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Evaluation of naturally ventilated onion storage structure for a specific period

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Abstract

Naturally ventilated onion bulb storage structure was designed and constructed in NCAM, Kwara State, Nigeria to minimize post-harvest losses by controlling internal temperature and relative humidity which could help extend the shelf life of onion. Storage was made with saw mail wood of high standard for high durability with dimension 1.68m X 1.2m. Structure was constructed as raised platform 0.91m above the ground level with down ventilation. Onions were stored for 90 days and they were in four different compartments C_1, C_2, C_3 and C_4 at 1.13 m, 1.35m, 1.57m and 1.79m to the ground level respectively. Internal and external temperature, relative humidity within and outside the storage were monitored and the physiological weight loss were recorded every two weeks interval. Data obtained were subjected to descriptive (mean and standard deviation) and inferential (ANOVA) statistics. Internal and external temperature of the structure ranged from 12.8°C to 29.5°C and 15.5 °C to 37.7°C, 18.3°C to 36.6°C and 24.6 °C to 42.8°C in the morning and afternoon respectively. Internal storage temperature parameters in the morning were within the optimum temperature range for bulb onion storage while in the afternoon is slightly above optimum temperature range for bulb onion storage. The Pearson Correlation, r, between the internal and external temperature in the morning and afternoon is 0.974 and 0.322 respectively. This indicates that there is large significance difference between the internal and external temperature in the morning while medium significance variation occurred in the afternoon. Relative humidity of both internal and external surrounding of the storage structure ranged from 38% - 75% and 40% - 83% in the morning, 34% - 69% and 35% - 75% in the afternoon. The internal relative humidity range in the morning is slightly above the recommended optimum value for bulb onion storage while in the afternoon is within the recommended optimum value. The Pearson Correlation, r, between the internal and external relative humidity in the morning and afternoon is 0.966 and 0.767 respectively, which show that there is large significance difference between them. The onions stored in compartment C_1 had a lowest physiological loss in weight of 7.31% followed by compartment C_4 with a 9.09% while compartment C_2 had 11.77% of highest loss in weight and compartment C_4 recorded a 9.84% weight loss. This study concluded that the design needs ventilation and roofing material that would aid significantly in the control of both temperature and relative humidity within the storage, hence the structure has been able to reduce internal temperature to minimal level near to suit onion storage.

Keywords: Physiological Loss, Relative Humidity, Temperature, Weight Loss

1. Introduction

Onion (*Allium cepal L.*) is regarded as one of the foremost commercial vegetable crops grown in most parts of Nigeria (Shehu and Muhammad, 2011) [11]. Its largest production is dominant in the northern part of the country, specifically Sokoto and Kebbi states among the major commercial producing states (Gulma, 2012; Muhammad, 2008) [6, 10]. It is regularly used as condiment when mature for food addition either in fresh form or dried and mixed with other spices. It serves as source of incomes for farmers and young people including all actors engaged in the production to its value chain.

Onion is a delicate produce to store due to its high-water content despite being considered as a semi perishable, though it depending on species type and pre harvest as well as post-harvest treatments. Onion bulbs can be stored at low temperature (0-5°C) or high temperature (25-30°C) maintaining the relative humidity in the range of 55%-70% (Chope, 2006 and Kukanoor, L. 2005) [3, 7]. Generally, storage losses are proportional increase with the increase in storage period, bulb sprouting and rooting are reported as the main reasons for storage loss (Milenkovic, *et al.*, 2009) [9]. Biswas *et al.*, (2010) [1] reported that 46% to 56% bulb storage losses are found under different kinds of storage structures.

Onion is always in abundance in Nigeria during dry season, during this bulk production period, onion farmers either sell their produce at throw out price in panic of high storage loss or store for a few days using traditional methods under ambient environment. In both cases, dealers have more control of onion price in favor of them than farmers. Improved onion bulb storage facilities such as cold storage are not available and beyond the reach of small holder farmers. Significant onion bulb quality can be retained until market is secured using mud structures that can be locally built under natural ventilation (Ghulam Nabi, *et al.*, 2013) [5]. Lord Abbey *et al,* (2000) [8] reported high rate of physiological weight loss in the first four weeks under naturally ventilated stored bulbs. Such results vary with the type of cultivar and physical property of the environment under study. In order to guarantee the availability of onion in the market, in good quality and stabilize price from one harvesting season to the other, calls for effective storage. This study is therefore, undertaken with the view to determine the storage performance of naturally ventilated structure for onion bulbs.

