb O_2 in respiration determines the rate of red onion respiration itself. Therefore, the rate of red onion respiration can be determined using O_2 percentages, i.e., as follows by eq (1)[4].

$$RO_2 = \frac{1\ x\ 10^4 \times (y_{O2}^{i} - y_{O2}^{f}) \times V_f \times P}{M \times (t_f - t_i) \times R_c \times (T + 273.15)} \quad (1)$$

The respiration rate can be calculated by two equations for respiration rate through O_2 consumption and respiration rate for CO_2 production, with the following equation. Then the respiration rate is based on the production of CO_2, which the following formula can calculate[4] (eq 2).

$$RCO_2 = \frac{1\ x\ 10^4 \times (y_{CO2}^{f} - y_{CO2}^{i}) \times V_f \times P}{M \times (t_f - t_i) \times R_c \times (T + 273.15)} \quad (2)$$

Where y_{O2}^{i}, y_{O2}^{f}, y_{CO2}^{f}, and y_{CO2}^{i} are O_2 and CO_2 volumetric concentration (%) in the jar, t_i is the initial time (h), and t_f is the final time (h). M is the mass of the onion (kg), Vf is the free volume inside the jar (m^3), P is the total pressure (Pa), Rc is the universal gas constant ($Jmol^{-1}K^{-1}$), and T is temperature storage (ºC).

The free volume (Vf) inside the jar was calculated by eq (3)

$$Vf = V - \frac{M}{\rho} \quad (3)$$

where V is the total volume of the jar (m^3), and ρ is the onion volumic mass (kg/m^3).

2.4 Image Processing

Onions were scanned using X-Ray CT with a resolution of 65 microns. The resulting images were reconstructed using the default X-Ray CT tool, VGStudio. Then the image, originally 32-bit in size, is changed to an 8-bit image, and the brightness and contrast are set in the ImageJ software. Furthermore, image processing to produce 3D images is performed on Avizo software. The processing stage with Avizo software is done in stages, starting with the input image and cropping the image according to the part to be processed. Then there is a median filter. The median filter reduces the noise in the image by blurring some noise without damaging the relevant onion structure[8]. A segmentation of the image is done afterward with adaptive thresholding. At this stage, the material part and the pore are separated in a binary image, where the material is blue (1) and the pore is black (0), corresponding to the background[6]. After that, the stages are divided into two to determine the skin and pores of the onion. After segmentation, the image is closed to determine the skin of the onion. The purpose of closing is to close all pores on the onion. Then fill holes are performed, which aim to close all unclosed holes in the closing stage. Remove small spots afterward to remove the spots or ingredients surrounding the onion so that when the label analysis is done, it does not interfere with the calculation of the onion. To determine the pore of the onion after a segmentation, the image is inverted. The goal is to reverse the value on the binary image of the pore to 1 and the material to 0. Then the result is prepacked with the result on the image after removing small spots. After that, label analysis is performed for measurements of volume, surface area, diameter, and other required parameters then generate a surfactant to produce a 3D image of onion skin and onion pores.

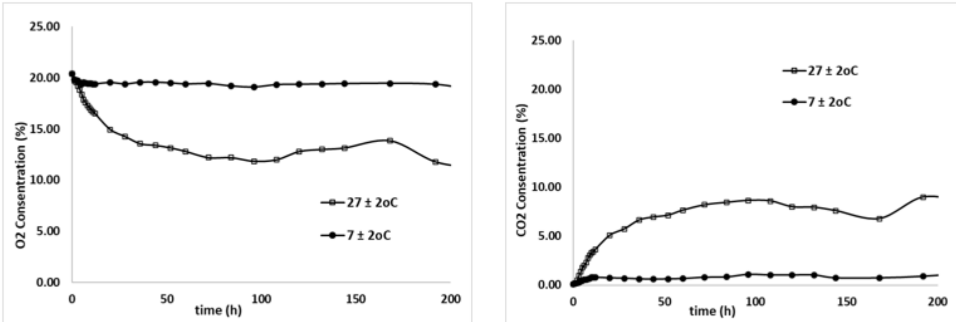
2.5 Statistical analysis

Statistical analysis was performed using SPSS software version 25.0 (SPSS Inc.; Chicago, IL, USA). All data were analyzed by repeated measure one-way (ANOVA). The analysis used a significant difference at $P < 0.05$, determined by Duncan's Multiple Range Tests.

