THE EFFECT OF DRYING AND STORAGE ON THE QUALITY OF SHALLOT (*Allium cepa* L. Aggregatum group) BULBS

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ABSTRACT

Post harvest handling in shallot such as drying of bulbs can influence bulb seeds quality during and after storage . The objective of this study was to determine the quality of shallot bulbs during 12 weeks of storage as the impact of drying and storage treatments. This study was carried out in Samiran hamlet, Parangtritis village, Bantul district, Special Region of Yogyakarta and Crop Science Laboratory of the Faculty of Agriculture, Universitas Gadjah Mada, in June-November 2016. The study was arranged in factorial randomized complete block design (RCBD) and consisted of two factors. The first was the drying treatments: drying the bulbs on the field and on woven bamboo nets both plastic covered and uncovered. The second was the storage treatments: storage the bulbs in the farmer's warehouse (31,03^{0}C±0,04 and RH of 60,50%±0,28), in air-conditioned room (22,40^{o}C± 0,02 and RH of 61,60%±0,09), and at room temperature (30,47^{o}C±0,03 and RH of 60,50%±0,12). Each treatment combination were replicated three times as blocks. The results showed that all treatments indicated fluctuating changes of water content and Total Soluble Solids in the bulb to the end of storage while bulb firmness tended to decrease. Bulbs stored in air-conditioned rooms showed the highest percentage of sprouted bulbs, vigor index and germination speed than other treatments. Meanwhile, drying treatment did not give significant influence.

Key words: seed, shallot, bulb, drying, storage, quality

INTRODUCTION

Providing qualified seeds is related to a proper postharvest handling that depends on the drying and storage techniques. According to Mitra *et al.* (2012), shallot bulb drying is aimed to reduce the moisture content in order to prevent any microorganisms causing-disease to survive and reproduce. Hall (1980) states that drying as a part of postharvest handling is required in order to prevent bulbs from any deterioration during the storage. Dried onion is indicated by the appearing neck shrinkage in the tubers, the drying of outer shell of the tubers and the rustling sound when rubbed against each other (Musaddad and Sinaga, 1995).

The common cultural practice of drying applied by the farmers is drying the shallot bulbs under the direct sunlight on the embankment of their field for 7 to 10 days after harvesting or when all leaves are dry. It has some negative effects, such as numerous scattered bulbs, scorched bulbs as indicated by changes in shallot skin color, flaccidity, and excessive moisture loss causing much weight loss (Asgar *et al*., 1992). Moreover, it requires a widespread open field. When harvesting in the wet season, shallot bulbs are susceptible to disease infection due to unoptimum drying process that consequently degrades the quality and shortens the durability within the storing.

Alternative method of bulbs drying is on woven bamboo nets supported with bamboo sticks to prevent the bulbs from direct contact with the ground. By using this method, an evenly dryness level can be obtained due to the presence of well-ventilated nets that results in more efficient drying period and minimizes the possibility of dirt contamination. This method is also expected to prevent the plant from disease because it is actually a manipulation of heating treatment to the bulbs from disease development on the field. Physical treatment of seed by using heat to control seed-borne disease dispersion has been widely used (Primasari, 2016). According to Raka *et al*. (2012), the heat treatment on seeds is able to control most seed-borne diseases as effectively as chemical treatment, except for diseases located far inside the seed

After the drying process, the next step is storing the seed in a specific room where temperature and humidity are set to prevent bulb deterioration. Storage temperature and relative humidity are related to sprouting, rooting, and physiological weight loss and storage periods (Nega *et al*., 2015). Purwanti (2004) notes that storage room is used to retain seed viability during the storage. Seed storage is aimed to obtain high-quality seeds until they are used as planting material (Yudono, 2012). Generally, the seeds are stored traditionally in a room set at temperature of 25-30^{o}C with relative humidity of 70-80%, which potentially reduces weight up to 25% after 2-months of storage (Komar *et al*., 2001). The weight loss is maintained to be as low as 10-17% by controlling the external factors, such as temperature and humidity. According to Purwanto *et al*. (2012), setting the storage room at low temperature is able to inhibit the weight loss process, retain moisture content, and sustain seed quality as well as prolong its shelf life.

