Effect of ultraviolet-C treatments and storage room condition on the respiration rate, weight loss, and color change of Shallots (*Allium ascalonicum L.*) during storage

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Abstract. Shallots (*Allium ascalonicum L.*) is one of Indonesia’s main agricultural commodities that has many benefits and high economy value. However, this commodity is very easily damaged after being harvested, such as high weight loss, fungal attacks, sprouting, and decay. UV-C treatments is one of technologies that can be used to maintain the quality of agricultural products, safely and non-toxic. UV-C treatments, in measurable doses, capable to inhibit the growth of microbial contaminants that cause damage, so it can reduce the rate of quality deterioration. During the process, an ionization process will occur which can cause collisions of chemical bonds in DNA molecules, this reaction will inhibit microbial growth in irradiated material. When the irradiation process is stopped, there is no negative energy left, in other words, the irradiation process does not result in food being radioactive or contaminated by radiation. This study was intended to evaluate the effect of combination treatment, between the duration of ultraviolet-C irradiation and room storage temperature on the respiration rate, weight loss, and color change on shallots during storage. The material used in this study was fresh shallots which had been cleaned from roots and leaves, then treated with UV-C for 30 minutes, 60 minutes, and 90 minutes. Shallots that had been treated by UV-C were stored at various room storage condition, T 5°C-RH 93.5%, T 10°C-RH 45.5%, and T 28°C-RH 76.1% (room temperature). Quality parameters, include respiration rate, weight loss, and color change observed every 1 week for 12 weeks. The results showed that the combination of ultraviolet-C irradiation treatment and low temperature room storage was able to inhibit the respiration rate (p < 0.05), and inhibit the weight loss of shallots during storage for 12 weeks (p < 0.05). The peel color of shallots was significantly affected by room storage temperature, but wasn’t significantly affected by UV-C treatment. So that this method was considered capable of being applied to maintain the quality of the shallots during storage.

1. Introduction

Shallot is one of Indonesia's main commodities that has a variety of benefits, as well as high economic value. Its very strategic role makes shallot much needed by the community. Meanwhile, shallot is a seasonal plant whose availability will be very large during on the growing season (on season), and its availability will be very limited out of the growing season (off season). This condition then causes the availability of shallots to be uneven throughout the year. In effect, shallots become one of the most...
commodities that have unstable prices [1]. The high needs of this community, while the availability was determined by the season, a good postharvest handling mechanism are needed.

In principle, storage of shallots aims to prevent the damage that can shorten the shelf life commodity, and control the supply continuously, so that it will prevent price fluctuations in the market. The storage methods applied to the shallots will affect its quality. Now, general storage in Indonesia is traditional storage, at room temperature, about 25-30°C and RH 70-80%, this method causes weight loss up to 25% after 2 months of storage [2].

Storage at low temperatures is one of the effective postharvest handling for agricultural commodities that are easily damaged. Low temperature can inhibit the weight loss, maintain moisture content and maintain quality of commodities [3]. Bendkeblia [4] states that storage of onions at 4 °C was able to maintain flavor content better than storage at 22 °C for 22 weeks. In a different reference, Rachmawati et al., [5] reported that the storage of chili at 10 °C was able to maintain the weight loss and content of vitamin C during storage.

Not only storage at low temperatures, some preliminary treatments have also been developed to get the optimal storage conditions, one of them is by UV-C treatment. The use of appropriate UV-C treatment can provide optimal results that are expected to be useful for human welfare [6]. In principle, UV-C treatment aims at the same as other treatments, to reducing losses due to damage and decay, reduce the microbial contaminants and other organisms that cause diseases carried by food [7]. Some research results show that the application of UV treatment is known to be able to maintain quality and extend the shelf life of postharvest agricultural products [8, 9], delay ripening in fruit [10, 11], inhibits the sprouting [12, 13], and as protection from pests and diseases, or disinfection [14, 15].

This fact makes the process of food irradiation become an alternative development of solutions that are safe and non-toxic (non-toxic) to improve the quality of postharvest commodities. Irradiation of food ingredients with gamma rays (γ), is one technique that is often used as an effective and safe sterilization effort to increase the shelf life and quality of fruits. However, the application requires expensive equipment and high-cost investment. Compared to gamma rays (γ), application of UV-C treatment is considered safer to operate and does not require expensive equipment or high investment [16]. Therefore, the topic of application of UV-C treatment for food was widely researched and developed as an effort to maintain the quality of vegetables and fruits during storage.