3 Result and Discussion

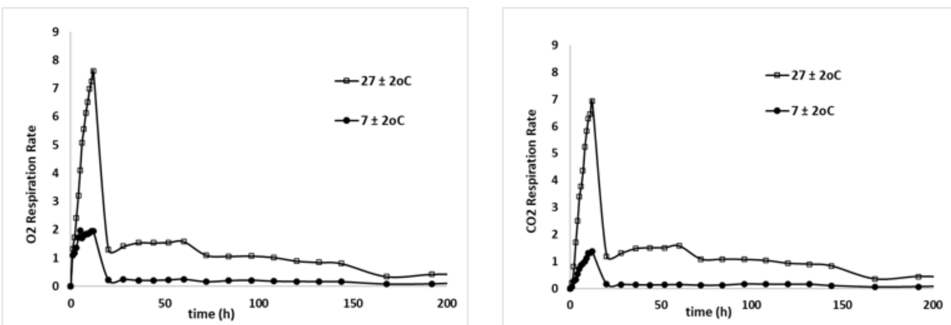
The rate of onion respiration will continue to change according to the change in concentration of O_2 and CO_2 gas in jar containers[12]. In the respiration process, the cells in the onions absorb O_2 and produce CO_2. Based on observations, it is known that the rate of O_2 absorption during the respiration process is the same as the rate of CO_2 produced during respiration. This is to the results of a study conducted by Sun (2023)[15] that the rate of O_2 absorption respiration is equal to the rate of CO_2 production. Therefore, in this process, only a graph of the respiration rate based on O_2 consumption is shown in Figure 2.

The process of red onion respiration begins at 0 o'clock when onions are placed in a sealed jar container. At that time, onions continued to respirate so that the speed of onion respiration continued to increase until the 6th hour reached the highest peak point of respiration. Then at the 8th hour, it decreased and rose again until the 12th hour, but the speed was lower than the 6th hour. After 12 hours, the respiration rate will slowly drop and then be constant at the 168th hour or, if in days, for seven days.



(a) (b)

Fig. 1. The rate of onion concentration (%) at different storage temperatures (a) based on O_2 consumption and (b) based on CO_2 production.



(a) (b)

Fig. 2. The rate of onion respiration (μmol kg^{-1} h^{-1}) at different storage temperatures (a) based on O_2 consumption and (b) based on CO_2 production.

This decrease in respiration rate after 12 hours is due to reduced O_2 concentration in the body due to O_2 consumption during respiration. Meanwhile, jars are tightly sealed and not opened during the study, so no O_2 supply is entered. The percentage of O_2 that goes down is shown in Figure 1.

A significant percentage drop in O_2 concentration is comparable to an increase in CO_2. As shown in Figures 1a and 1b, the consumption rate of O_2 is equal to the production rate of CO_2. At room temperature storage, it is seen that the concentration of O_2 in the jar is decreasing, and the concentration of CO_2 in the jar is increasing. Then in cold air storage, the concentrations of O_2 and CO_2 tend to be constant.

Figures 2 show that onions stored at room temperature (27 ± 2ºC) have a faster respiration rate than onions stored at cold temperatures. This follows Naik's (2014)[10] study that onions with 30ºC storage have a higher respiration rate than onions with 5ºC storage temperature. Onions stored at low temperatures (7 ± 2ºC) experience slower respiration because cold temperatures can suppress the red onion respiration process, and room temperature cannot suppress the respiration process during storage[9]. It also follows the[13] statement that as temperatures rise, the respiration process will go faster, and on[12], the respiration rate will decrease as storage temperature decreases. Storage temperature plays an essential role in onions' physical and photochemical processes. The higher the storage temperature for onions, the faster the internal activity occurs[14].

3.1 Image Analysis

Onions are stored in MAS (modified atmosphere storage) for 30 days, where every day, the air concentration is adjusted to 5% O_2 concentration and 2% CO_2 concentration. Every ten days, the MAS is opened to measure changes in onion weight. In Table 1 it is known that the weight loss of onions stored at MAS with temperatures 7°C and 27°C compared to onions left in the air at the same temperature (7 °C and 27 °C). It is known that onions stored in free air have more significant weight loss than modified air. In addition, as previously discussed, the storage temperature of 7 ± 2°C results in lower weight loss; than the storage temperature of 27 ± 2°C.