Based on the abovementioned, a proper postharvest handling for both the drying and storage aspects is urgently required in order to have shallot bulbs with high vigorousness when grown. The objective of this study was to identify the quality of the shallot bulbs during the 12 weeks of storage as the impact of the drying and storage treatments.

MATERIALS AND METHODS

The experiment was carried out in Samiran hamlet, Parangtritis village, Bantul district, Yogyakarta and the Crop Science Laboratory, Universitas Gadjah Mada, Yogyakarta from June to October 2016.

The study was arranged in randomized complete block design (RCBD) factorial. The first factor was the drying treatments: drying the bulbs on the field and on woven bamboo nets both plastic covered and uncovered. The second factor was storage treatments: storing the bulbs in the farmer's warehouse (30,80^{0}C±0,04 and RH of 60,43%±0,19), in an air-conditioned room (22,37^{o}C± 0,02 and RH of 62,10%±0,09) and at room temperature (30,52^{o}C±0,03 and RH of 60,93%±0,15). Each treatment combination were replicated three times as blocks.

Materials used in the experiment were shallot seeds of the Crok Kuning cultivar at the age of 60 DAP (days after planting) obtained from the farmers in Bantul district in the form of shallot bulbs with leaves. Bulbs were cleansed, sorted from any bruise and disease, weighed at 2 kg, and dried based on the drying treatments. Bulbs were dried within 7 to 10 days or until all leaves were dried before limed and covered with pesticide. Lastly, the bulbs were packed in mesh nets bags and stored according to the storage treatments.

The observation variables after drying were:

1. Temperature and humidity of the environment of drying
2. Moisture content (%), measured byusing the oven method (AOAC, 1995)

$$\text{Moisture content} = \frac{\text{gross weight} - \text{dry weight}}{\text{gross weight}} \times 100\%$$

3. Weight loss, measured by weighing the initial and final weight of bulbs under the following formula

$$\text{Weight loss} = \frac{\text{weight of bulbs before drying} - \text{weight of bulbs after drying}}{\text{weight of bulbs before drying}}$$

Before the seeds were stored, the seeds initial condition, such as water content, total soluble solids and bulb firmness, was measured. The storage was 12 weeks with monitoring carried out once in two weeks; except for the final weight-loss variable, the bulbs damage, and the sprouting bulbs, which were examined after the end of the storing. The observation variables during the storage were:

1. Moisture content (%), the formula was similar to the moisture content when in the drying process.

2. The bulb firmness, measured by using a pneumatic tool "Barreiss Prufgeratebau GmbH type BS 61 II / BS 61 II OO 'series 2553". Measurements were made by placing the bulbs on the tool pads and pressing them until the needle touched the skin surface of the bulbs. The numbers shown on the monitor indicated the firmness level of the bulb measured. The fruit firmness was expressed in Newton's unit.
3. Total soluble solids (TSS), measured by using the hand-held refractometer "ATAGO' A-01-37 in scale 0-32% Brix. The PTT measurement was done by refining the shallot bulbs and squeezing them to remove the essence, which was dripped on the refractometer prism and covered. The TSS measurement result was directly readable by the numbers listed on the refractometer scale.
4. Damaged bulbs (%), measured by comparing the number of damaged bulbs, including rotten, porous (empty) and rooted seeds with the number of bulbs stored.

$$\text{Damaged bulbs} = \frac{\text{total of damaged bulbs}}{\text{total of bulbs stored}} \text{x100 \%}$$

5. Sprouting bulbs (%), measured by comparing the number of sprouting bulbs with the number of bulbs stored.

$$\text{Sprouting bulbs} = \frac{\text{total of sprouting bulbs}}{\text{total of bulbs stored}} \text{x100 \%}$$

6. The final weight loss (%), measured by weighing the initial and final weight of the bulbs under the following formula.

$$\text{Final weight loss} = \frac{\text{weight of bulbs before storage} - \text{weight of bulbs after storage}}{\text{weight of bulbs before storage}} \text{x100 \%}$$

After 12 weeks of storage, the viability and vigorousness of shallot seed bulbs were tested in 14 days. It included:

