The Effect of Curing and Leaves Cutting in Longterm Storage of Shallot

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Abstract. Shallot is important as one of the spices for cooking various foods, as raw materials for the food industry, and as one of the ingredients for Indonesian traditional herbs. Postharvest handling is needed to extend its shelf life and to maintain its quality during storage. The aims of this research are: 1) to evaluate the effect of curing and leaves cutting on the quality changes of shallots during storage, and 2) to get the best pre-storage procedure in maintaining the quality of shallots during storage. Shallots leaves were cut before drying while the others are stored with leaves as control. Then, half of the samples were cured for three days, and sundried for four days, while other samples were sundried directly for seven days without curing them first. Then samples were stored for 16 weeks in two different conditions. The results showed that the treatment of curing without leaves cutting and stored at 5°C with 65-70% RH gave the best quality than other treatments. It could minimize damage and weight loss, maintaining hardness, color, and important ingredients until 12 weeks of storage. However, there were drastic decreases in some quality parameters, 32.0% damage and 38.7% weight loss after 16 weeks of storage.

1. Introduction
Shallot (Allium ascalonicum L.) is one of the important horticultural commodities in Indonesia with increasing demand to fulfill daily needs both as a food flavoring, raw material for the food industry, and herb medicine makes the need for continuous product availability. Shallot contains lots of vitamins B, C, micronutrients such as potassium, phosphorus, and other minerals with a distinctive aroma and taste. In 2012-2016 national production of shallot reached an average of 108,853 tons/month in May-October, while in February-April, it was still low with an average production of 78,054 tons/month [1]. The national shallot production itself is increasing at 3.93%/year, while total consumption is also increasing with the growth of 3.3%, which increased in the surplus during 2011-2015 [2]. Indonesian shallot production is expected to continue with an increasing surplus. However, this does not guarantee the availability of products that are evenly distributed throughout the year due to seasonal weaving and postharvest handling mechanisms that have not been running well so that there is an excess stock in the planting season (on-season) and stock shortages outside the planting season (off-season). This also has an impact on price fluctuations. Appropriate postharvest handling is very important to overcome the lack of stock of shallots products during off-season collected and stored from surplus production on-season while maintaining the quality of shallots that are still acceptable to consumers. The availability of storage facilities is needed in overcoming oversupply by extending shelf life as inventory [3].
Traditional storage practices of shallots usually done by farmers are very simple by using para-para, such a rack made from wood or bamboo. Shallots are classified as layer bulbs whose outer skin is dry and easy to peel so that their weight loss is high during storage [4]. Several previous studies have proven that the use of 5 °C is the best temperature in maintaining the quality of shallots during storage. Mutia reported that storage shallots for 12 weeks with an initial moisture content of 80% resulting in a weight loss of 12.49% and a damage rate of 1.71% [5]. Mardiana also mentioned that storage for three months for large, medium, and small sizes of shallots experienced a percentage of damage 17.60%, 7.53%, and 10.46%, respectively [6].

The shelf life of shallot is also very much determined by the initial conditions of the product before storage. Some farmers do the drying on the land by direct sun-drying without curing first. Curing or withering is good for a more shiny color of the shallot skin and forms an epidermal layer that covers the wound on the part of the skin due to scratches during harvesting. The previous study showed that curing for 80 and 90 hours using a cabinet dryer produced good quality bulbs for 6 weeks storage at room temperature, with the hardness of 4.5 kg/m² and weight loss of 12.03% [7].

In handling of harvested shallots, some farmers cut some leaves (±5 cm above the tubers) before drying. Curing shallots still with their leaves under the sun for 10 days followed by storage at room temperature (22.10 °C) for 90 days showed better quality in some parameters like moisture loss, sprouts and total bulbs shrinkage and weights loss, compared to results of the same treatment with leaf cutting prior to curing process [8]. However, there are no reports about the combination of curing and cutting of leaves in the process of drying shallots followed by storage at low temperatures to observe its effect on the quality and shelf life of shallots. The purposes of this study were to examine the effect of curing and cutting of leaves on changes in the quality of shallots before storage and to make optimum pre-storage procedures in maintaining the quality of shallots during storage.

2. Materials and method

2.1 Materials

The materials used in this study were Bima variety of shallots grown in Brebes with a harvest age of 60 DAP (days after planting), warping plastic, and plastic knitting. The chemicals used for laboratory analysis were lime (CaCO₃), HClO₄, HNO₃, BaCl₂, and silica gel.