2. Materials and method

The experiment was carried out using a wood constructed storage structure located behind the Department of Processing and Storage Engineering, National Centre for Agricultural Mechanization, Ilorin, Kwara State, Nigeria. Research was carried out between January and March, 2021. The structure was constructed and sited in a way to avoid any obstruction for adequate ventilation under ambient environmental condition. It was uncovered to the atmosphere where the temperature and relative humidity readings recorded during the period of experiment were not be obstructed. Readings that were taken included internal and external temperature of the structure, internal and external relative humidity of the structure and weekly weights of the onions.

2.1 Description of the storage structure

The onion storage used for the experiment was made with saw mail wood of high standard for high durability. It is a 1.68m X 1.2m dimension, the structure was constructed as raised platform 0.91m above the ground level with down ventilation. This is because the experimental area is not in any form of threat either by termite or topography of the area but the area only covered with flat green grass.

The columns and beams were made from softwood, while wire mesh was used as side walls to allow the required amount of ventilation and optimum heat flow out of the structure and also to obstruct insect invasion.

The storage's roof was made with grass which was weaved together at the base with a twine and rolled on top of the structure in an anti-clockwise. A thick wire mesh was used for the construction of the storage compartments to allow uniform flow of air around the onions during storage. Structural components were assembled using nails by professionals (Fig 1).

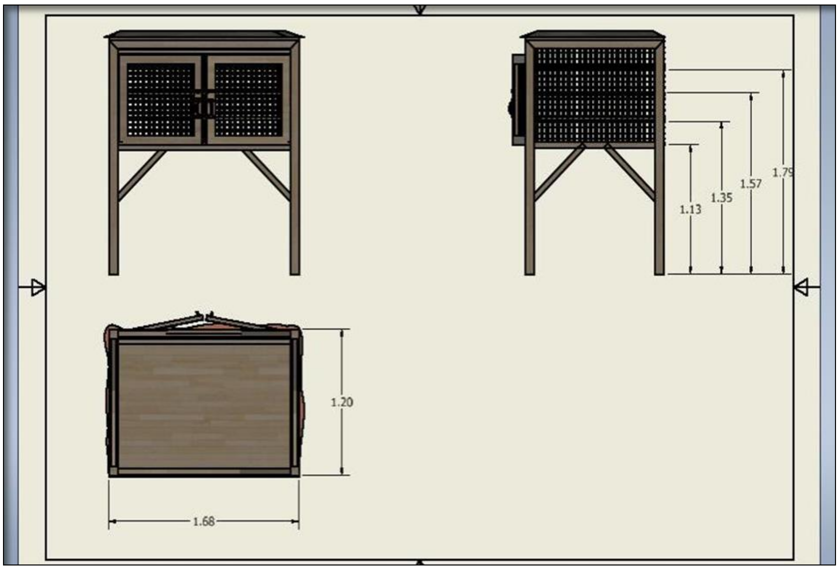

Fig 1: Orthographic view of the storage structure

2.2 Structural Evaluation

A total weight of eight five kilogram of almost equal size onions were used for the evaluation of the storage. These onions were in four different compartments C_1, C_2, C_3 and C_4 at 1.13 m, 1.35m, 1.57m and 1.79m to the ground level respectively. The bulbs were monitored every two weeks interval to observe physiological changes and parameters; internal and external temperature, internal and external relative humidity were measured twice daily (in the morning and afternoon). The temperature and relative humidity were measured twice daily at three different points within (internal) and outside (external) the structure with a digital thermohygrometer for a duration of three months.

These sample bulbs were visually assessed and weight data on physiological loss which include; rotting and sprouting were recorded every two weeks interval. A bulb was considered to have started rotting when there is any sign of decay around the neck area and considered sprouted when the sprout leaves had emerged from the neck. The rotted and sprouted bulbs were sorted from each compartment after recording so as to avoid double counting.

The weights of the onions were measured two-week interval using an analog weighing balance. The physiological changes observed included; sprouting, appearance of black mould and rotting. The physiological loss in weight percentage was calculated using the formula:

$$\text{PLW (\%)} = \left(\frac{P_0 - P_n}{P_0}\right) \text{X} \frac{100}{1}$$

Where P_0 = Initial weight

P_n = Weight after n days

2.3 Statistical analysis

Data obtained were subjected to descriptive statistics and analysis of variance (ANOVA) to test for significant differences and Microsoft Excel software.

3. Results and discussion

3.1 Temperature

The hourly temperature of the internal and external surrounding of the storage structure during the storage period have been monitored and the daily mean values were plotted to compare the relationship between the internal and external surrounding of the structure in the morning and afternoon as shown in Fig 2 and 3.

The temperature parameters for internal and external surrounding of the storage both in the morning and afternoon follow a different pattern with the higher external temperature condition in both morning and afternoon.