1. Germination

$$G = \frac{\Sigma \text{ the germinating seeds until day 14}}{\Sigma \text{ the bulb planted}} \text{x100 \%}$$

2. Vigor Index

$$VI = \frac{G1}{D1} + \frac{G2}{D2} + \frac{G3}{D3} + \ldots + \frac{Gn}{Dn}$$

Description:

VI = Vigor index

G = number of bulbs germinating on certain days

D = time corresponding to G

N = the number of days in the final calculation

3. Germination speed

$$GS = \sum_{i=0}^{i=n} \%Kn / etmal$$

Description:

GS = Germination speed

% Kn = Percentage of normal sprouts on certain days

etmal = 24 hours

The data was analyzed by using analysis of variance (ANOVA). When significant effect was shown, it was further tested by using the Duncan's Multiple Range Test (DMRT) at α=0.05.

RESULTS AND DISCUSSIONS

Observation during the drying period

Temperature and air humidity are two key factors contributing to the loss of water vapor on seeds during drying. The average values of temperature and humidity are presented in Table 1.

Table 1. Temperature (^{0}C) and relative humidity (%) in the drying process.

Drying methods	Temperature (^{0}C)	Relative Humidity (%)
On field	41,9±0,55	56,3±1,70
On woven bamboo nets covered with plastic	40,8±0,64	64,6±1,39
On woven bamboo nets not covered with plastic	37,7±0,46	63,3±1,31

As seen in Table 1, bulbs drying on the field showed the highest temperature (41.9^{o}C) and the lowest relative humidity (56.3%), whereas bulbs drying on woven bamboo nets not covered with plastic showed the lowest temperature (37.71^{o}C) and relative humidity of 63.3%.

Table 2. Weight loss (%) and moisture content (%) of shallot bulbs after drying.

Methods of drying	Weight loss (%)	Moisture content (%)
On field	22,18	83,08
On woven bamboo nets covered with plastic	20,10	84,31
On woven bamboo nets not covered with plastic	21,82	84,87

The higher temperature during drying on the field caused the greater weight loss (Table 2). Such high temperature on field caused the moisture content easily evaporated and resulted in lower water content than other treatments (Table 2). In line with the statement of Astuti (2008), the higher the drying temperature, the lower the water content would be, due to more opened material pore and loosen air density that facilitated water to evaporate from the material.

Observation during storage period

Prior to 12 weeks of storage, the initial quality of shallot including bulb moisture content, bulb firmness, and total soluble solid (TSS) was measured (Table 3).

Table 3. Moisture content (%), bulb firmness (N), and total soluble solid (TSS) (^{0}Brix) before storage

Treatment	Moisture content (%)	Bulb Firmness (N)	TSS (^{0}Brix)
Drying methods			
On the field	83,08 a	98,86 a	15,88 a
On woven bamboo nets covered with plastic	84,31 b	98,77 a	15,59 a
On woven bamboo nets not covered with plastic	84,87 c	98,77 a	15,55 a
Storage methods			
Farmer's warehouse	83,70 p	98,75 p	15,40 p
Air-conditioned room	84,21 p	98,87 p	15,83 p
Room temperature	84,35 p	98,77 p	15,50 p
Interaction	-	-	-
C.V (%)	1,66	0,76	6.73

Remark: The numbers in the columns followed by the same letters are not significantly different according to Duncan Multiple with $\alpha = 5\%$; (-): There is no interaction between factors being tested.

Based on the data, there was a significant difference on the bulb moisture content due to the curing method, where drying bulbs on the field showed the lowest moisture content in compare to other drying methods. Drying bulbs on woven bamboo nets not covered with plastic had the highest moisture content. The low level of moisture content from drying on field was associated with the higher temperatures during the drying (Table 3).

Moisture content was one of the important factors considered during the storage because it could potentially affect the food quality (Mardiana, 2016). Changes in moisture content of shallot bulbs during 12 weeks storage are presented on Figure 1.