2.2 Equipment

The equipment used in this study were a refrigerator for storing shallots at a temperature of 5°C, a thermometer, a hygrometer for measuring humidity (RH), an oven (Isuzu brand), an analytical balance (Adam PW 184 and a Mettler PM 4800), a rheometer for hardness testing, an atomic absorption spectrophotometer (AAS) instrument and Chromameter for color measurement.

2.3 Method

Harvested shallots were taken as initial quality measurements (for measurements of moisture content, hardness, sulphur content, and color). Then the samples were grouped into two groups with 2.5 kg each, leaves were cut (leaves ±5 cm above the bulb) for a group, and the other remained with leaves. After that, each sample was given a curing treatment in the field for 3 days by covering the shallots using a tarp plastic that had been given a pole in the middle (±70 cm) to provide a space under the tarp plastic, followed by 4 days sun-drying. As for the other sample were drying without curing by direct sun-drying for 7 days in the field to reach 80-85% of moisture content. After drying, quality measurements were measured again, and then the shallots are cleaned and sorted to separate the damaged bulbs before storage. Each sample was packaged using plastic knitting and then stored at 5 °C with 65-70% RH and at room temperature of 25-32 °C with 50-88% RH. At 5 °C storage, lime (CaCO₃) and silica gel were placed in the refrigerator and alternated weekly to maintain the desired RH, and the storage is carried out for 16 weeks. Observations were carried out every week with parameters observed were moisture content, weight loss, percentage of damage (rot/fungus, vacuum, and shoots), hardness, sulphur content, and color.
The experimental design used was a factorial complete randomized, which consisted of two factors with three replications. The treatment factors used were curing treatment (C), drying without cutting leaves and without curing (COL), drying by cutting leaves without curing (CON), 3 days curing without cutting the leaves before drying (C3L), and 3 days curing and leaf-cutting before drying (C3N). Storage temperatures were 5 °C with 65-70% RH (TC) and room temperature (25-32 °C) with 50-88% RH (TR). Data were analyzed using analysis of variance with a significance level of 5%, then continued with the Duncan multiple range test (DMRT) if it had a significant effect.

2.4 Observation Parameters
Moisture content was measured and calculated using the following formula:

\[ \text{Moisture content (%wb)} = \frac{W_i-(W_o-W_c)}{W_i} \times 100\% \]  

where:
- \( W_i \) = initial weight of the sample (g)
- \( W_o \) = weight of container plus final weight of sample (g)
- \( W_c \) = weight of empty container (g)

Weight loss is expressed as a weight ratio of initial and final weight different to the initial weight, calculated using the following equation:

\[ \text{Weight loss (%)} = \frac{W_i-W_o}{W_i} \times 100\% \]  

where:
- \( W_i \) = initial weight of sample (g)
- \( W_o \) = final weight of sampel (g)

Damage of shallot bulb is expressed as a ratio of damage pieces of shallot to the initial number of stored shallots, calculated using the following equation:

\[ \text{Damage (%)} = \frac{B_d}{B_t} \times 100\% \]  

where:
- \( B_d \) = number of damage bulbs
- \( B_t \) = number of stored bulbs

Hardness which is measured using a rheometer based on the level of resistance of the bulb to the probe with a diameter of 5 mm, set at a depth of 10.0 mm, a maximum load of 10 kg, with a needle speed of 60 mm/minute, expressed in force needed for the above process.

Sulphur content in shallot bulb is determined by laboratory test and calculated using the following equation:

\[ S (\%) = Ds \times \left( \frac{Es}{1000 \text{ (ml)}} \right) \times \left( \frac{100}{Ws} \right) \times f_c \times f_s \]  

where:
- \( S \) = Sulphur content (%)
- \( Ds \) = Standard time series analysis (ppm)
- \( Es \) = Extraction results (ml)
- \( Ws \) = Sampel weight (mg)
- \( f_c \) = Moisture content correction factor (%)
- \( f_s \) = Solution factor
Color is measured using a chromameter to obtain L* for lightness, a* for green to red portion, and b* for blue to yellow portion.

3. Results and Discussion

3.1 Initial quality of shallot

Initial quality measurements were carried out right after harvesting of shallots, which included sulphur content, moisture content, color, and hardness. The results of the initial physical quality measurements of shallots were used as a reference in analyzing quality changes after curing, sun-drying, and during 16 weeks of storage (Table 1). Direct sun-drying by placing the shallots on the ground showed the differences in temperature and humidity conditions under the hood of the plastic tarp with the temperature and humidity of the open (ambient) air, as shown in Table 2.