Application of UV-C in the right amount and dosage can maintain the quality of fruits and vegetables, if stored at optimal storage conditions. The results showed that chunks of "Chokanan" and pineapple "Josephine" which were treated with UV-C and stored at 10°C had a lower damage rate, and a longer shelf life compared to mango samples without UV-C treatment. [17, 18]. Application of UV-C treatment for 5-10 minutes can significantly reduce the level of damage to strawberries and grapes [19]. In the results of other studies mentioned that the UV-C treatment can extend the shelf life of spinach, leeks, cabbage [9], and tomatoes [16, 20]. The use of UV-C treatment can also be combined with low temperature storage to get better post-harvest quality, especially for fruits, such as guava [15]. The application of ultraviolet irradiation to shallots has not been widely carried out, so the level of effectiveness in changing quality during storage.

2. Materials and methods

2.1. Materials
The material used in this study was fresh shallots, Bima Brebes varieties, which were harvested at the age 60 days after planting, from farmers in Srikayangan village, Kulonprogo regency, Yogyakarta. Shallot bulbs were harvested in the morning, and then transported to the Laboratory of Environmental Engineering and Agricultural Buildings for temporary storage. Before the UV-C treatment, sample of shallot had been cleaned from roots and leaves.
2.2. Ultraviolet-C treatment
UV-C treatment was performed using germicide UV-C lamps (General electric, 20 W G20T10, Sankyo Denki, Japan), which were installed inside a wooden cabinet (80 x 60 x 60 cm) with UV-C range ±253.7 nm. Samples of shallot were placed on tray without overlapping the samples, and then treated with UV-C for 30 minutes, 60 minutes, and 90 minutes. After treatment, samples were placed on tray, and stored at various room storage condition, T 5°C-RH 93.5%, T 10°C-RH 45.5%, and T 28°C-RH 76.1% (room temperature). Quality parameters, include respiration rate, weight loss, and color changes was observed every 1 week for 12 weeks.

2.3. Measurement of quality parameters

2.3.1. Respiration rate. Respiration rate was determined based on the rate of CO₂ production and O₂ consumption (Palanimuthu et al., 2009). Change concentration of O₂ and CO₂ were measured with a portable O₂ and CO₂ analyzer (Quantek 902D-DualTrak). Measurements were carried out in closed system (static).

2.3.2. Color analysis. The color change of shallots was measured using Chromameter (Konika Minolta CR-400/410), with the color index measured including L*, a*, and b*.

2.3.3. Texture analysis. The firmness value of shallots was measured using a Brookfield Texture Analyzer (CT3-10K, USA) with cylindrical probe (flat surface) with a diameter of 4 mm (TA44), depth of deformation up to 10 mm, maximum load cell 10 kg, and speed test 0.5 mm/s.

2.4. Statistical analysis
Analysis of variance and Duncan’s multiple range tests with significance at p < 0.05 were performed using the SPSS ver. 23 program. All results of analysis were expressed as the mean ± standard deviation of three replicate.

3. Results and discussions

3.1. Effect of UV-C treatment on respiration rate
After being harvested, horticultural products still carry out various metabolic activities such as respiration and transpiration. Both of these metabolic activities will greatly affect the quality of the product during the storage period. This condition causes agricultural products to be handled and stored properly [21]. A large number of studies have shown that exposure the low dose of UV-C treatment can be able to delay deterioration of some fruits [19, 22] and can reduce decay of vegetables such as carrots [23], onion [24], tomatoes [25], and zucchini squash [26].
Respiration rate of shallots, both O₂ consumption and CO₂ production has decreased gradually during storage (Figure 1), this condition applies for all treatment, both in the control and in the samples that treated by UV-C treatment. At low temperature storage, both at storage temperature of 5 °C and temperature of 10 °C, shallots with UV-C treatment for 60 minutes and 90 minutes have a lower respiration rate than control. This condition shows that the UV-C treatment for 60 minutes and 90 minutes can reduce the rate of respiration of shallots to be lower. The higher the rate of O₂ consumption of a product, the shorter the potential shelf life of the product [27]. This condition indicates that shallots with UV-C treatment for 60 minutes and 90 minutes have the potential for a longer shelf life than shallots no treated. Different from other treatment, (Figure 1) shows that shallots with UV-C treatment for 30 minutes causes the respiration rate to be very high, both at low temperature and at room temperature storage. In assumed that, application of UV-C treatment for 30 minutes, the irradiation process lasts quite short, so that the effect of UV-C treatment can’t be utilized by shallots, and at the same time shallots received heat that generated by UV-C lamps.
At a storage temperature 28 °C (RH 76.1%), shallots treated by UV-C treatment have a higher respiration rate than controls, this is thought to occur due to the heat generated by UV-C lamps during the irradiation process. Temperature is a factor that greatly influences the respiration rate of a product. Generally, biological reactions increase 2-3 times with each 10°C rise in temperature. So that, the application of UV-C treatment for 30 minutes was considered not to have delayed effect on reaching the peak of respiration rate without causing damage.