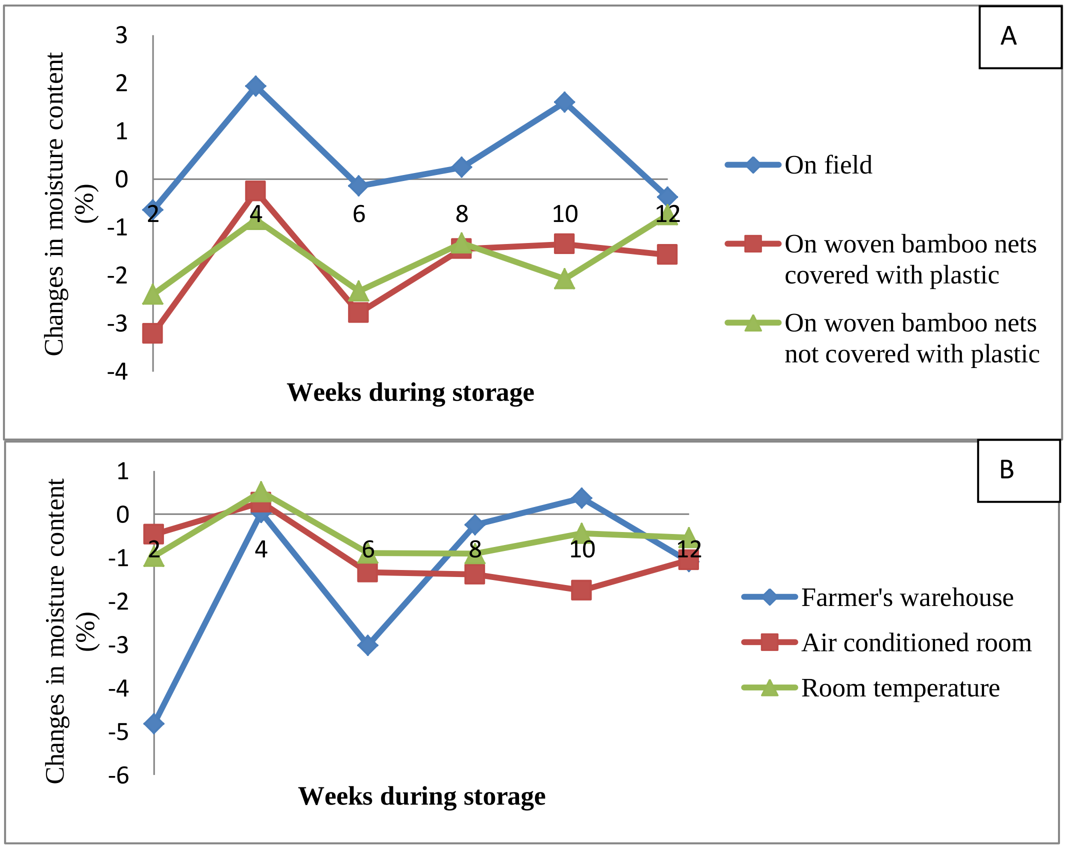


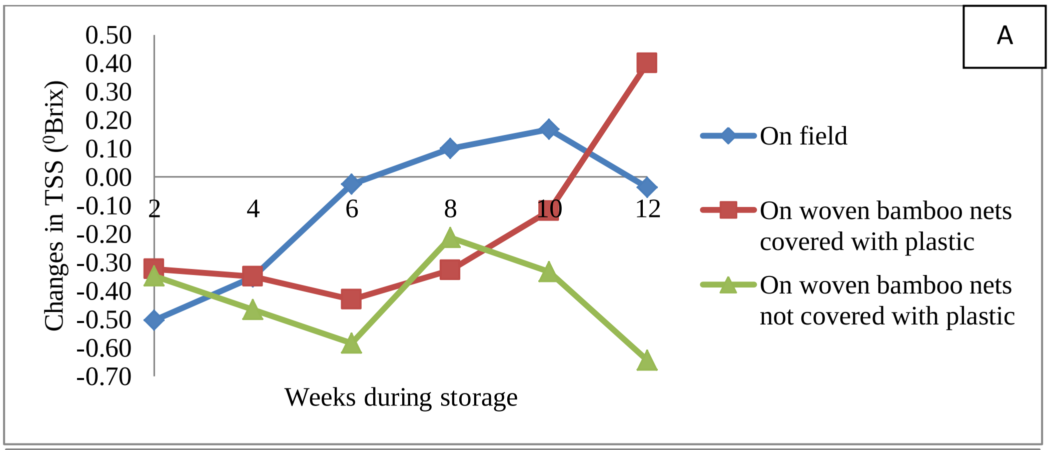
Figure 1. Changes in moisture content of shallot bulbs during 12 weeks of storage. A: Drying treatment; B: Storage treatment

