

Effects of storage duration and bulb size on physiological losses of white creole onion (*Allium cepa L.*) bulbs stored in improved naturally ventilated storage structure

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ABSTRACT

This study was conducted to determine the effects of storage duration and size grades on physiological losses in White Creole onion bulbs stored in Improved Naturally Ventilated Storage Structure (INVSS) under room condition at Teaching and Research Farm of the Department of Agricultural and Environmental Engineering, Modibbo Adama University of Technology, Yola. The Onion bulbs were sourced from local farmers in Loko district of Song Local Government Area of Adamawa state. The effects of storage duration and sizes on physiological losses of onion bulbs were evaluated in a factorial experimental design consisting of fifteen treatments with storage duration of 5 months and sizes graded in 3 categories laid out in the Completely Randomized Design (CRD) with 3 replications. The data collected were subjected to analysis of variance and the means were separated using LSD at $p \leq 0.05$. The results indicated that storage duration and variation of sizes of onion bulbs had significant effects ($p \leq 0.05$) on weight losses, rot losses and sprout losses. Jumbo size onion bulbs (<50mm) had the highest Storage Weight Losses (SWL) by a mean of 2.33%, followed by medium size (50-70mm) with a mean value of 1.67% and the least was recorded among the small size (>70mm) onion bulbs which had a mean value of 1.33%. It was recommended that the INVSS should be used to store medium and small size onion bulbs for at least 5 months to achieve minimum storage losses.

Keywords: White Creole; pathological; physiological; rot loss; sprout loss; weight loss

INTRODUCTION

White Creole onion bulb (*Allium cepa L.*) belongs to the family Alliaceae is silvery white attractive in colour and roundish flat in shape. Its size ranges from 4-7.5 cm in diameter and has TSS of 13-14%. Its drying ratio is 9:1 and matured in 130-140 days, flavor and nutritional value in supplying minor constituents such as minerals and trace elements. It also has good keeping quality. Its yield usually ranges from 25-35 tons/ha under good growing and

management conditions (Green, 1971; Fariyike and Adewale, 2008). In general, the estimated world total area under onion cultivation is 4,955,432 ha in 2016 with a total output production of about 60.5 million tons (Hanci, 2018 and FAO, 2018). The major producing countries are China, India, United States of America (USA), Netherlands, Spain, and Turkey. Others are Niger, Nigeria, Burkina Faso, Mali, and Senegal. India is the second largest producer of onions in the world after China,

accounting for 10% of the world production (FAO, 2000). In Nigeria, onion is mainly grown for its bulb. The bulbs are boiled and used in soups and stews as fried, or eaten raw. They are also preserved in the form of pickles. Onion leaves, especially from the Spring onion, are also used in salads and soup. An estimated total land area of 0.1-0.2 million ha is cropped annually with a production capacity of about 2.5 million tons, (Aduyiet *et al.*, 2002). Three varieties of onions such as red, white and yellow are grown annually under both wet and dry seasons in Northern Nigeria. Onions are commonly grown by farmers under dry season conditions and normally harvested between February and May with high yields of up to 25 tons ha⁻¹. Generally, proper storage of bulbs is necessary for both consumption and seed production in order to provide quality crops with minimal losses from physical, physiological and pathological agents, throughout the storage period (Thompson, 1982). Effective preservation can only be achieved by partial or complete control of the storage environment. Conventional methods of storing onions are costly. Storing onions in Controlled atmosphere (CA) gives encouraging results but the gains usually do not justify the commercial application. Similarly, storing onions at 0°C often requires expensive refrigeration or heating systems. It is therefore, necessary to explore alternatively very low cost and environment-friendly methods to store onions without compromising the quality. The storage of onion bulbs for long period under ambient conditions possesses a great problem due to high humidity and high temperature prevalence in the area. A lot of work has been conducted to understand the causes of postharvest losses of onion bulbs in storage, especially at room temperature and humidity. Stow and Ward (1978) reported that the major causes of bulb deterioration during storage are in order of importance from rotting, physiological loss of weight and even sprouting. High temperatures of 30-35°C encourages bulb

rot caused by *Aspergillus niger*, while low temperatures favored bulb rot caused by *Botrytis alli*(Tucker *et al.*, 1977; Stow and Ward, 1978). Ward (1976) reported that respiration was responsible for less than 20% of physiological weight loss of onion in the United Kingdom (U.K).

