Performance Evaluation of a Modified Onion Storage Structure

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Abstract
The rate of deterioration of onion in the tropical humid environment due to inadequate storage structure cannot be overemphasized. The storage life of onion is dependent mainly on temperature and humidity. Onion is grown in the northern states mostly by peasant farmers and transported to the various regions in the country. To ensure supply of the commodity all year round, adequate storage facilities must be put in place. The objective of this study is to evaluate a modified onion storage structure in terms of its potentials to reduce ambient temperature and relative humidity which would help extend the shelf life of onion and reducing post-harvest losses. A storage structure capable of storing onions in a humid tropical environment was re-designed and constructed using locally available materials and tested for nine-weeks. The structure was constructed with 50.8 mm × 50.8 mm and 50.8 mm × 76.2 mm soft wood, naturally ventilated and was covered with asbestos roofing sheets and chicken mesh. The storage structure is 2000 mm × 1800 mm × 1900 mm for length, breadth and height respectively and is divided into three compartments (A, B and C). The parameters measured included temperature, relative humidity and weight of the onions and the results were subjected to appropriate statistical analysis. Temperatures within and outside the structure ranged from 25.1°C to 31.6°C in the morning period, 29.0°C to 41.7°C in the afternoon period and 24.0°C to 31.4°C in the evening period. Physical examination performed on the stored onions bulbs after nine weeks revealed minimal deterioration, with onions stored at compartment C recording the lowest percentage of weight loss of 5.91% while compartment B had a 6.80% weight loss and compartment A recorded a 6.69% weight loss. Relative humidity within and outside the structure ranged from 74% to 96% in the morning, 54% to 95% in the afternoon and 70% to 96% in the evening. The highest relative humidity value (96%) was recorded in the morning period and the lowest (54%) was recorded in the afternoon. The test of correlation analysis performed on the results indicated large significant difference between the internal and external temperature and relative humidity readings. It then can be concluded that the structure has performed well by reducing ambient temperature and relative humidity thereby prolonging the shelf life of the product.

Keywords: onion, deterioration, relative humidity, temperature, moisture content

INTRODUCTION
Onions (Allium cepa L.) are highly valued as flavouring agents. They have been successfully cultivated by man for thousands of years. One of the reasons for the success of onions in agriculture is their ability to be stored for long periods of time. Onions are biennial plants and the bulbs, formed after the first year of growth, are intended to be used by the plant as a nutrient source for the second year of growth. Onion bulbs are over-wintering structures that exist in a state of dormancy until environmental conditions for growth are favourable (Isenberg, 2009). Humans have long since utilized the storage attributes of onion bulbs and have selected varieties based on their storability (Jaggi and Dixit, 2009). Not all types of onions however, have the same storage attributes. Onions grown at low latitudes, where bulb- ing can be induced with 11-12 hour day-lengths, are called short-day onions (Jamali et al, 2012). Because the climate in these regions is mild and winters brief, short day onions usually have a limited dormancy period and are not well suited for storage. Typically short-day onions are soft, low in dry matter, and mildly flavoured with high rates of disease and softening during storage. Long day onions, in contrast are usually high in dry matter, with little decay and disease in storage (Kader, 2002). Onion is valued for its distinct pungent flavour and is an essential ingredient for the cuisine of many regions. Onion is the queen of kitchen (Maini and Chakrabarti, 2000). It includes more than 300 species of which about 70 are cultivated, some as ornamentals, most as vegetables. A distinct characteristic of onion is its alliaceous odour, which accounts for their use as food. The pungency in onion is due to a volatile compound known as allyl-propyl disulphide.

The onion which we eat (Allium cepa) is a hardy biennial grown from seed or from sets (small bulbs). It is usually grown for its firm, ripe bulbs, but also grown for its immature stems (shallots and green...
onions). Onion can be grown on various types of soil, they grow best on light soil, which may be sandy-loam or silt loam with a pH between 5.8 and 7.0. A relatively high temperature as well as a long photo period is desirable for bulb formation. Onion is an important vegetable crop whose distinctive flavour is appreciated by people throughout the world. One of the advantages of onion is that the bulbs can be harvested and sold either green in salads (Lannoy, 2001). Mature onion contain approximately: water (86%), protein (1.4%), fat (0.2%), carbohydrate (11%), fibre (0.8%) and (0.6%). The carbohydrate is principally in the form of sugar (F.A.O 1998). The bulb onion is normally harvested at the start of the dormant period (Brice et al., 1997), but in the tropics it is mainly grown as an annual and the bulb is harvested as a vegetable crop. Onions are not highly nutritious but have health-giving properties partly associated with its high sulphur content (Straub and Emmett, 1992).