Figure 1 shows the changes of water content in the shallot bulb seed with drying treatment and 12 weeks of storage. Given with the drying treatments, it shows the fluctuating changes of water content toward the end of observation (Figure 1.a). From the beginning to the highest end of the storage, the decreases of water content in the plastic-covered bamboo woven drying treatment and on-field drying treatment were 1.57% and 0.37%, respectively. Although water content decreased during the drying storage, it was still within the safe limit for the seed quality. In line to the study by Djali (2013); Mardiana (2016) and If'all & Idris (2016), 80-85% water content would result in good quality tube.

Not so much different results were obtained from the storage treatment, where water content in the bulb also fluctuated. From the beginning of storage to the highest end of the storage, the decrease of water content of the shallot bulb given with farmer's warehouse storage treatment was 1.08%. This was not much different than with air-conditioned room storage treatment (1.05%). The lowest decrease of water with room temperature storage treatment was 0.54%. Such as with the drying treatment, the decrease of water content with the storage treatment was also within the safe limit of sustaining shallot seed quality.

Fluctuating changes referred more to its response to the environmental conditions during the storage. This was due to its hygroscopic characteristics, in which the moisture content of the bulbs always adjusted to the water content. In accordance to Mutia's statement (2014), seeds stored at 26-32^{0}C temperature and 52-88% humidity easily absorb and evaporate water from the bulbs, and causes changes in moisture content. Further, Priyantono et al. (2013) states that the unstable condition and temperature of the storage environment will cause the shallot to easily absorb and evaporate water from the bulbs. However, if the water content remained low within the maximum limit, the seed would be able to maintain its quality where the viability and vigor remained fit (Iffal and Idris, 2016).

Total Soluble Solids (TSS) was defined as all existing solids and water-soluble solids in the bulbs including reduced sugars, sucrose, organic acids and water-soluble vitamins (Asgar and Marpaung, 1998). Changes in TSS content during 12 weeks of storage are presented in Figure 2.



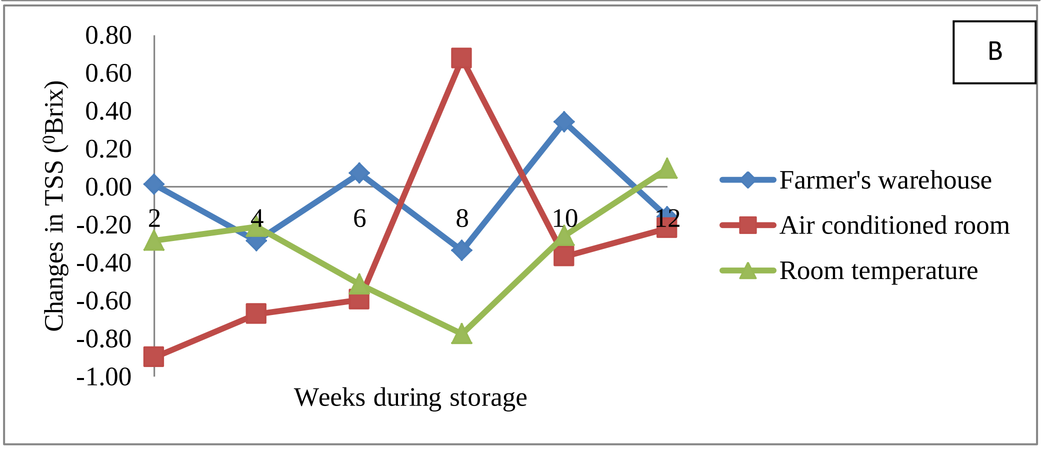


Figure 2. Changes in TSS content during 12 weeks of storage. A: Drying treatment; B: Storage treatment

The changes of TSS in the end of the storage with plastic-covered bamboo woven treatment tended to increase (0.39 ^{0}Brix), which was different from two other treatments. Drying on field treatment and plastic-uncovered treatment tended to experience decreases of TSS, each by 0.04 and 0.64 ^{0}Brix (Figure 2A), respectively. The tendency of increasing TSS content from plastic-covered woven bamboo treatment began from week 6. Meanwhile, the tendency of TSS decrease from on the field and plastic-uncovered woven bamboo treatments began from week 10.