Several methods of onions storage have been designed throughout the ages and modified according to the local materials available for their construction. The methods used to store fresh onions in Northern Nigeria vary with locations. The common methods include; hanging on trees in bunches storage in traditional barns, cribs, and jute sacks as well as the use of sprout inhibitors to impede sprouting. Other factors such as the variety of cultivar, bulb maturity, environmental conditions, agro-climatology, degree of physical damage, as well as and other pre-harvest factors such as soil type, fertilizer application, irrigation schedule among others largely influences onion preservation. The study was carried out with the following objectives; to evaluate the shelf life of White Creole onion bulbs in terms of their potentials to resist sprouting, rotting and physiological weight loss for a period 5 months.

MATERIALS AND METHODS

The Study Area

The research was conducted at the Research Farm of the Department of Agricultural and Environmental Engineering, Modibbo Adama University of Technology (MAUTech), Yola, Adamawa State, Nigeria. The experimental research area lies on the following geo-coordinates; 09° 21.307'N and 012° 30.193'E; 09° 21.325'N and 012° 30.189'E; 09° 21.291'N and 012° 30.141'E and 09° 21.320'N and 012° 30.132'E; with an average elevation of 217. The area is an agrarian environment marked by dry (November to May) and wet (June to October) seasons. The mean annual rainfall usually ranges from 700 mm to 1050 mm (Adebayo,2004). The vegetation is basically of 3 types; Southern Guinea Savannah,

Northern Guinea Savannah, and Sudan Savannah type, within each vegetation type there is an interspersed thicket tree Savannah, open grass savannah, and fringing forests in the river valleys (Adebayo and Tukur, 1999).

Source of Materials

The freshly harvested White Creole onion bulbs used for this experiment were procured from the local farmers in Loko district of Song local government area not too far from the experimental area. The bulbs used for the study were grown at farmers' fields. This variety of onion is currently under production in different parts of Adamawa State and beyond. Both the pre-harvest and post harvest treatments, which have immense contribution on the effect of storage, were done according to farmers' practice.

Treatments and Experimental Design

The effects of duration of storage duration and sizes on physiological losses of onion bulbs were evaluated in a factorial experimental design consisting of fifteen treatments with storage duration of 5 months and sizes graded in 3 categories laid out in Completely Randomized Design (CRD) with 3 replications.

Cleaning and Sorting of Onion Bulbs

The cleaning process was carried out manually, whereby all the root attachments and dry necks were thoroughly trimmed off. The healthy onions were carefully separated from infected bulbs and foreign materials

such as soils. In addition, all thick-necked bulbs were also screened for moisture content (90-95% wet basis) in order to increase the longevity (storage life) of the healthy onions. The onion bulbs were then sorted and graded for storage.

The white Creole onion bulbs were properly dried and cured to average moisture content of 84.1% w_b before storage this conforms with the standard range of 80 – 85% w_b as recommended by Bakker-Arkemaet *al.*, (2004) and Rouamba, *et al.*, (2010) for storage of onion bulbs in tropical regions. The onion bulb samples were sorted into 3 size categories for storage.

Determination of Onion Bulbs Physical Parameters

After sorting the onion bulbs into their various size categories, one hundred onion bulb samples were selected for each size category. Each bulb was weighed using G & G Digital Electronics Scale (Plate 2) and their diameters were measured using a vernier caliper. The initial weight and size of each onion bulb before storage were recorded and labeled before they were introduced into the storage structure. The storage structure was fitted with thermo-hygrometer device for temperature and relative humidity measurements (Plate 1). The measurements were recorded 3 times on a daily basis (6:00 am, 12:00 noon and 6:00pm) and the average value of each was computed and recorded.



Plate 1: Digital Thermo-hygrometer for measuring temperature and relative humidity in the storage structure

The pathological and physiological activities of the stored onion bulbs were carefully monitored and the number of spoiled onions in form of rotting, physiological loss of weight and sprouting in each group was counted and recorded on the daily basis throughout the storage period.