Approximately 28 MT of bulb onions are grown worldwide, of which almost 60% are grown in developing countries (F.A.O 1996). In many of these countries onions make an important contribution to nutrition by providing much needed minerals and trace elements. However large quantities of bulbs are lost each year owing, in many cases to poor storage practices.

In Nigeria, onion is grown in the northern states mostly by peasant farmers and transported to the various regions in the country. To ensure supply of the commodity all year round, adequate storage facilities must be put in place. The objective of the study is to evaluate a modified onion storage structure with a view to ascertain its storage potentials and extending the shelf life of onion thereby reducing post-harvest losses.

**MATERIALS AND METHOD**

**Experimental Location**

The experiment was carried out using a wood-constructed storage structure located at the department of Agricultural Engineering, The Federal University of Technology Akure, Ondo State, Nigeria which is between the Latitude of 30° North and Longitude 15°West. Experiment took place between July and September; 2013. The structure was positioned in a way to avoid any obstruction in east-west direction for adequate ventilation under ambient environmental condition. It was exposed to the atmosphere where the temperature and relative humidity readings that were recorded during the period of the experiment would not be interfered with. 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.

**LIMITATION OF THE STUDY**

The evaluation of the structure was carried out in Akure, Ondo State in South Western part of Nigeria and not in the Northern part of the country where the crop is produced.

**DESCRIPTION OF STRUCTURE**

The onion storage used for the experiment was made with wood to avoid much expense and for high durability. It is a 2000mm X 1800mm X 1900 mm structure. 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. Asbestos was used for construction of the roof because of its low heat absorption. 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 members were assembled using nails. Detailed design of the structure has been reported by Falayi and Isa (2013) but the orthographic view of the structure is shown in Figure 1.

**PERFORMANCE EVALUATION OF THE STRUCTURE**

A total of seventy two equal sized onions were used for testing the structure. These onions were in three in three different compartments A, B and C at 1.3 m, 0.9 m and 0.5m to the ground level respectively. The bulbs were monitored daily to observe physiological changes and parameters measured included internal and external temperature, internal and external relative humidity and weight of the onion bulbs. The temperature and relative humidity were measured thrice daily at three different points within and outside the structure with a digital thermo-hygrometer for a duration of nine weeks.

The weights of the onions were also measured weekly using a digital 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:

\[ \text{PLW(%) } = \left( \frac{P_o - P_n}{P_o} \right) \times \frac{100}{1} \]

Where \( P_o = \text{initial weight.} \)

\( P_n = \text{Weight after } n \text{ days} \)

**METHOD OF ANALYSIS**

Data collected were subjected to appropriate statistical analysis such as descriptive statistics and analysis of variance (ANOVA) using SPSS and Microsoft Excel software.
RESULTS AND DISCUSSION

Temperature Analysis

The temperature gradient relationship between the inside and outside of the structure in the morning, afternoon and evening period is shown in figures 2 to 4. From the figures, we observe that the temperature of both inside and outside the structure ranged from 25.1°C to 31.6°C in the morning period, 29.0°C to 41.7°C in the afternoon period and 24.0°C to 31.4°C in the evening period. The highest temperatures (41.7°C) were recorded in the afternoon period while the lowest temperature (25.1°C) was recorded in the morning period. Temperatures were lower than the ambient temperature in the afternoon while it was higher inside the structure in the evening. This was due to the slow rate of heat dissipation by the asbestos roofing sheets. Fast movement of air helped reduce the moisture on the onions which were deposited as a result of precipitation.
Figure 5: Relationship between internal temperature in the morning, afternoon and Evening

Comparing the internal and external morning temperature of the structure, the Pearson Correlation, r, between the internal and external temperature in the morning period is 0.712, which implies that there is large significance difference between the internal temperature and the external temperature. This large difference indicates that the structure has been able to reduce temperature to suit onion storage. Comparing internal and external temperatures in the afternoon, the Pearson Correlation r, between the internal and external temperature in the afternoon period is 0.436, which implies that there is medium significance difference between the internal temperature and the external temperature. The Pearson Correlation r, between the internal and external temperature in the evening period is 0.701, which implies that there is large significance difference between the internal temperature and the external temperature. This analysis further shows that a change in the external temperature (increase or decrease) affects the internal temperature.