3.2 Changes in the quality of shallots during storage

3.2.1 Moisture content. The quality of shallots during storage was greatly influenced by the moisture content. The results of the analysis of variance showed that the sun-drying treatment had a significant effect on changes in the moisture content of shallots at weeks 1, 6, and 8 of the storage. During storage fluctuations, changes in moisture content for each treatment were observed due to changes in temperature and humidity. However, overall it still meets the quality requirements of first-grade market demand (80-85%) [10]. According to the above reference, the temperature and RH conditions that undergo variable changes caused the shallot bulbs to easily absorb water or evaporate water during storage [5]. It was also known very well that shallots with higher water vapor pressure would release water vapor into the storage environment [7].

An increase in the moisture content of the shallot bulbs after drying was estimated to be due to some of the moisture content in the leaves, stems, and neck parts of the tubers infiltrated into the bulbs during the drying process. This could be observed in the enlargement of the bulb size, and its shape became more compact and harder after drying. The metabolic process that continued in harvested shallots was thought to trigger cell division resulting in an enlargement of bulbs (table 1). Figure 1 shows that the storage temperature of 5°C in each treatment tends to have a higher moisture content until week-8 of storage. Low temperatures are more capable of suppressing the rate of respiration of shallot bulbs compared with room temperature during storage. However, in the week-9 until the week-16, a drastic decrease occurred so that the moisture content becomes lower [11]. This is thought to be caused by an increase in tubers sprouting and rooted so that the moisture content available in the bulbs were used for the growth process. While shallots stored at room temperature has a moisture content

### Table 1. Results of initial quality measurements of shallots

| Parameter              | Before sun-drying | After 7 days sun-drying |
|------------------------|-------------------|-------------------------|
|                        | Without plastic tarp | With plastic tarp |
|                        | Without leaves | With leaves | Without leaves | With leaves | Without leaves | With leaves |
| Moisture content (%)   | 84.07±0.22a       | 84.69±0.96a            | 85.12±0.85a           | 85.07±0.86a           | 85.11±0.57a           |
| Sulphur content (%)    | 0.26±0.00b        | 0.37±0.01a             | 0.33±0.00a            | 0.36±0.01a            | 0.35±0.06a            |
| Hardness level (N)     | 4.37±0.40a        | 4.45±0.39a             | 4.40±0.44a            | 4.47±0.29a            | 4.55±0.32a            |
| Lab color: L*          | 45.66±4.00b       | 50.19±2.71a            | 45.98±3.11b           | 47.56±2.44ab          | 44.83±2.93b           |
| a*                    | 22.81±2.99c       | 28.15±2.63b            | 31.89±2.52c           | 30.81±2.62ab          | 32.47±2.34c           |
| b*                    | 5.97±1.46d        | 2.43±1.34b             | 3.07±1.78b            | 2.05±0.96b            | 2.81±2.27b            |

a,b,c Numbers with different letters in each characteristic show a significantly different effect (α = 0.05) based on Duncan's multiple range test.
that tends to be lower until the week-8 in each treatment, due to having a higher temperature (25-30 °C) and lower humidity with a range (44 -64%), thus accelerating respiration and transpiration rates.

Based on further tests with a 5% significance of DMRT, it showed that COL treatment followed by storage at room temperature gave the best result in preventing the rate of reduction of moisture content of shallots bulbs at week-16, which was 84.11%, significantly different from all treatments at 5°C. While the room temperature C0N treatment had the lowest moisture content at the beginning to the week-9 of storage, which was 83.76%, while at the week-14 until the end of storage, the lowest moisture content at the C3N treatment at 5°C was 80.55%, which was significantly different from all treatments at room temperature. These facts show that the leaves cutting treatment has a lower but not significant moisture content after 16 weeks of storage.