Slightly different result was shown from the storage treatment (Figure 2B). TSS with farmers' warehouse storage treatment fluctuated form the begining toward the end of the storage. Different from room-temperature treatment storage, within week 4 to 8, TSS tended to decrease and began to increase toward the end of the storage. With air-conditioned room storage treatment, TSS tended to increase up to week 8 and decreased when entering week 10 but increased again to the end of the storage. The highest TSS decrease from the beginning to the end of storage occurred from air-conditioned room storage was 0.22 ^{0}Brix, while the lowest water content decrease occurred from farmer's warehouse storage treatment by 0.16 ^{0}Brix.

According to Djali (2013), the change of dissolved solids is related to the pattern of changes in moisture content that a decrease in water content will result in an increase of TSS content. However, the present result of this study was not in accordance to the abovementioned statement. It was supported by Nega et al. (2015) stating that after the curing, there is no obvious trend on TSS values for 90-days of storage. Other research showed that storage treatment and onion size had no meaningful impacts on TSS (Malek & Heidarisoltanabadi, 2015).

Different from the water content and PTT changes, the bulb firmness from all treatments experienced decrease at the end of 12 week of storage (Figure 3A and 3B). It was indicated that during the storage process, all treatments were not able to prevent changes in bulb firmness. In line with the statement of Nugraha et al. (2009), generally the firmness decreased during the storage process. The low level of firmness indicated softening shallot texture. It might occur due to changes in the composition of the cell wall belonging to one of the softening mechanisms commonly found in fruit ripening (Tucker et al., 1993). In line with the opinion of Heatherbell et al. (1982) and Pantastico (1986), during the ripening process, fruit changes its pectin content and the enzyme activity softens the fruit. The degree of firmness depends on the outer shell thickness, the total solid and the starch content of a material (Pangidoan et al., 2014; Pantastico, 1986).