The details of methodology adopted for recording this observation during the experiment are described below.

Determination Storage Weight Losses (SWL)

The weights of onion bulb samples were recorded using G & G Electronics Scale model-JJ 300. The weight of each onion bulb was taken as the initial weight before storage and was labeled on its surface for easier identification



Plate 2: G & G Electronic Scale

The cumulative loss in onion bulbs weight was calculated as the differences in weight between the initial weight before storage and the weight recorded at the intervals of one week for a period of 20-weeks of storage and expressed as percentage Storage Weight Loss (SWL) suggested by Kukanoor (2005).

$$SWL = \left[1 - \frac{W_f}{W_i} \right] \times 100 \dots\dots\dots (1)$$

Where:

W_i = initial weight before storage, (grams)
 W_f = final weight after storage, (grams)

Determination Storage Rot Losses (SRL)

The number rotten onion bulbs at the end of every week was counted after physical observations using hand feel to test for the firmness of each bulb. The onion bulb was considered rotten when it became softened (Plate 3).



Plate 3: Samples of rotten onion bulbs

The percentage SRL was calculated using equation (2) as was used for cocoyam by Obetta, et al., (2007).

$$SRL = \left[1 - \frac{N_r}{N_t} \right] \times 100 \dots\dots\dots (2)$$

Where:

N_r = No. of rotten onion bulbs

N_t = Total no. of Onion bulbs

Determination of Storage Sprout Losses (SSL)

The percentage SSL of onion bulbs on designated days of storage, was determined by counting the bulbs showing a sprout were counted and separated from the lot. The onion bulb was considered sprouted when the leaf primordia of stored onion bulbs begins to develop green leaves rather than scale leaves as described by Abdalla and Mann (1963).

The percentage sprouts, which indicated the number of onion bulbs sprouted at the end of the storage period, was calculated using equation (3) as was used for cocoyam by Obetta et al., (2007).

$$SSL = \left[1 - \frac{N_h}{N_t} \right] \times 100 \dots\dots\dots (3)$$

Where:

N_h = No. of Healthy Bulbs retained

N_t = Total no. of stored Onion bulbs

Statistical Analysis

The data sets were analyzed following the generalized linear model of SAS for Windows version 8.0 for ANOVA. The sample means were compared using standard error (SE) and the Least significant difference (LSD) was also used for mean separation at $P < 0.05$.

RESULTS

Results obtained from the field on environmental parameters such as temperature and relative humidity are presented in Table 1. It revealed that temperature in the Naturally Ventilated Storage Structures (INVSS) recorded higher in May (32.5°C) and least (25.2°C) in September. Similarly, the highest relative humidity (75%) was recorded, while the least (66.2%) was observed in May. The fluctuations in both temperature and relative humidity in the INVSS during the study period may be attributed to the presence of cross ventilation openings along the whole sides of the INVSS which facilitated adequate ventilation within the storage structures.

Table 1: Average Temperatures and Relative Humidity Recorded in the Onion bulbs Storage structure during the Storage Period (May-October, 2011).

<u>Month</u>	<u>Temperature (°C)</u>		<u>Relative Humidity (%)</u>		<u>Average</u>	
	Min	Max	Min	Max	Temp (°C)	R/Humidity (%)
May	26.2	31.7	59.53	72.8	29.0	66.2
June	25.0	30.0	63.0	75.4	27.5	69.2
July	24.5	29.5	66.0	76.2	27.0	71.1
August	24.1	27.9	69.4	77.03	26.0	73.2
September	23.56	26.82	72.2	79.43	25.2	75.8
October	24.45	28.79	68.5	77.15	26.6	72.8

The results in Table 2 showed that storage duration and bulb size had high significant ($p < 0.01$) effect on storage weight losses (SWL) in White Creole onion bulbs. The highest SWL was observed during the last month (October) of storage, irrespective of the size differences. However, the highest was observed among the Jumbo size (2.33%), followed by medium size (1.67%) and the least was observed among the small

size onion bulbs (1.33%). The study also indicated that smaller onion bulbs had longer shelf-life than the medium and larger size onion bulbs, because it was observed that there was no storage loss among the small (<50mm) size onion bulbs throughout the first-three months of storage as differed from both medium (50-70mm) and Jumbo (>70mm) that showed SWL at second month of storage.