The temperature of both internal and external surrounding of the structure ranged from 12.8°C to 29.5°C and 15.5 °C to 37.7°C in the morning, 18.3°C to 36.6°C and 24.6 °C to 42.8°C in the afternoon. The highest internal temperature in the morning is 29.5°C while the least is 12.8°C. The values were within the optimum temperature range (25°C - 30°C) for bulb onion storage as reported by (Chope, 2006 [3] and Kukanoor, L. 2005 [7]). The internal temperature of the storage in the afternoon is slightly above optimum temperature range for bulb onion storage. The higher value internal temperature in the afternoon began to observe after 70 days of experiment which is equivalent to the middle of March due to inability of roofing material (grass) to absorb intensive heat in the month of March when harmattan was over.

The Pearson Correlation, r, between the internal and external temperature in the morning is 0.974, which indicates that there is large significance variation between the internal and external temperature. The large variation indicates that the structure has been able to reduce temperature to minimal level near to suit onion storage. The Pearson Correlation r, between the internal and external temperature in the afternoon is 0.322, which suggests that there is medium significance variation between the internal temperature and the external temperature.

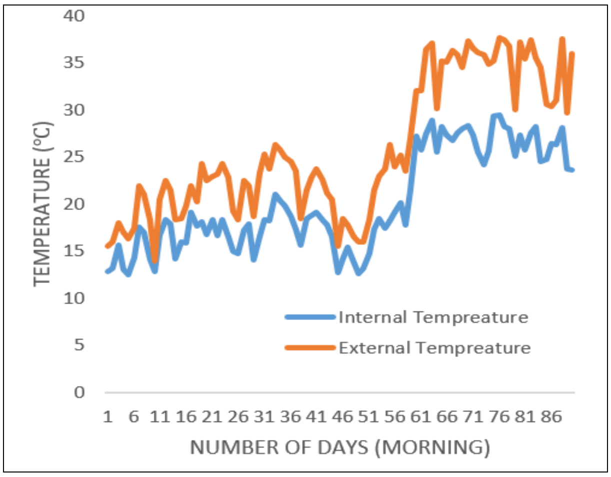

Fig 2: Relationship between Temperature Gradient from Internal to External of the Storage Structure in the Morning

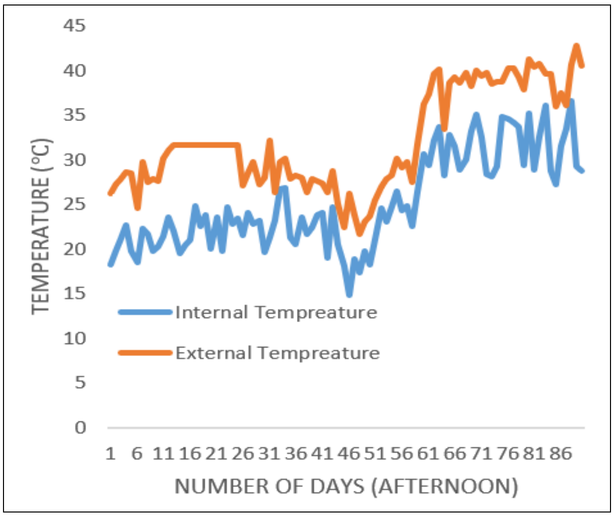

Fig 3: Relationship between Temperature Gradient from Internal to External of the Storage Structure in the Afternoon

3.2 Relative Humidity

The daily mean relative humidity results of both internal and external relative humidity during the storage period in the morning and afternoon have been recorded and plotted as shown in Fig 4 and 5.

The internal and external surrounding relative humidity of the storage both in the morning and afternoon follow a similar pattern with inconsistent value. It was observed that the relative humidity of both internal and external of the structure ranged from 38% - 75% and 40% - 83% in the morning, 34% - 69% and 35% - 75% in the afternoon.

The internal relative humidity range in the morning is slightly above the recommended optimum value (55%-70%) for bulb onion storage while in the afternoon is within the recommended optimum value.

The highest internal relative humidity recorded in the morning is in conformity to the report by Falayi and Yusuf (2014) [4]. The higher value in the morning contributed a serious challenge as onion bulbs absorbed moisture during this period thereby resulting in physical change of the onions.

The Pearson Correlation, r, between the internal and external relative humidity in the morning and afternoon is 0.966 and 0.767 respectively, which implies that there is large significance difference between the internal and external relative humidity in the morning and afternoon.