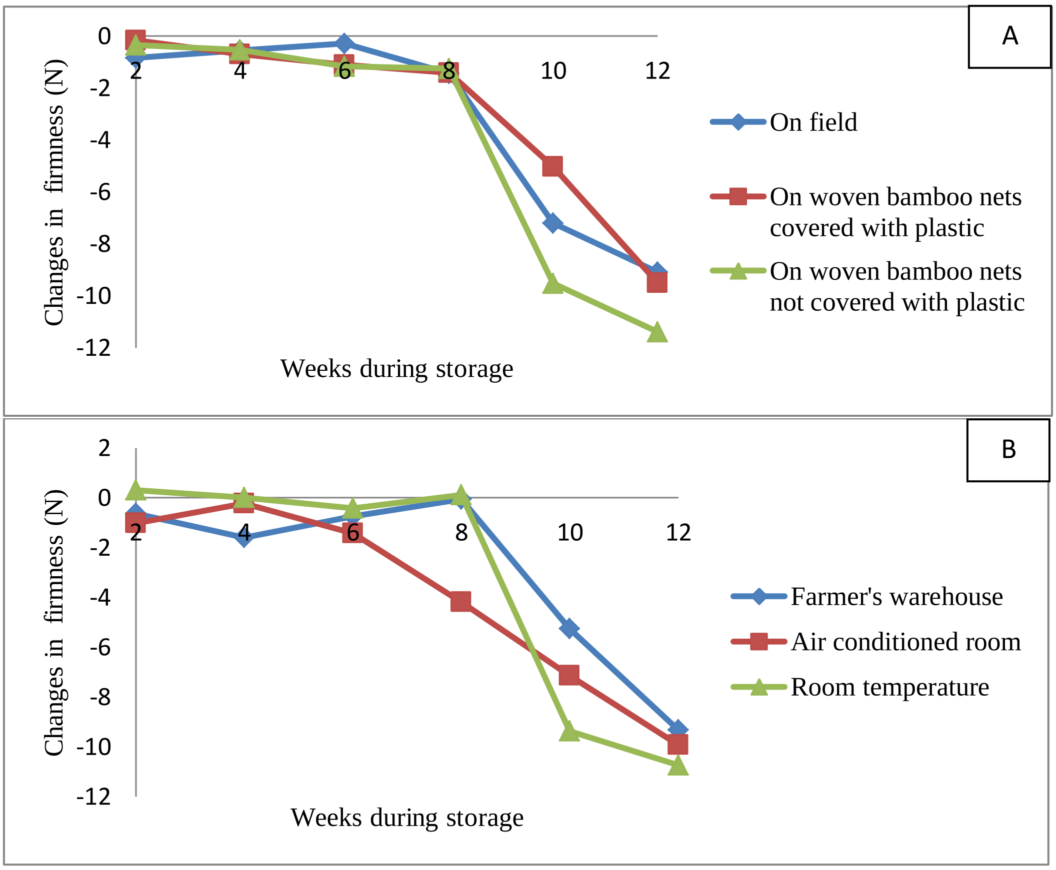


Figure 3. Changes in bulb firmness during the 12 weeks of storage. A: Drying treatment; B: Storage treatment

Weight loss was a quality parameter to represent the bulb freshness. During the storage, shallot bulbs loosed the weight due to vaporization, decay, and damage. Pantastico (1993) notes that most of weight loss is mostly influenced by respiration and transpiration. As shown on Table 4, the curing method showed insignificant effect among all treatments with significant effect found on the storage method. Bulbs stored in the warehouse showed the lowest weight loss although insignificantly different in compare to the ones stored at room temperature. This indicated that the treatment was able to suppress the weight loss until the end of storage, while the air conditioned room storage treatment was not able to suppress the weight loss due to the high rate of average damage and the number of sprouted bulb. The data showed that the number of damaged bulbs and the highest sprouted bulbs occurred were affected by air-conditioned room storage (Tables 5 and 6). Thus, the weight loss value occurred together with the increase of damage value. In line with the statement of Maemunah (2010), the increase of weight loss was due to the large number of damaged, rooted, and decayed bulbs during storage.

Table 4. Final weight loss (%) of shallot bulbs after 3 months of storage.

Drying methods	Storage methods			Average
	Farmer's warehouse	Air-conditioned room	Room temperature	
On the field	8,41	15,79	12,31	12,17 a
On woven bamboo nets covered with plastic	12,12	14,91	11,77	12,94 a
On woven bamboo nets not covered with plastic	10,82	16,60	13,39	13,60 a
Average	10,45 q	15,77 p	12,49 q	12,90
CV (%): 16,86				

Remark: The numbers in the columns followed by the same letters are not significantly different according to Duncan Multiple with α = 5%; (-): There is no interaction between factors being tested

The number of sprouted bulbs was only affected by the storage method (Table 5). Bulbs stored in the air-conditioned room showed larger number of sprouted bulbs than those from other treatments. It was suspected that such larger number of shoots in AC room storage was due to the AC temperature that could spur the shallot bulbs. According to Maya (2012), shallot bulbs at 20^0C temperature showed larger number of sprouted bulb than in 10^0C temperature. This indicated that 20-22^0C temperature storage accelerated the dormancy breakage of the shallot bulbs that were ready grow. According to Mardiana et al. (2016), the occurrence of sprouting is due to the increasing enzyme and gibberellin activities in the cell. Such condition improved the cell division process and the breakage of dormancy, and resulted in the changes of appearance that triggered the formation of roots and shoots.

