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Post Harvesting Technique
ORIGINAL ARTICLE

Effect of curing and storage temperature on shelf life of onion (*Allium cepa* L.) bulbs

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ABSTRACT

Simple and low cost farm technologies are required for small-scale farmers in developing countries to improve marketability and reduce postharvest losses of onion (*Allium cepa* L.) bulbs. Two experiments were conducted to evaluate the effect of curing and storage temperature on shelf life of onion bulbs. In the first experiment, the cured bulbs of yellow onion 'Shippo' were stored at five different temperature levels: 15 °C, 20 °C, 25 °C and 30 °C, and room condition (Rc) for 11 weeks from May to August 2015. It was arranged in a completely randomized design with twelve replications. In the second experiment, cured and non-cured red onion bulbs 'Shonan Red' were stored at four different temperature levels: 15 °C, 20 °C, 25 °C and 30 °C, for eight weeks from June to August 2015. It was arranged as a two factorial experiment with 10 replications. Onion shelf life was measured by recording weight loss, sprouted, rotten, and mould infected bulbs, as well as general appearance. The results indicated that curing treatment significantly reduced weight loss and rotting percentage, while maintaining high score of the general appearance. The non-cured bulbs stored at 30 °C showed higher percentage of rotten bulbs (40%) after eight weeks of storage. On the other hand, in case of the cured onion bulbs, rotting and mould infection (%) were recorded only at 15 °C. Sprouting of 8.3% bulb was observed only when stored at 20 °C in the first experiment after nine weeks of storage. The obtained results suggest that onion bulbs should be cured and stored at 25−30 °C for better marketability and longer shelf life. Further experiments can be conducted to evaluate the performance of cured bulbs for different onion cultivars stored in ambient conditions of Rwanda.

Keywords: Curing, onion, postharvest, storage life, water loss

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1 Introduction

Onion (*Allium cepa* L.) is a bulbous crop of great economic and nutritional importance worldwide and can be grown under a wide range of climates from temperate to tropical (Lawande, 2018). The world production of dried onions was 97.9 million tonnes during the year 2017 (FAOSTAT, 2020). According to the same source, the top major onion producing countries are China, India, the United States, Iran, and Egypt. Though onions are known to be less perishable, postharvest losses in the tropics could be still as high as 66% (Biswas et al., 2010). These losses from farms to retailers are due to physiological processes: water loss, rooting, sprouting, and pathological development where different pathogens lead to rotten bulbs (Petropoulos et al., 2016).

Temperature has been reported as an important factor that affects the shelf life and quality of stored onions (Biswas et al., 2010; Nega et al., 2015; Lawande, 2018). Storage temperature can be manipulated to control or minimize water loss, rotting, sprouting, and mould infection of onion bulbs (Yoo et al., 2012; Petropoulos et al., 2016). Lawande (2018) reported that longer onion shelf life is easily achieved at low temperature (0−2 °C) because it keeps onion bulbs in almost dormant state, which significantly decreases sprouting, rooting, decay and weight loss. However, most small scale farmers in developing countries, including Rwanda, cannot afford to store onions under cooling systems (Clay and Turatsinze, 2014). They try to sell onions immediately after harvest in order to avoid the risk of losses at their farms. However, the market price of onion during the peak harvesting period is usually low.