Table 2. Air temperature and RH fluctuations during drying in the field

| Condition       | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
|-----------------|-------|-------|-------|-------|-------|-------|-------|
| Without plastic | T (°C)| 48.0  | 45.5  | 41.3  | 44.0  | 47.0  | 47.0  |
| tarp            | RH (%)| 33.0  | 46.0  | 44.0  | 33.0  | 24.0  | 30.0  |
| With plastic    | T (°C)| 40.0  | 36.0  | 36.4  | -     | -     | -     |
| tarp            | RH (%)| 50.0  | 58.0  | 60.0  | -     | -     | -     |

Figure 1. Changes in moisture content of shallots under various temperature and sun-drying treatments during storage

3.2.2 Weight loss. The results of analysis of variance on weight loss data showed that the sun-drying treatment had a significant effect on the weight loss of shallots in the week-1 to week-3 of storage. Whereas the temperature treatment had a significant effect on the week-1 to week-16. The results of further tests using DMRT with a 5% significance show that the sample of C3L treatment stored at room temperature has the highest weight loss until the week-10, and the difference was significant until the week-4. This happened due to the C3L treatment having the lowest duration of exposure to sunlight when sun-drying on the ground took place, so it makes sense to have a higher moisture content at the outer skin and parts of the bulb neck compared to shallots with other treatments.

The rate of evaporation of shallot bulbs moisture was influenced by the outer skin moisture content and the diameter of the bulb neck [7]. The highest weight loss at the room temperature for C0N treatment in week-11 to week-16 was 47.74% and significantly different from all treatments at 5°C. Weight loss at room temperature was observed to reach 42% at week-12 storage [12]. Increased weight loss is largely due to moisture loss caused by transpiration and the process of respiration, which breaks down glucose into CO₂ and H₂O, as well as damage from shallot bulbs [5, 13]. The large amount of moisture that decomposes when respiration goes faster causes the outer secular layer of the shallot bulbs to dry out, and the greater the value of its weight loss [4, 14].
Figure 2 shows that the 5°C storage temperature has a lower weight loss and is significantly different from all treatments stored at room temperature until the week-10, with the C3L treatment produced the lowest weight loss (24.59%) in the week-12. However, these results indicated that the weight loss obtained was higher than the results of previous studies. Priyantono reported that the storage of shallots for 12 weeks resulting in a weight loss of Bima Brebes, Tajuk, and Bali Karet varieties was 22.30%, 21.99%, and 17.29%, respectively [11]. Mardiana also mentioned that storage for three months for large, medium, and small sizes of shallots had resulted in weight losses of 24.76%, 26.14%, and 15.95%, respectively [6].

At low temperatures, some enzymatic reactions occur so that it can slow down the metabolic process [15]. Shrinking rate of shallot bulbs’ weight could be inhibited by suppressing metabolic processes including respiration [11]. The increased rate of weight loss in the week-11 on the sample stored at 5°C temperature was due to the increasing bulbs sprouts. The process of formation of shoots and roots requires food reserves contained in the bulbs for metabolic processes so that they experience a decrease in weight, and the quality of shallot bulbs [6, 16].

3.2.3 Physical damage. Shallots are very susceptible to damage caused by microorganisms or physiological changes that arise during storage. Results analysis of variance showed that the sun-drying treatment significantly affected the percentage of damage in the week-11 to the week-16, while the temperature treatment showed a significant effect in the week-3 to week-14. The results also showed that the storage temperature of 5°C with RH 65-75% resulted in no damage due to rotten or moldy bulbs in all treatments during storage (figure 3). Activity of microorganisms and enzymatic reactions that caused roots to rot could be inhibited with appropriate low temperatures and humidity of the storage [11, 18].

The highest rot bulbs damage occurred at room temperature storage, namely C0L and C3L treatments, respectively, with 3.67% damage, while damage for C3N and C0N treatments were 1.33% and 1%, respectively. The leaves cutting treatment resulted in a lower percentage of roots rot damage. Bulbs that are exposed to direct sunlight during drying cause the outer part of the skin to be dried so that it was more resistant to invading microorganisms. Bulbs that have decayed or moldy damage are suspected to have been infected with disease or the presence of microorganisms carried from the land. According to [5] and [17], Microbial causes of rot/fungal bulbs damage are Aspergillus spp., Botrytis spp., Fusarium spp., Pseudomonas spp., and Erwinia spp. that can develop quickly at room temperature storage due to suitable temperature and humidity.