Relative Humidity Analysis
Figures 6 to 9 show the relative humidity gradient relationship between the inside and outside of the structure in the morning, afternoon and evening period. From the graphs we observe that the relative humidity of both inside and outside the structure ranged from 74% to 96% in the morning, 54% to 95% in the afternoon and 70% to 96% in the evening. The highest relative humidity reading (96%) was recorded in the morning period and the lowest relative humidity reading (54%) was taken in the afternoon.

It was observed that humidity was very high in the morning period and this posed a serious challenge as onion bulbs absorbed moisture during this period leading to swelling and contraction of onions thereby causing cracking of the outer skin, weight loss and gain and change in physical appearance (greening and black dots). Relative humidity was highest within the structure but it didn’t pose any serious challenge as high temperature and the steady rate of air flow within the structure removed the moisture.
Figure 8: Relative Humidity Gradient from inside to outside the structure in the Evening

Figure 9: Relationship between internal relative humidity in the morning, afternoon and Evening

Comparing the internal and external morning relative humidity of the structure, the Pearson Correlation, r, is 0.708, which implies that there is large significance difference between the internal and external relative humidity. This large difference indicates that the structure has been able to reduce humidity to suit onion storage. Comparison done on the internal and external relative humidity in the afternoon indicates that the Pearson Correlation, r, is 0.627, which implies that there is large significance difference between the internal and external relative humidity. The Pearson correlation, r, between the internal and external relative humidity in the evening period is 0.509, which implies that there is slightly large significance difference between the internal temperature and the external relative humidity. This analysis further shows that a change in the external relative humidity (increase or decrease) affects the internal relative humidity.

Weight Loss during Storage
The average unit weight of onions on compartment A reduced from 77.53g at the start of the experiment to 72.34g at the end, indicating an average physiological loss in weight (PLW) of 6.69% after nine weeks, the average weight of onions stored on compartment B reduced from 92.32g to 86.04g indicating an average physiological loss in weight (PLW) of 6.80% at the end of nine weeks and the average weight of onions stored on compartment C showed reduction from 93.48g to 87.96g at the end of the experiment indicating a 5.91% average physiological loss in weight (PLW) at the end of nine weeks. Weight loss was lowest on compartment C (5.19%) and highest on compartment B (6.80%) because of the effect of precipitation which was highest in compartment B.

Although compartment C had the lowest average physiological loss in weight, the weekly loss in weight in the compartment was not consistent as it had a 7.14% average physiological loss in weight in the 8th week, this phenomenon cannot guarantee safe storage for onion bulbs unlike compartment A. The floor surface where the structure was placed contributed significantly to the irregular weight loss in onions on the compartment C due to the evaporation effect from the moist soil (due to rain), also flow of air was lowest in the lowest compartment thereby reducing the rate of drying the onions after rainfall. Figure 10 shows the weight loss in compartments A, B and C of the structure.

Figure 10: Weight loss in compartments A, B and C of the structure

CONCLUSION
The conclusion of this research can be summarized below:
1. Design elements like ventilation and type of roofing sheets contributed significantly in the control of temperature and humidity within the structure.
ii. There were no cases of sprouting of onion bulbs throughout the experiment.

iii. Compartment A had the highest number of cracked skins while compartment C had the least number due to the difference in sun intensity on the compartments.

iv. All the onion samples had developed black spots by the end of experiment.

v. Compartment A had the least number of incidence of onion greening at the end of experiment.

vi. The average physiological weight losses recorded during the experiment indicated that the compartment C had the lowest weight loss percentage (5.91%).

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viii. Overall, compartment A which is 1.3m to the ground possesses the best storage properties with an average weight loss of 6.69% and also low incidence in greening and black spot of bulbs.

REFERENCES