Curing of onion bulbs is also recognized as a useful practice to avoid postharvest losses. It is a drying process intended to dry off the necks and outer scale leaves of the bulbs to prevent moisture loss and attack by decay pathogens during storage (Ghulam et al., 2013). It allows healing of harvesting wounds and formation of new protective layers against pathogens and water loss (Cardoso et al., 2016; Nega et al., 2015; Lawande, 2018). According to Agblor and Waterer (2001), Botrytis neck rot, black mould (*Aspergillus niger*), blue mould (*Penicillium*) and bacterial soft rot (*Erwinia*) are triggered by mechanical damage of onion bulbs at harvesting and storage in humid conditions. Incidence of these diseases can be reduced effectively by curing treatment (Wright and Triggs, 2005). Schroeder and du Toit (2010) reported that the susceptibility to fungal decay decreased in the cured onion bulbs as compared to the non-cured bulbs. Besides, curing improves the external appearance of onion bulbs, which may result in better market price (Cardoso et al., 2016). However, most small scale farmers in Rwanda do not practice curing partly due to lack of information on affordable way of bulb curing. Non-curing practice and inappropriate storage temperature lead to losses of weight, external appearance, and internal quality parameters (Sharma et al., 2015; Petropoulos et al., 2016). When analyzing the adoption of specific postharvest technologies by small-scale horticultural farmers in Sub-Saharan Africa and South Asia, Kitinoja and Kitinoja and Al-Hassan (2012) found that simpler postharvest technologies have higher chance for being used over the long term. Affordable and effective postharvest technologies are required to be developed at farm level to extend the shelf life of onion and to increase its marketability. Specifically, there is a need to find out the optimum temperature to keep shelf life of cured onions for a longer period. Therefore, this study was aimed to evaluate the effect of curing and storage temperature on shelf life of onion.

2 Materials and Methods

Two experiments were conducted to study the effect of curing and storage temperature on shelf life of onion bulbs, as a part of technical training curriculum at Tsukuba International Centre (TBIC) of the Japan International Cooperation Agency (JICA). Bulbs of yellow onion 'Shippo', collected from Japan Agricultural Cooperatives (JA) Group's market and had been cured at the production area, were stored under five different temperature levels: 15 °C, 20 °C, 25 °C, 30 °C, and room conditions for 11 weeks from 25th May to 10th August 2015. These treatments were set as the ambient temperature in Rwanda could range around 15 °C in the western mountainous highlands and around 25 °C in the eastern lowlands in the country. Four incubators were used to control the constant storage temperature at 15 °C, 20 °C, 25 °C, and 30 °C. The storage temperature in room conditions (Rc) varied as shown in Fig. 1. Within each treatment, twelve onion bulbs were stored and considered as replications of the treatment in a completely randomized design.

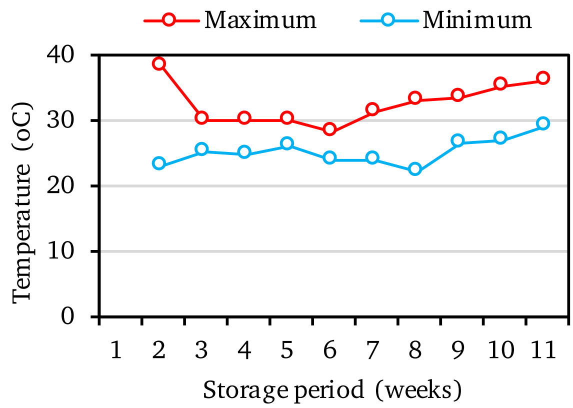

Figure 1. Temperature variation in room conditions during storage of yellow onion bulbs

Bulbs of red onion 'Shonan Red' were harvested from TBIC field, at Tsukuba City, Ibaraki Prefecture, Japan on 11th June 2015 when the tops have fallen down. The study was carried out as a factorial experiment with two factors: curing and storage temperature arranged in a completely randomised design. Curing had two levels: cured and non-cured. Curing was achieved using air blown by an electrical ventilator under room condition for 10 days before storage. Storage was carried out for 8 weeks from June to August 2015 at four different temperature levels: 15 °C, 20 °C, 25 °C and 30 °C. The constant storage temperature levels were attained using four incubators. By combining curing and storage temperature, eight treatments were used in a factorial completely randomized design (Table 1). Within each treatment, ten onion bulbs were stored and considered as replications of the treatment

Data were collected on weight loss, scoring of general appearance, and the percentage of sprouted, rotten, and mould infected bulbs. These parameters were taken as determinants of onion shelf life. Weight loss was expressed as the percentage obtained