The highest hollow damage due to loss of volatile compound occurred on C0L treatment stored at room temperature, which was 15.67%, while C3L, C0N, and C3N experienced smaller damage, which are 15.00%, 14.33%, and 13.00%, respectively. Whereas the storage temperature of 5°C was able to prevent the damage until the week-12 for all treatments. The C3L treatment at 5°C gave the lowest
damage compared to other treatments, only 3% (figure 4). Damage to the hollow bulbs at 5°C storage was characterized by lower moisture content and hardness of the bulbs, causing their size to shrink, the skin to shrink, and somewhat supple so that the bulbs shrunk. The metabolic process uses the energy available in the bulbs so that the amount decreases, causing the size of the shallot bulbs to shrink [5].

Hollow damage in the week-3 to week-7 of room temperature storage was suspected due to injury or bruising during the harvesting, drying process, and transportation to the collecting point. Damage to the structure of the bulbs tissue caused an increase in the rate of transpiration and respiration at room temperature. While hollow damage of the week-12 to the week-16 was due to the increasing amount of moisture loss over the duration of storage. The increase in hollow bulbs damage at room temperature storage was caused by excessive evaporation resulting in a large amount of moisture loss [5, 11, 17].

![Histogram](image)

**Figure 3.** Percentage of rot or shallot fungus damage at various temperature and sun-drying treatments during storage

![Histogram](image)

**Figure 4.** Percentage of damage to pests or porous shallots at various temperature and sun-drying treatments during storage

Bulbs sprout damage for shallot stored at 5°C began to occur in the week-6. Overall the percentage of bulbs sprouts and roots was higher at 5°C than in the room temperature. The C3L treatment at 5°C at week-12 was still as low as 7.33%, but at week-14 it increased in all treatments, while the high rate of budding and rooting in the C3N and C0N treatments were thought to be caused by the drier of bulbs with the lowest moisture content at the end of storage, 80.55% and 80.68%, respectively. An increase in the activity of enzymes and gibberellins in cells at a storage temperature of 5°C can trigger a break in dormancy, causing increased sprout/root tuber damage [5, 11].

The highest bulbs sprout damage at room temperature was shown by C3N treatment as 28.67%, while C0N, C3L, and C0L were 27.33%, 16%, and 10.66% respectively. Figure 5 shows the leaf
cutting treatment at both room temperature and 5°C storage had a higher percentage of bulbs damage. C0L and C3L treatments were more able to suppress the rate of sprout and rooting than others.

The total damage (bulb damage of rotted/moldy, hollow/porous, and sprouting/rooted bulbs) during storage was shown in figure 8. The results of further tests using DMRT with 5% indicated that changes in the level of damage bulbs were different significantly every week. The high damage at a storage temperature of each treatment was dominated by pests or porous shallots and rot or shallot fungus damage, while damage at 5°C was dominated by sprout and root bulb. The C3N treatment at room temperature had the lowest damage in the week-16 as 30%. However, at the beginning of the week-12 storage showed the best treatment was C3L at 5°C with the lowest damage, which was 7.33%, significantly different from others.

![Figure 5. Percentage of damage sprouts and rooted shallots at various temperature and sun-drying treatments during storage](image)

![Figure 6. Percentage of bulbs damage total at various temperatures and sun-drying treatments during storage](image)

3.2.4 Hardness. Bulb hardness is one of the indicators in physical quality changes or the level of shallot freshness, which is a reference for consumer acceptance. Results analysis of variance showed that the sun-drying treatment had no significant effect on the change of hardness of shallot during storage, while the temperature treatment showed a significant effect on the week-2 to week-6. The level of hardness of shallots that stored at 5°C had a higher hardness value than room temperature during storage. Figure 7 showed that the value of bulb hardness at 5°C storage increased dramatically in the week-9 to week-11. However, it was followed decreased until the week-16. While at room temperature, the change of pattern tends to increase until the week-8, but no drastic. Then sharply decline in the week-14.

The results of DMRT with 5% showed that the COL treatment at week-8 and week-10 at 5°C had the highest hardness values of 5.48 N and 5.47 N respectively, the highest of C0N treatment at week-9
was 5.76 N. Whereas C3N treatment was the highest at weeks-16, i.e., 4.52 N. Each treatment only had a significant effect on the treatment at room temperature. The increase of bulbs hardness at 5°C was due to outer skin to become moist, soft and elastic so that the binding strength became stronger as a result of the long exposure to cold temperature with the range of RH 65-75%. Low-temperature exposure could reduce the rate of respiration and transpiration in cell walls, which caused stronger or tougher tissue skin cells of shallots bulb so that the value of hardness increased. At room temperature, its increase was due to the strengthening of the pectin bond that due to the drying of the outer shell, as well as the evaporation between cell spaces caused the cells to constrict and coalesce, and also the pectin substance became bonded, so the hardness increased. [5, 11].