3.2. Effect of UV-C treatment on weight loss

Significant differences were obtained between the storage room condition and the duration of UV-C treatment during storage of shallots. During storage, the percentage of weight loss of shallots has increased with a different percentage for each treatment. Increase in weight loss onions during storage can be seen in Figure 2. At storage temperature 5°C (RH: ± 93.5%), the highest percentage of weight loss occurred in control sample (without UV-C treatment), then followed by sample with UV-C treatment for 30 minutes, 60 minutes, and 90 minutes, with weight loss value 22.99%, 20.72%, 12.67, and 12.55%. This condition shows that UV-C treatment can reduce the weight loss on shallots during storage. This is consistent with the results of observation by Vieira et al., [15], combination UV-C with a dose of 16 kJm² and storage room temperature of 8°C can reduce the weight loss of guava type kumagai. Application UV-C treatment can causing the ionization which will cause metabolic disorders, so it can inhibit the process of physiologicall changes during storage (ripening, decay) [8].

Table 1. Value of respiration rate (ml/kg.h), weight loss (%), and color (°hue) of shallots during storage for 12 weeks, treated and untreated by UV-C

| Room storage (°C) | Duration of UV-C (minutes) | Respiration rate (ml/kg.h) | Weight loss (%) | Color (°hue) |
|------------------|--------------------------|--------------------------|----------------|------------|
|                  |                          | Consumption O₂           | Production CO₂ |             |
| 5                | 0                        | 0.09 ± 0.01              | 0.06 ± 0.01    | 22.99 ± 0.51 | 0.37 ± 0.10 |
|                  | 30                       | 0.13 ± 0.01              | 0.07 ± 0.01    | 20.73 ± 1.17 | 0.47 ± 0.13 |
|                  | 60                       | 0.04 ± 0.01              | 0.03 ± 0.01    | 12.67 ± 0.42 | 0.34 ± 0.05 |
|                  | 90                       | 0.04 ± 0.01              | 0.02 ± 0.01    | 12.55 ± 0.38 | 0.36 ± 0.02 |
| 10               | 0                        | 0.10 ± 0.01              | 0.05 ± 0.01    | 39.96 ± 1.07 | 0.28 ± 0.02 |
|                  | 30                       | 0.14 ± 0.01              | 0.08 ± 0.01    | 34.18 ± 1.79 | 0.28 ± 0.02 |
|                  | 60                       | 0.06 ± 0.01              | 0.03 ± 0.01    | 27.99 ± 6.94 | 0.27 ± 0.01 |
|                  | 90                       | 0.05 ± 0.01              | 0.03 ± 0.01    | 26.69 ± 6.36 | 0.24 ± 0.02 |
| 28               | 0                        | 0.34 ± 0.06              | 0.42 ± 0.01    | 27.00 ± 2.04 | 0.62 ± 0.08 |
|                  | 30                       | 0.49 ± 0.01              | 0.46 ± 0.01    | 36.27 ± 1.36 | 0.53 ± 0.20 |
|                  | 60                       | 0.42 ± 0.01              | 0.36 ± 0.04    | 33.22 ± 1.56 | 0.51 ± 0.19 |
|                  | 90                       | 0.38 ± 0.04              | 0.36 ± 0.04    | 30.37 ± 1.72 | 0.50 ± 0.13 |
Figure 2. Weight loss of shallots during storage - untreated and treated by UV-C at various room storage condition