Table 1. Treatments used in the experiment

Factor 1: Curing	Factor 2: Storage temp.	Treatment combinations
Non-cured (C0)	15 °C	C0T15
	20 °C	C0T20
	25 °C	C0T25
	30 °C	C0T30
Cured (C1)	15 °C	C1T15
	20 °C	C1T20
	25 °C	C1T25
	30 °C	C1T30

through dividing the difference between the initial weight and the weight measured at every week of storage by the initial bulb weight. The weight of rotten and sprouted bulbs was recorded as zero. The percentage of sprouted, rotten and mould infected bulbs was calculated by dividing the number of sprouted, rotten, and mould infected bulbs into the total number of stored bulbs per treatment. General appearance was estimated using five scores as follow: 5 = As harvested, 4 = Excellent, 3 = Still marketable, 2 = Edible, 1 = Not edible. Analysis of variance was performed for the data on weight loss using the Statistical Analysis System package, SAS software version 9.2 (SAS Institute 2010) where the level of significance was set at $p<0.05$. Means of significantly different treatments were separated using Tukey's honestly significant difference (HSD) test.

3 Results

3.1 Effect of storage temperature

Storage temperature significantly ($p<0.05$) affected the weight loss of yellow onion bulbs (Table 2). The onion bulbs stored at 15 °C showed the highest weight loss among the treatments throughout the storage period; while there was no significant difference in weight loss of onion bulbs stored at 20 °C, 25 °C, 30 °C, and room conditions. The highest weight loss was largely due to rotten and mould infected bulbs observed at 15 °C from the second week of storage. Only one onion bulb was sprouted at 20 °C after the 9th week of storage (Fig. 2). The general appearance deteriorated during the storage (Fig. 3). The onion bulbs stored at 15 °C turned into unmarketable (below score 3.0) in the second week of the storage; while the onion bulbs stored at 20 °C, 25 °C, 30 °C, and room condition remained good and still marketable up to the 8th week of storage.

3.2 Effect of curing

Curing, storage temperature, and their interaction significantly ($p<0.05$) influenced weight loss of onion bulbs during the storage period (Table 3). The non-cured bulbs (C0) generally showed higher weight loss as compared to the cured bulbs (C1) under the same storage temperature. The non-cured onion bulbs stored at 30 °C (C0T30) resulted in the highest weight loss (43.8%) among the treatments at the end of storage period. Apart from the normal physiological weight loss, there was also loss due to rotten bulbs in the non-cured bulb treatments. Weight loss was significantly lower in the cured onion bulbs stored at higher temperature levels (20 °C, 25 °C and 30 °C) (Fig. 4).

3.3 Effect of temperature and curing

Sprouted and moulds infected onion bulbs were not observed during the second experiment. However, rotten bulbs were observed after the 2nd week of storage and increased continuously up to the end of experiment (Fig. 4). The non-cured onion bulbs started rotting earlier as compared to the cured bulbs. The higher storage temperature resulted in the higher percentage of rotten bulbs in the non-cured onions (C0T30 > C0T25 > C0T15). The score of general appearance was largely affected by the number of rotten onion bulbs (Fig. 5). The score started declining from the 2nd week of storage and gradually declined more in the non-cured bulbs stored at higher temperatures of 25 °C and 30 °C. However, the cured onion stored at these higher temperatures maintained the highest score 5.0 throughout the storage period.