In the week-12 of storage, there was a drastic decrease in the value of hardness at all treatments at 5°C. This happened because there were cavities or porous on the inside of the shallot. It was thought to be caused by the decrease of moisture content and the metabolic process of bud formation so that it made the bulbs easily depressed. [7] Bulb hardness was influenced by the strength of the outer shell and the level of dissolved solids.

3.2.5 Sulphur content. The distinctive aroma of shallots is due to the presence of sulphur as a volatile substance. Sulphur content of shallot bulbs increased after sun-drying (table 3). Some flavour components were formed after tissue damage during processing, and postharvest handling caused flavor component precursors (S-alk (en) il-L-cysteine) to contact with alliinase enzymes to form various volatile compounds including thiosulfinates which were degraded to be disulfide as the main flavor of shallot [19].

Based on Duncan’s further test results with 5% showed that C3N treatment at room temperature had the highest sulphur content at week-8 as 0.63% that was significantly different from the COL treatment at 5°C storage with the lowest sulphur content of 0.35%. At week-0 storage, C0N treatment had the highest sulphur content as 0.37%, while the lowest at COL treatment was 0.33%. Sulphur content of shallot was indicated to be influenced by bulb moisture content, where the CON treatment had the lowest moisture content while COL had the highest post-drying. The concentration of flavor and aroma components of shallots was determined moisture content of bulb. Its components of aroma decrease at a high moisture content [5, 20].

The storage at week-4 of 5°C, there was an increase in sulphur levels in the C0N, COL, and C3L treatments. The highest sulphur content as 0.89 % at C0N treatment difference was significantly from the C0N, COL, and C3N treatments at room temperature, and also C3N and C3L at 5°C. This indicated that the storage at 5°C could prevent the rate of decrease in sulphur content, which was thought to be related to the lower rate of transpiration so that the percentage of sulphur to evaporate became lower. According to [21], the temperature and humidity of storage can influence the level of evaporation of shallot sulphur content.
The decrease in sulphur content at 5°C storage in the week-8 was due to start to the formation of shoots and other metabolic activities that used sulphur content so that the amount decreased. This was similar to [5] that the development of cells forming shoots on shallots used sulphur so that its levels more decreased equally with higher levels of sprouting.

Table 3. Effects of sun-drying and various temperature treatments in a change of sulphur content (%) of shallots during storage

| Treatments | Storage time (weeks) | 0  | 4  | 8  |
|------------|----------------------|----|----|----|
|            | harvest              |    |    |    |
| CON Tc     | 0.26<sup>a</sup>     | 0.37<sup>a</sup> | 0.89<sup>a</sup> | 0.44<sup>ab</sup> |
| C0N Tr     | 0.26<sup>a</sup>     | 0.37<sup>a</sup> | 0.37<sup>b</sup> | 0.47<sup>ab</sup> |
| C0L Tc     | 0.26<sup>a</sup>     | 0.33<sup>a</sup> | 0.62<sup>ab</sup> | 0.35<sup>b</sup> |
| C0L Tr     | 0.26<sup>a</sup>     | 0.33<sup>a</sup> | 0.28<sup>b</sup> | 0.49<sup>ab</sup> |
| C3N Tc     | 0.26<sup>a</sup>     | 0.36<sup>a</sup> | 0.35<sup>b</sup> | 0.43<sup>ab</sup> |
| C3N Tr     | 0.26<sup>a</sup>     | 0.36<sup>a</sup> | 0.26<sup>b</sup> | 0.63<sup>a</sup> |
| C3L Tc     | 0.26<sup>a</sup>     | 0.35<sup>a</sup> | 0.46<sup>b</sup> | 0.38<sup>ab</sup> |
| C3L Tr     | 0.26<sup>a</sup>     | 0.35<sup>a</sup> | 0.69<sup>ab</sup> | 0.52<sup>ab</sup> |

<sup>a,b</sup> Numbers with different letters in each characteristic show a significantly different effect (α = 0.05) based on Duncan's multiple range test.