At storage temperature 10 °C (RH: ± 45.5%), the highest percentage of weight loss occurred in control sample (without UV-C treatment), then followed by sample with UV-C treatment for 30 minutes, 60 minutes, and 90 minutes, with weight loss value 39.96%, 34.18%, 27.99%, and 26.29%. Compared with other treatment, the highest weight loss occurred at this condition, which reached 39.96% at the end of storage (at 12 weeks). This condition presumably because the storage of 10 °C was carried out in a refrigerator with low humidity, around 45.5%. Relative humidity is one of the factors that can trigger water loss in fresh horticulture products [30]. Water vapor from the product will only move out when the atmospheric vapor pressure is lower than the vapor pressure in the product. Relative humidity (RH) describes the ratio of actual vapor pressure to air vapor pressure in a saturated state, at the same temperature. This moisture will affect the function of the pores of the material. Under these conditions, the pores of the material will open wide at low RH because the water content in the surrounding environment is lower than the water content in agricultural products, and water in the material will more easily move towards the surface of the material.

Different from storage at low temperature, at storage temperature 28°C (RH: ± 76.1%), the highest percentage of weight loss occurred in sample with UV-C treatment. The highest weight loss occurred on samples of shallots with UV-C treatment for 30 minutes, then followed by sample with UV-C treatment for 60 minutes, 90 minutes, and then controls (without UV-C treatment), with weight loss value 36.27%, 33.22%, 30.37%, and 27.00%. The value of this weight loss is similar to what has been reported by Mutia [31] that shallots have a weight loss of about 28.10% after being stored for 12 weeks, at room temperature storage.

The high weight loss occurs shows that the treatment of UV-C irradiation without low temperature storage can increase the weight loss during storage. The heat produced by the UV-C lamp can raise the air temperature and surface temperature of materials, as a result, the pores of the materials will open, and the process of water loss from inside will occur faster. Not only relative humidity (RH), temperature is one of the external factors that greatly influences the transpiration of agricultural products. A similar
condition was reported by Ridwan [32], irradiation treatment using gamma rays on shallots at a dose of 2.25-6.55 kGy, and stored at 28°C can increase weight loss during 8 weeks storage.

3.3. Effect of UV-C treatment on color change

The peel color of shallots was significantly affected by room storage temperature, but wasn’t significantly affected by UV-C treatment (Figure 3). During storage, the peel color of shallots changes along the time of storage. The observation results shows the value of degree of hue has gradually increased.

**Figure 3.** Change in color of shallots untreated and treated by UV-C at various room storage condition

At temperature 5 °C-RH 93.5% the peel color of shallots change from *hue* = -0.18 at the beginning, to *hue* = 0.34 – 0.42 on weeks 12, and at temperature 10°C-RH 45.5% the peel color of shallots change from *hue* = -0.18 on weeks 0, to *hue* = 0.24 – 0.28 on weeks 12.

There was a rapid change on the peel color of shallots stored at 28 ± 0.5 °C - RH 76.1 ± 5.8% during storage, there was a change in color from light red-purple (*hue* = -0.18) on weeks 0, to red-yellow (*hue* = 0.50 – 0.62) on weeks 12. For the shallots stored at low temperature, the peel color change process is slower than room temperature storage. Low temperature can inhibit the occurrence of heavy shrinkage, maintain moisture content and maintain quality and extend shelf life [3].

In this study, no significant effect of UV-C treatment to color change of shallots during storage. On visually observed, the fresh shallots have bright purplish red color, and this color gradually changes to yellowish red, and dull, during storage for 12 weeks. It assumed because the UV-C treatment was given in a low dose, so it doesn’t have a significant effect on color change of shallots during storage. Moy *et al.* [33] reported that application irradiation in low doses does not give a significant effect to discoloration in papaya fruit. The same result was stated by Vieira *et al.* [15] that the treatment of UV-C did not cause a color change (hue value) on guava skin during 10 days of storage. In another study it was also mentioned that UV-C treatment on green onions gave the same L*, a*, and b* values as control samples [34].
4. Conclusion
The UV-C treatment for 60 minutes and 90 minutes combined with low temperature room storage was able to inhibit the respiration rate and inhibit the weight loss of shallots during storage for 12 weeks. The peel color of shallots was significantly affected by room storage temperature, but wasn’t significantly affected by UV-C treatment. The use of UV-C treatment for maintain the quality of shallots sholud be combined with low temperature room storage in order to obtain better post-harvest quality.

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