4 Discussion

In experiment one, higher weight loss was observed in yellow onion bulbs stored at 15 °C. In addition to physiological weight loss, other major causes for the high weight loss were rotting and mould infection, which implied that the temperature at 15 °C favoured the development of decay pathogens. Sprouting was noticed only at 20 °C. These results agree with the findings of Krawiec (2002) and Ko et al. (2002) who reported that storage temperatures of 10 °C and 20 °C significantly increased sprouting, decay, and weight

Table 2. Cumulative weight loss (%) of yellow onion bulbs weeks after storage at different levels of temperature

Storage temp.	Cumulative weight loss (%)										
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
15 °C	0.5 b	33.7 a	33.9 a	34.0 a	34.1 a	34.3 a	34.4 a	34.5 a	34.8 a	43.1 a	43.2 a
20 °C	0.3 c	0.5 b	0.6 b	0.8 b	0.9 b	1.1 b	1.2 b	1.4 b	1.5 b	1.6 b	1.8 b
25 °C	0.4 bc	0.8 b	1.0 b	1.1 b	1.3 b	1.5 b	1.6 b	1.7 b	1.9 b	1.9 b	2.1 b
30 °C	0.7 a	1.3 b	1.5 b	1.8 b	2.0 b	2.4 b	2.7 b	2.8 b	3.0 b	3.4 b	3.6 b
Rc	0.4 bc	0.7 b	1.0 b	1.3 b	1.5 b	1.7 b	1.8 b	2.0 b	2.3 b	2.4 b	2.6 b

Mean values followed by the same letter(s) within the column are not significantly different at 5% level of Tukey's test; W = weeks after storage; Rc = Room condition.

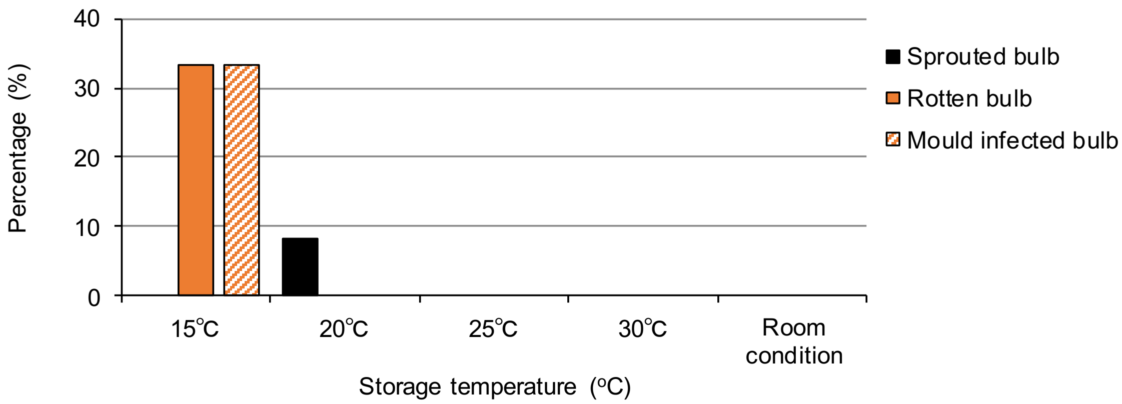

Figure 2. Percentage of sprouted, rotten and mould infected yellow onion bulbs after the 11th week of storage at different temperature levels

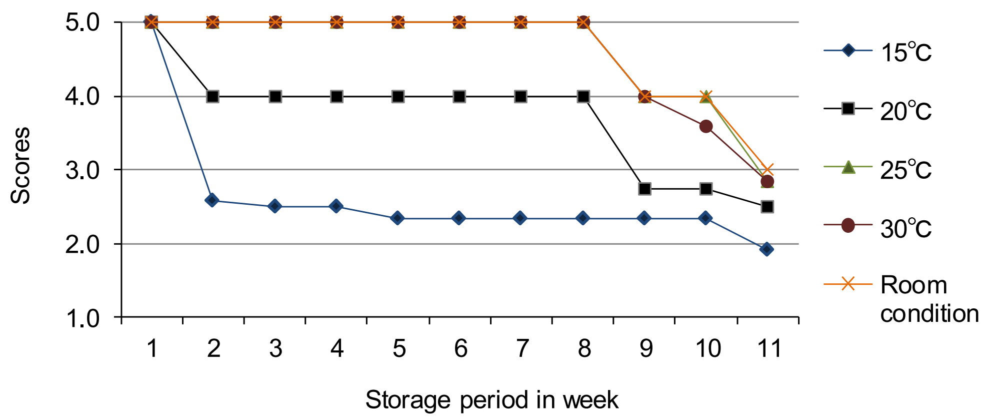

Figure 3. Variation of general appearance scoring in yellow onion bulbs during the storage. Score: 5 = As harvested, 4 = Excellent, 3 = Still marketable, 2 = Edible, 1 = Not edible