Table 5. Percentage of sprouting bulbs (%) after 3 months of storage

Drying methods	Storage methods			Average
	Farmer's warehouse	Farmer's warehouse	Farmer's warehouse	
On the field	0,00	2,99	0,00	0,99 a
On woven bamboo nets covered with plastic	0,00	4,41	0,00	1,47 a
On woven bamboo nets not covered with plastic	0,00	2,60	0,00	0,87 a
Average	0,00 q	3,34 p	0,00 q	1,11

Remark: The numbers in the columns followed by the same letters are not significantly different according to Duncan Multiple with α = 5%; (-): There is no interaction between factors being tested: *= Data was transformed with a $\sqrt{X+1}$

Based on the variance analysis results (Table 6), the drying and storage method did not give significant effect to the number of damaged bulbs. This indicated that during the storage, all treatments still experienced disease attack that caused bulbs damage. However, the damaged bulbs percentage was categorized as being low and ranged from 3.24 to 5.72. This was expected due to the low humidity effect which was between 54-71% and suppressed the microbial growth. According to Komar (2001), high humidity can stimulate the decay process, especially when there is a change or variation of indoor temperature. Further, it was explained that when 100% relative humidity was reached, it would also give impact to the occurrence of water condensation and consequently, resulted in more difficult fungus control.

Table 6. Percentage of damaged bulbs after 3 months of storage.

Dry methods	Storage methods			Average
	Farmer's warehouse	Air-conditioned room	Room temperature	
On the field	1,53	6,10	2,24	3,29 a
On woven bamboo nets covered with plastic	4,06	5,75	3,11	4,31 a
On woven bamboo nets not covered with plastic	4,12	5,32	3,88	4,44 a
Average	3,24 p	5,72 p	3,08 p	4,01
CV (%): 22,47				

Remark: The means in one column followed by the same letter were not significantly different according to DMRT (α 5%); (-): There is no interaction between factors being tested; Data was transformed with $\sqrt{X+1}$

Germination percentage is one of the seed viability parameters. There was no significant interaction between drying and storage methods to the germination percentage, vigor index, as well as germination speed (Table 7 and Table 8) . All drying and storage treatments resulted in similar germination percentage (100%) indicating fine germination percentage for all treatments with no inhibited seed germination. According to Soedomo (2006), high germination percentage is positively correlated to high quality bulbs.

Table 7. Vigor index of shallot bulbs after 3 months of storage.

Drying methods	Storage methods			Average
	Farmer warehouse	Air-conditioned room	Room temperature	
On the field	4,13	4,87	4,06	4,35 a
On woven bamboo nets covered with plastic	4,06	5,51	4,06	4,54 a
On woven bamboo nets not covered with plastic	4,10	5,25	4,21	4,52 a
Average	4,10 q	5,21 p	4,11 q	4,47 (-)
CV (%): 9,03				

Remark: The means in one column followed by the same letter were not significantly different according to DMRT (α 5%); (-): There is no interaction between factors being tested

One of high vigor indicators is shown by the ability of the plant to grow (germination percentage) more than 80% (Sutopo, 2004). The high number of vigor index indicated the seed ability to germinate simultaneously. As presented on Table 7, the drying methods did not significantly affect the vigor index, but the storage methods did. Bulbs stored in the air-conditioned room resulted in highest vigor index and differed significantly among other treatments, while the effect of bulbs storage in warehouse and at room temperature resulted in the lowest vigor index. High vigor index obtained by air-conditioned room storage treatment was followed by high germination speed (Table 8). This was in line with Yudono (2012) that one of the primary characteristics of vigor seed is high speed germination.

Table 8. Germination speed (%/etmal) of shallot bulbs after 3 months of storage.

Drying methods	Storage methods			Average
	Farmer warehouse	Air-conditioned room	Room temperature	
On the field	26,00	31,96	25,49	27,81 a
On woven bamboo nets covered with plastic	25,62	38,30	25,45	29,79 a
On woven bamboo nets not covered with plastic	25,87	36,33	27,05	29,75 a
Average	25,83 q	35,53 p	26,00 q	29,12
CV (%): 12,54				

Remark: The means in one column followed by the same letter were not significantly different according to DMRT (α 5%); (-): There is no interaction between factors being tested.

As seen on Table 8, bulbs stored in the air-conditioned room grew faster and were significantly different among other treatments. The effect of bulbs storage in the farmer's warehouse and at room temperature was the lowest germination speed. The faster the bulbs germinated, the better the quality of the plants would be (Marthen *et al.*, 2013).

CONCLUSION

The quality of shallot bulbs during 12 weeks of storage experienced changes of quality within the drying and storage treatments; yet, in the terms of germination, vigor index and germination speed when planted after the storage period, the quality could still be maintained.

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