Table 2: Effects of Storage Duration and Bulb Size on Storage weight losses among White Creole Onion Bulbs

<u>Duration of Storage</u>	<u>Size Category</u>		
	<u>Small (<50mm)</u>	<u>Medium (50-70mm)</u>	<u>Jumbo (>70mm)</u>
June	0.00	0.00	0.00
July	0.00	0.33	0.67
August	0.00	0.67	1.33
September	0.67	1.33	1.67
October	1.33	1.67	2.33
LSD ($p \leq 0.05$)	0.72	1.33	1.66
Level of significance	*	*	**
SE (\pm)	0.11	0.16	0.19

** = highly significant at 1%, level of probability, * = significant at 5% level of probability

The results presented in Table 3 showed storage duration had significant ($P < 0.05$) effects on sprouting of White Creole onion bulbs. The highest percentage (2.67%) of storage sprout loss (SSL) was observed in the last month (October) of storage among the small size onion bulbs, followed by the medium and jumbo size onion bulbs with respective mean values of 2.0% and 1.67%.

The study also indicated that Jumbo (>70mm) size onion bulbs had longer shelf-life in terms of SSL compared to the medium and small size onion bulbs, because it was observed that there was no storage loss among the jumbo (>70mm) size onion bulbs throughout the first-two months of storage as differed from both medium (50-70mm) and small (<50mm) that showed SSL at second month of storage.

Table 3: Effects of Duration of Storage and Bulb size on Storage Sprout Losses among White Creole Onion Bulbs

Duration of Storage	Size Category		
	Small (<50mm)	Medium (50-70mm)	Jumbo (>70mm)
June	0.00	0.00	0.00
July	0.67	0.33	0.00
August	1.00	1.00	0.67
September	2.00	1.33	1.00
October	2.67	2.00	1.67
LSD (p≤0.05)	2.00	1.67	1.00
Level of significance	**	*	*
SE (±)	0.18	0.16	0.15

** = highly significant at 1%, level of probability, * = significant at 5% level of probability

The results presented in Table 4 showed storage duration had significant ($p < 0.05$) effects on the storage rot losses (SRL) in all the 3 size categories of White Creole onion bulbs. The highest percentage (2.33%) of SRL was observed during the last month (October) of storage among the jumbo size (>70 mm) onion bulbs followed by medium (50-70mm) onion bulb (2.0%) while the

least was found among the small size (<50 mm) onion bulbs with a mean SRL of 1.0%. The study also indicated that small (<50mm) size onion bulbs had longer shelf-life in terms of SRL compared to the medium and Jumbo size onion bulbs, because it was observed that there was no storage loss among the small (<50mm) size onion bulbs throughout the first-two months of storage as differed from Jumbo (>70mm) that showed SRL at second month of storage.

Table 4: Effects of Storage Duration and Bulb Storage Rot Losses among White Creole Onion Bulbs

Duration of Storage	Size Category		
	Small (<50mm)	Medium (50-70mm)	Jumbo (>70mm)
June	0.00	0.00	0.67
July	0.00	0.00	1.00
August	0.33	0.67	1.33
September	0.67	1.33	1.67
October	1.00	2.00	2.33
LSD (p≤0.05)	0.67	1.33	1.67
Level of significance	*	*	**
SE (±)	0.11	0.15	0.16

** = highly significant at 1%, level of probability, * = significant at 5% level of probability

DISCUSSION

Storage duration and bulb size had high significant ($p < 0.01$) effect on Storage Weight Losses (SWL) in White Creole onion bulbs due to temperatures and relative humidity fluctuations, these translated into 2.8 and 2.5 Kpa water vapor pressure (P_{wv}) on a psychrometric chart, respectively,

which is in line with the assertion made by Thompson (1982) that explained the rate of moisture loss from a fresh produce is mainly controlled by P_{wv} difference between the intercellular spaces of plant material and the surrounding air. This difference could be the major factor that contributed to the high SWL observed during the last month (October) of storage. However, no SWL

was observed among the small size onion bulbs from the first-two months of storage, this implies that there was no significant difference at $P < 0.05$ level of significance among the small size categories of onion bulbs. The phenomenon observed among the small size onion bulbs could be attributed to the relatively low initial rate of water loss through the skin as a result of low level of respiration due to dormancy period of the bulbs that was followed by an abrupt change observed in the subsequent months, indicating more rapid weight loss, due to high respiration rate and senescence of older fleshy scales after dormancy breaks which are agreement with the findings of Koet *al.* (2002)