Table 3. Effect of curing and storage temperature on cumulative weight loss (%) of onion bulbs

Treatment	Cumulative weight loss (%)							
	W1	W2	W3	W4	W5	W6	W7	W8
Curing (C)								
Non-cured (C0)	2.9 a	6.0 a	15.9 a	18.5 a	18.7 a	23.6 a	23.6 a	23.9 a
Cured (C1)	0.4 b	0.8 b	1.0 b	1.2 b	1.4 b	1.5 b	1.9 b	7.1 b
Storage temperature (T)								
15 °C (T15)	1.6 b	2.1 a	2.5 a	2.8 b	3.2 b	12.6 a	12.8 a	23.0 a
20 °C (T20)	1.2 c	1.4 a	1.7 a	2.0 b	2.2 b	2.4 a	2.6 a	2.9 a
25 °C (T25)	1.6 b	2.1 a	11.9 a	12.1 ab	12.3 ab	12.5 a	12.7 a	12.9 a
30 °C (T30)	2.3 a	7.8 a	17.6 a	22.4 a	22.6 a	22.8 a	23.0 a	23.2 a
Interaction (C x T)								
C0T15	2.8 b	3.5 a	4.1 ab	4.5 b	4.9 b	23.7 ab	23.8 ab	24.2 a
C0T20	2.1 b	2.5 a	2.9 b	3.2 b	3.5 b	3.7 b	3.8 b	4.1 a
C0T25	2.8 b	3.4 a	22.9 ab	23.2 ab	23.2 ab	23.4 ab	23.5 ab	23.7 a
C0T30	3.9 a	14.5 a	33.7 a	43.2 a	43.3 a	43.6 a	43.6 a	43.8 a
C1T15	0.4 c	0.8 a	1.0 b	1.1 b	1.4 b	1.6 b	1.9 b	21.7 a
C1T20	0.2 c	0.4 a	0.6 b	0.8 b	1.0 b	1.0 b	1.5 b	1.8 a
C1T25	0.4 c	0.8 a	1.0 b	1.1 b	1.5 b	1.5 b	1.9 b	2.1 a
C1T30	0.6 c	1.1 a	1.5 b	1.7 b	1.9 b	2.0 b	2.3 b	2.6 a

Mean values followed by the same letter(s) within the column are not significantly different at 5% level of Tukey's test; W = weeks after storage.