Table 1. Percentage of onion weight loss at temperatures of 27 ± 2°C and 7 ± 2°C.

Treatment	Weight loss (%)	k	R^2
O5C2T27	1.997 ± 0.055	-0.004 ± 0.001	0.940 ± 0.057
O5C2T7	1.764 ± 0.088	-0.007 ± 0.004	0.933 ± 0.040

Based on image processing in the Avizo software that has been done, the image results are obtained, namely in Table 2.

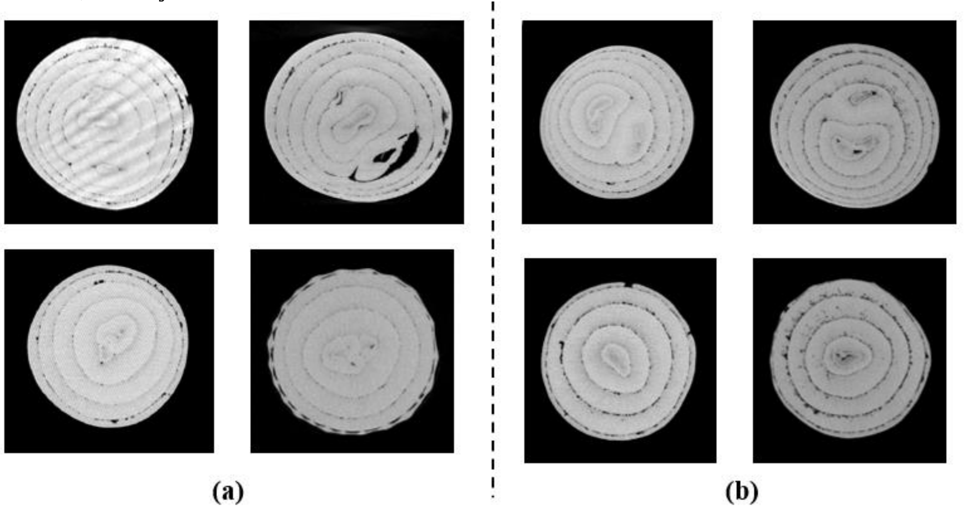


Fig. 3. X-Ray image result (a) onions stored at temperature 27 ± 2°C (left of onion conditions before storing and right of onion conditions after storing) (b) onions stored at temperature 7 ± 2°C (left of onion conditions before storing and right of onion conditions after storing).

We can see in the picture that after experiencing the storage process, onions undergo structural changes both externally and internally. After calculating using the “label analysis” feature, the calculation results are in Table 2. It is clear that after storage, the onions experience size shrinkage, such as reduced diameter, volume, and sphericity equivalent values. This happens because the water content in the onions has decreased so that the onions become shrunken or wrinkled[6]. Then the porosity value increases, indicating internal damage that causes the porosity to increase. Figures 3a and 4b show the degree of internal damage of onions stored at room temperature more than onions stored at cold temperatures. This result corresponds to the previous explanation of the respiration rate. The higher the storage temperature, the faster the respiration rate[3], so the potential for product damage will be more significant.

Table 2. Calculations of equivalent diameter, volume, sphericity, and porosity with analytical labels on onions with controlled air conditions and different temperatures.

Parameter	O5C2T27		O5C2T7	
	Before	After	Before	After
Equivalent diameter (mm)	24.44	24.18	24.18	23.86
Volume (mm^3)	7851.59	7628.39	7429.78	7144.67
Sphericity	0.96	0.915	0.96	0.88
Porosity (%)	19.46	21.65	21.503	22.37

4 Conclusion

Storage temperature affects the rate of red onion respiration. Onions stored at low temperatures have a slower respiration rate than onions stored at room temperature. The rate of respiration affects the speed at which onions are broken. Internal analysis on X-Ray CT shows that onions stored at room temperature have a greater degree of damage than onions stored at cold temperatures. The results of this study can be the basis that X-Ray CT can be used as a method for determining internal damage to onions in a non-destructive manner. Image processing results can clearly show internal damage to onions. In addition, it is also possible to determine the size of onions, such as the equivalent diameter, volume, sphericity, and porosity of the ingredients appropriately.

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