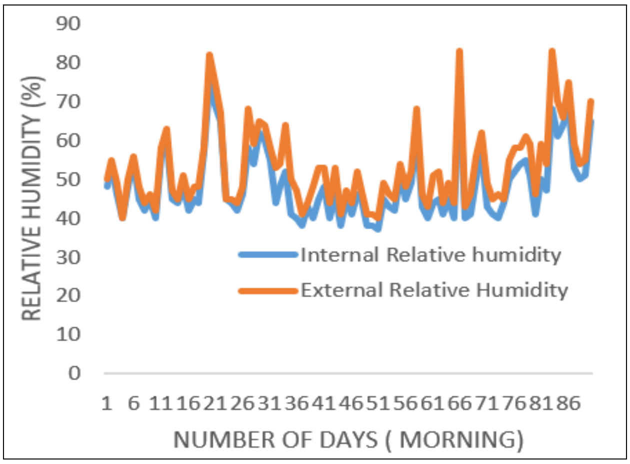

Fig 4: Relationship between Relative Humidity Gradient from Internal to External of the Storage Structure in the Morning

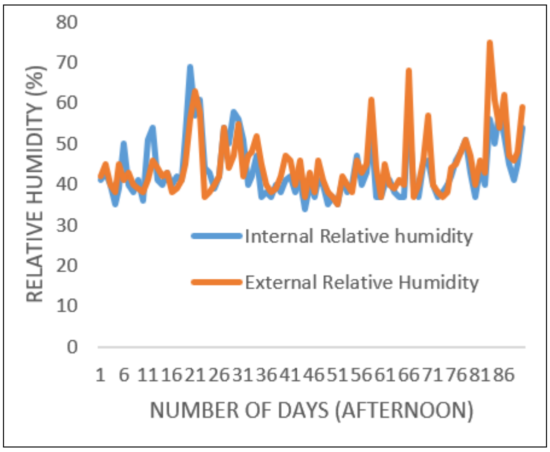

Fig 5: Relationship between Relative Humidity Gradient from Internal to External of the Storage Structure in the Afternoon

3.3 Reduction in weight during storage

The average unit weight of onions on compartment C_1, reduced from 23.50kg at the beginning of the experiment to 21.78kg at the end, representing an average physiological loss in weight (PLW) of 7.31% after three months of storing, the average weight of onions stored on compartment C_2 decreased from 19.20kg to 16.94kg showing an average physiological loss in weight (PLW) of 11.77% at the end of three months and the average weight of onions stored on compartment C_3 reduced from 21.75kg to 19.61kg at the end of the experiment indicating 9.84% average physiological loss in weight (PLW) after the expiration of storing period. While on compartment C_4 average physiological loss in weight (PLW) was 9.09% when the average unit weight of onions dropped from 20.55kg to 18.68kg at the start of the experiment to the end.

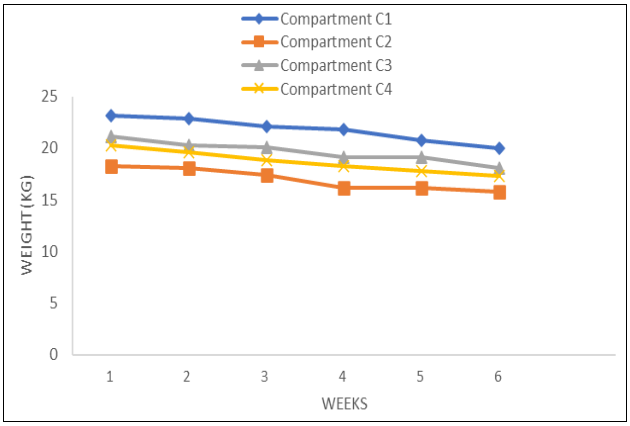

Fig 6: Weight loss in compartment C_1, C_2, C_3 and C4 of the storage structure

The lowest physiological loss in weight was recorded in compartment C_1 which could be as a result of more ventilation it received than other compartments because it is the first compartment to the ground the way the structure is being constructed, helps to maintain low internal temperature as well as increasing the internal air relative humidity of the structures. This conforms to the report by Cantwell and Kasmire (2002) [2] that elevating a storage structure above 500mm from the ground level to enhance adequate air circulation. On the other hand, highest physiological loss in weight was recorded in compartment C_2 follow by compartment C_3 which could be attributed to inadequate space for ventilation between the compartments while on compartment C_4 there was little reduction in weight loss, perhaps due to space between the compartment and roof.

The two-week interval loss in weight in all the compartment were consistent from the beginning of the experiment to the end as shown in Fig 6, as the week increases physiological loss in weight also increases, this phenomenon cannot guarantee safe storage for onion bulbs.

4. Conclusion

Based on the results of this study, the following conclusions were drawn:

1. The storage design needs ventilation and roofing material aided significantly in the control of both temperature and relative humidity within the storage.
2. The lowest physiological loss in weight was recorded in compartment C_1 which could be as a result of more ventilation it received than other compartments.
3. The large significant difference between internal and external temperature of the storage indicates that the structure has been able to reduce internal temperature to minimal level near to suit onion storage.
4. The onion storage can be built from locally available materials within the farm land and skill with a reasonable cost.

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