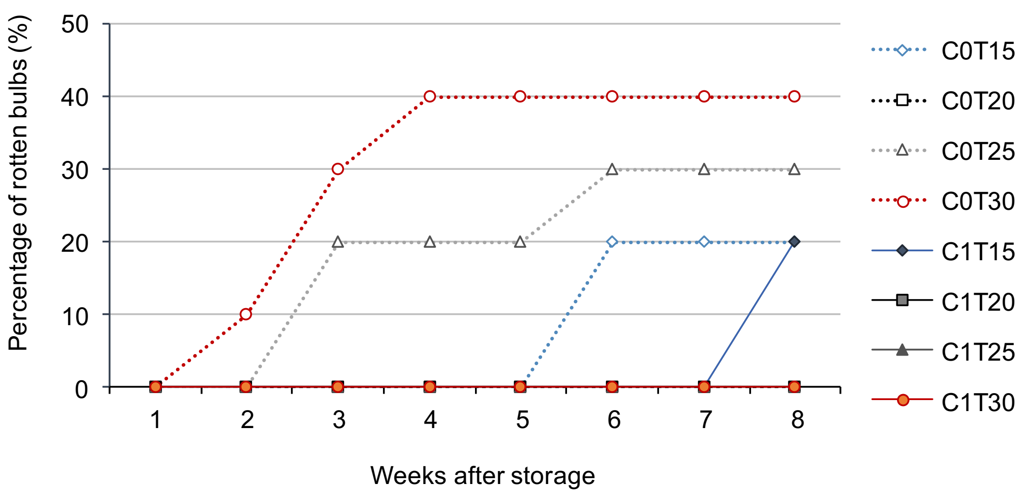

Figure 4. Percentage of rotten onion bulbs stored at different temperature levels after curing and non-curing treatments. C0 and C1 indicate the treatments of non-cured and cured onions, respectively. T15, T20, T25, and T30 indicate storage temperature at 15 °C, 20 °C, 25 °C, and 30 °C, respectively.

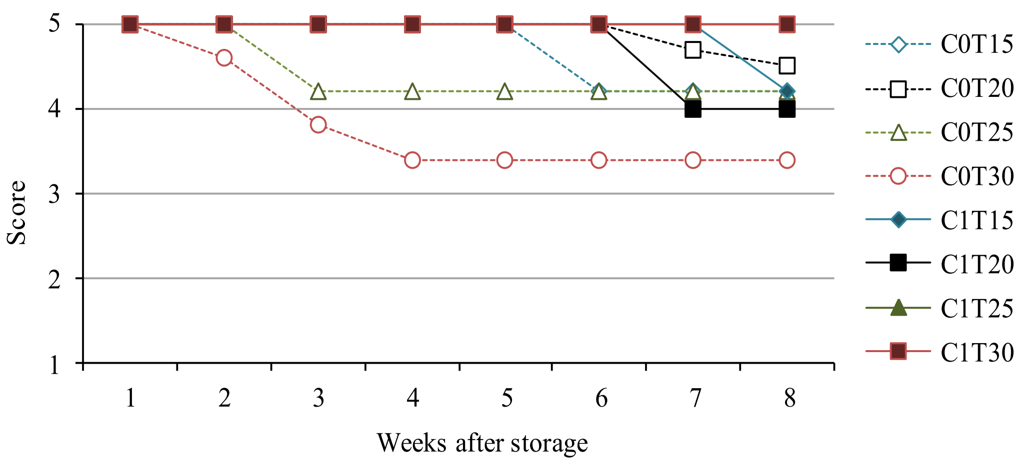

Figure 5. Change in general appearance scoring of the cured and non-cured red onions bulbs stored at different temperature levels. C0 and C1 indicate the treatments of non-cured and cured onions, respectively. T15, T20, T25, and T30 indicate storage temperature at 15 °C, 20 °C, 25 °C, and 30 °C, respectively. Score: 5 = As harvested, 4 = Excellent, 3 = Still marketable, 2 = Edible, 1 = Not edible

losses. According to Abdalla and Mann (1963), the rate of elongation of sprouts within the bulb and the rate of leaf initiation were much faster at 15 °C than at 0 °C or 30 °C, indicating that the state of dormancy becomes low at around 15 °C. Some long-lasting dormancy-enhancing process is engendered by storage of onion bulbs at 25−30 °C (Brewster, 2008). Yoo et al. (2012) also reported that temperature higher than 27 °C inhibits sprouting and rooting. In accordance with Nega et al. (2015), sprouting was observed later during the storage period of yellow onion. Onion sprouting is undesirable because it results into transfer of dry matter and water from the edible fleshy scales to the sprouts, leading to shrivelling and loss of appearance as well as market value for these bulbs (Nega et al., 2015). The cured onion bulbs stored at 25 °C, 30 °C and room condition (22−38 °C) maintained better quality at the end of the experiment. Lawande (2018) also reported the possibilities to store onion bulbs at high temperatures of 25−35 °C for three to six months without sprouting or rotting. This gives an idea that in areas where the ambient temperature reaches more than 25 °C, like in lowlands of Rwanda, the possibilities exist for small scale farmers to store successfully onion bulbs under ambient conditions.