The higher SWL observed in Jumbo (>70mm) size onion bulbs was probably because the bulbs contain the highest moisture and had more surface area per unit of bulb that gave highest rate of transpiration. Sighn and sighn (2003) reported that large size of onion bulbs exhibited the highest SWL compared to smaller size onion bulbs. This is in agreement with the findings of this work. The study also indicated that stored smaller onion bulbs had longer shelf-life than the medium and larger size onion bulbs. Similar assertion was reported by Ward (1979) and Koet *al.* (2002).

Storage duration and bulb size had high significant ($p < 0.05$) effect on Storage Sprout Losses (SSL) in White Creole onion bulbs. The highest percentage of sprouting was observed in the last month (October) of storage among the small size onion bulbs, followed by the medium and jumbo size onion bulbs respectively. However, no sprout losses were observed during the first month among all the 3 sizes onion bulbs. However, the small and medium sizes started sprouting during the second months of storage and it increased proportionately with time of storage. This may be attributed to the high fluctuation in storage temperature, which contributed to the

termination of their state of dormancy at that period that ultimately leads to increase sprouting among this variety of cultivar. The results of the present investigation are in conformity with the findings of (Abdalla and Mann 1963).

Storage duration and bulb size had high significant ($p < 0.05$) effect on Storage Rot Losses (SRL) in all the 3 size categories of White Creole onion bulbs. The SRL was observed immediately during the first month of storage in Jumbo size onion bulbs. This indicated that there was no significant difference ($P < 0.05$) among the small and medium size White Creole onion bulbs during the first-two months of storage. The high percentage of SRL observed in jumbo size White Creole onion bulbs studied may be attributed to the fact that larger onions contain higher amount of water and thick necks which prone them to attacks by disease causing microorganisms (Rajcumar, 1997). Ward (1979) earlier confirmed that number of rotten bulbs increased with increasing bulb sizes. Cho et al. (2010) also reported that, larger onions bulbs are more susceptible to bruising, disease and other damages than smaller bulbs. However, the probable cause of rotting observed was as a result of high relative humidity recorded during the last month (October) of storage which harbors fungal pathogens that were responsible for higher percentage rot of onion bulbs observed among the jumbo size White Creole onion bulbs. Lee et al. (2001) also reported that larger bulbs had higher incidences of bulb rots, than smaller onion bulbs.

CONCLUSION AND RECOMMENDATIONS

Duration of storage and type of storage structure are important parameters that play a significant role in preservation of onion bulbs. The findings indicated that long time storage had significant effect on storage quality of onion bulbs stored in INVSS. However, proper sorting and grading of onions into different size categories before

storage could help in sustaining the onion bulb quality and as well reduce crop wastage. The results further indicated that small size onions (<5 cm diameter) were found as the most suitable for storage in the INVSS where their post-harvest losses were significantly lower than medium and the jumbo size onions. This indicates that White Creole onion bulbs can be stored using INVSS in Adamawa State up to 5 months during glut period with a tolerable loss until market price stabilizes. The structure can also be built from locally available materials with minimum skills and at a reasonable cost.

Based on the results of this study, the following recommendations are made:

1. The use of hydrated calcium to absorb CO₂ produced by the onion bulbs during storage is recommended for further studies relating the onion bulbs shelf-life.
2. Studies on the changes of some important biochemical and physical characteristics during storage in onion (*Allium cepa L.*) cultivars is recommended for increasing the understanding of the mechanisms of onion bulb dormancy and shelf life.
3. The use of sprout and rot inhibitors like maleic hydrazide, cycocel, streptocyclin, benomyl, and cabendazim is recommended for application before storage.

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