3.2.6 **Color.** The outer skin color of shallot bulbs is one of the components that greatly influences consumer attractiveness and market value. Bulbs with a higher level of reddish and shiny are considered better performers specifically for consumption needs. Based on the results of the analysis of variance showed that sun-drying treatment significantly affected changes in the value of L* during storage. While the storage temperature treatment only had a significant effect on the week-2. Room temperature storage in each treatment had a value of L*, which tended to be higher (figure 8). The results of further tests using DMRT with 5% showed that the C0N treatment at room temperature storage had the highest value of L*, which was significantly affected by other treatments, i.e., 52.50 at week-16. The high value of L* on the CON and C3N treatments both storage at room temperature and 5°C was caused the bulbs to be exposed to direct sunlight during sun-drying, causing the color to appear whiter. The C0N treatment had a longer duration of exposure to sunlight than C3N treatment. The C0L treatment had the lowest value of L* until the week-16 as 44.15. They then followed C3L 46.01 at 5°C and 46.17 at room temperature. This happened due to their leaves to protect the bulbs during sun-drying so that only a part of their bulbs were exposed to direct sunlight. The C3L treatment was the best to prevent an increase in the value of L* both at 5°C and room temperature during storage.

The skin color of shallots at harvest tends to turn purple. Then it turns to be reddish and brighter after drying. Results of analysis of variance showed that sun-drying treatment had a significant effect on changes in the value of a* until week-14 of storage. While the storage temperature treatment had a significant effect at week-1, then week 8 to week 16, in this study obtained a* value of 22.81 at harvest, then experienced a significant increase after sun-drying with the highest a* value in C3L treatment, i.e., 32.47 (table 1). Low anthocyanin concentrations caused color, not red but purple. After harvesting, the color of anthocyanin was increasingly seen due to chlorophyll degradation [22].
The results of further tests of DMRT at a level of 5% showed that C3L treatment at 5°C was the best in preventing the redness of the bulbs during storage with the highest a* value of 30.01 at week-16 of storage, then C0L treatment of 27.98. In contrast, the lowest value at room temperature C0N treatment was 21.46. The high value of a* in the C3L treatment due to the curing treatment before sun-drying allowed the bulbs to make adjustments to the temperature, including wound healing so that they were better able to adapt to sunlight. Likewise, the presence of leaves serves to provide protection against the skin of the shallots from excessive sunlight so that the resulting bulb color was redder and shiny. According to [23], heat treatment could reduce anthocyanin content in the skin of shallots. [19] and [22] temperature influenced the reaction of pigment synthesis, which contributed to color change. The formation of anthocyanin would decrease when the temperature rose [7]. The intensity of the red pigment had changed along with the activity of physical changes in the outer skin of the bulbs. The change in color of purple to red due to a decrease in moisture content caused a decrease in the hydroxyl group and an increase in the methoxyl group during the curing process.

Storage at 5°C had a higher a* value in week-8 to week-6 of each treatment. According to [23], the concentration of red shallots could decrease due to heat treatment during postharvest processing and storage. The C3L treatment was the best for inhibiting the rate of decrease in red color compared to other treatments at both room temperature and 5°C storage (figure 9). Fluctuating color changes caused by the removal of the outer skin of the bulbs then replaced by new skin [7].
The red color on the outer skin of the bulbs would turn yellowish and duller as a longer duration of storage. In week-8 to week-6, the stored at 5°C showed that each treatment was better to prevent the rate of increase in the value of b* (figure 10). The results of the further test of DMRT with 5% showed that C0L treatment at 5°C was the best in preventing the rate of skin discoloration for turning yellowish with the lowest b* value at the end of storage, which was 5.85 significantly different from C0N, C3N, and C3L treatments at room temperature storage. Whereas the C0N treatment indicated the most quickly changes color to be yellowish both storage at 5°C and room temperature, i.e., 7.14 and 11.43 respectively at week-16 storage.

4. Conclusion
Curing and cutting of leaves significantly influenced changes in moisture content, weight loss, damage, and color of the bulbs during storage. The storage temperature treatment has a significant effect on moisture content, weight loss, damage, hardness and sulphur content, and color of bulbs.

C3L treatment (Curing and uncutting of leaves) at 5°C storage with RH around 65-75% had the best quality compared to other treatments with the lowest damage of 7.33%, lowest weight loss of 24.59%, hardness of 4.32 N, sulphur content of 0.38%, moisture content of 82.91%, L* value of 47.38, the highest a* value of 31.06, b* value of 5.78 at week-12. However, there were drastic decreases in some quality parameters, 32.00% damage and 38.7% weight loss after 16 weeks of storage.

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