In experiment two, higher weight loss obtained at higher storage temperature (30 °C) as compared to lower temperature could be because the higher temperature resulted into higher respiration and higher water release (Kitinoja and Al-Hassan, 2012; Lawande, 2018). Higher weight loss observed in non-cured onion bulbs as compared to cured bulbs may be associated with the absence of dry outer scales which would act as a barrier to water loss and isolate the inner part of cured bulbs from outside environment preventing free exchange between bulbs and its environment (Nega et al., 2015). Higher rotting percentage recorded in non-cured red onion bulbs as compared to cured bulbs demonstrates the positive effect of curing on preventing bulbs rotting during storage, as also reported by other researchers (Wright and Triggs, 2005; Schroeder and du Toit, 2010; Cardoso et al., 2016). The curing process reduced bulb weight by 4.2% before the commencement of storage, which is comparable to the findings of Bahnasawy (2000) who reported a weight reduction of 4% in the curing process. Though curing treatment results in loss of some weight, it pays back by prolonging shelf life of stored onions and fetching better price during off-season of onion marketing. Our results confirm that onion curing is important to avoid weight loss and rotting during storage. The obtained results concur with Kitinoja and Al-Hassan (2012) and Ghulam et al. (2013) who reported that provision of optimum curing enhances the storage performance of onion bulbs by reducing weight loss, rotting, and sprouting.

Baloch et al. (2012) reported that proper curing and adequate storage temperature can delay rooting and sprouting of onion bulbs. Rotting was low in cured red onion bulbs stored at higher temperature levels in comparison to lower temperature. Thus, if onion bulbs are cured and stored at the temperature between 20 and 30 °C, rotting can be controlled. Small scale farmers can practice field curing by spreading onions on a flat surface in full sun and allow them to dry for a few days until the onion roots and the plant itself are dry and brown. Then, cut off the tops to about 2.5 cm from the bulb and trim off dried roots. Continue to cure the onion bulbs out of direct sun light in a warm and well ventilated area for additional two to three weeks after which the bulbs will be ready for long term storage. Apart from curing and storage temperature, the type of cultivar also affects shelf life of onion bulbs. For instance, long day cultivars reportedly have longer storage life than short-day cultivars (Petropoulos et al., 2016). Other factors affecting onion shelf life include: fertilizers, irrigation, harvesting stage and method, store management, and storage environment among others (Biswas et al., 2010; Petropoulos et al., 2016; Lawande, 2018).

5 Conclusion

Affordable and effective technologies are needed to reduce postharvest losses and to increase income of small scale farmers in developing countries, including Rwanda. This study demonstrated that curing and storage temperature have effect on onion bulbs shelf life, which can be kept longer by curing and storing at high temperatures of 25−30 °C. Thus, in areas with the temperature range of 25−30 °C, like most parts of Rwanda, possibilities exist to store successfully cured onion bulbs in ambient conditions. Further experiments should be conducted to evaluate the performance of cured bulbs for different onion cultivars stored in ambient conditions of Rwanda. This would provide tangible results which can convince small scale farmers to store their onion bulbs until market price becomes better, and therefore, contribute to consistent supply of onion throughout the year.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Abdalla AA, Mann LK. 1963. Bulb development in the onion (*Allium cepa* L.) and the effect of storage temperature on bulb rest. Hilgardia 35:85–112. doi: 10.3733/hilg.v35n05p085.

Agblor S, Waterer D. 2001. Onions post-harvest handling and storage. Department of Plant Sciences, University of Saskatchewan, Saskatchewan, Canada.

Bahnasawy AH. 2000. Onion losses during storage as influenced by curing method. Misr Journal of Agricultural Engineering 17:209–225.

Baloch JuD, Baloch S, Munir M, Alizai AA. 2012. A study on root growth of onion (*Allium cepa* L.) under storage conditions. Pakistan Journal of Life & Social Sciences 10:156–160.

Biswas SK, Khair A, Sarker PK, Alom MS. 2010. Yield and storability of onion (*Allium cepa* L.) as affected by varying levels of irrigation. Bangladesh Journal of Agricultural Research 35:247–255. doi: 10.3329/bjar.v35i2.5887.

Brewster JL. 2008. Onions and Other Vegetable Alliums, 2nd Edition. volume 15. CABI International, Wallingford, UK.

Cardoso DSCP, Pereira AM, Correia TD, Finger FL. 2016. Drying time and post-harvest quality of onion bulbs submitted to artificial curing. Revista Ceres 63:822–828. doi: 10.1590/0034-737x201663060011.

Clay D, Turatsinze J. 2014. Baseline Report on the Rwanda Horticulture Organisation Survey. Rwanda Horticulture Organisation, Kigali, Rwanda.

FAOSTAT. 2020. Food and Agriculture Organization Corporate Statistical Database. Food and Agriculture Organization, Rome, Italy.

Ghulam N, Abdur R, Muhammad S, Abbas SJ, Imran A. 2013. Influence of curing methods and storage conditions on the post-harvest quality of onion bulbs. Pakistan Journal of Botany 45:455–460.

Kitinoja L, Al-Hassan HY. 2012. Identification of appropriate postharvest technologies for small scale horticultural farmers and marketers in Sub-Saharan Africa and South Asia – Part 1. Postharvest losses and quality assessments. Acta Horticulturae :31–40doi: 10.17660/actahortic.2012.934.1.

Ko SS, Chang WN, Wang JF, Cherng SJ, Shanmugasundaram S. 2002. Storage variability among short-day onion cultivars under high temperature and high relative humidity, and its relationship with disease incidence and bulb characteristics. Journal of the American Society for Horticultural Science 127:848–854. doi: 10.21273/jashs.127.5.848.

Krawiec M. 2002. Evaluation of storage losses of onion sets depending on the storage temperature. Folia Horticulturae (Poland) :13–20.

Lawande KE. 2018. Onion and garlic storage for value addition and supply chain management. Journal of Allium Research 1:1–6.

Nega G, Mohammed A, Menamo T. 2015. Effect of curing and top removal time on quality and shelf life of onions (*Allium cepa* L.). Global Journal of Science Frontier Research: D Agriculture and Veterinary 15:26–36.

Petropoulos SA, Ntatsi G, Ferreira ICFR. 2016. Long-term storage of onion and the factors that affect its quality: A critical review. Food Reviews International 33:62–83. doi: 10.1080/87559129.2015.1137312.

Schroeder BK, du Toit LJ. 2010. Effects of postharvest onion curing parameters on enterobacter bulb decay in storage. Plant Disease 94:1425–1430. doi: 10.1094/pdis-06-10-0457.

Sharma K, Lee YR, Park SW, Nile SH. 2015. Importance of growth hormones and temperature for physiological regulation of dormancy and sprouting in onions. Food Reviews International 32:233–255. doi: 10.1080/87559129.2015.1058820.

Wright PJ, Triggs CM. 2005. Effects of curing, moisture, leaf removal, and artificial inoculation with soft-rotting bacteria on the incidence of bacterial soft rot of onion (*Allium cepa*) bulbs in storage. Australasian Plant Pathology 34:355–359. doi: 10.1071/ap05051.

Yoo KS, Lee EJ, Patil BS. 2012. Changes in flavor precursors, pungency, and sugar content in short-day onion bulbs during 5-month storage at various temperatures or in controlled atmosphere. Journal of Food Science 77:C216–C221. doi: 10.1111/j.1750-3841.2011.02529.x.

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