EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON RESPIRATION RATE AND NUTRITIONAL PROPERTIES OF STORED ONION

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ABSTRACT

Effect of temperature and relative humidity on respiration rate and nutritional properties of stored onion was investigated. Gas constituents and nutritional properties of onion evaluated include oxygen (O_2) and carbon dioxide (CO_2); moisture content (Mc), dry-matter (Dm), carbohydrate (CHO), crude protein (Cp) and vitamin C (VC). Three cabinets (A, B and C), with three storage chambers, each, were maintained at selected temperatures (14°C, 27°C and 34°C) at ±2°C. The relative humidity within the 9 chambers were independently controlled, using saturated salt solutions of sodium chloride (NaCl), sodium nitrite ($NaNO_2$) and ammonium sulphate [$(NH_4)_2SO_4$] with respective predictable humidity levels (64%, 75% and 80%RH) at ±1. The investigated properties were evaluated for a period of 6 weeks at the intervals of 2 weeks. The results indicate that temperature and relative humidity significantly influenced the compositions of O_2 and CO_2 in the storage chambers. The highest O_2 (19.5%) and CO_2 (0.16%) compositions were observed in storage chambers maintained at low (63.7%) relative humidity and high (34°C) temperature. The highest Percent moisture content of 88%, carbohydrate content of 7.79%, protein content of 1.83% and vitamin C content of 17.81% were obtained in chambers at 80.3% relative humidity and 14°C temperature, while the highest (19.75%) percent dry-matter content was recorded in a chambers maintained at 63.7% relative humidity and 34°C temperature. The results suggest that to conserve the nutrients constituents of onion bulbs the storage conditions should be maintained at moderate (14°C) and at high (80.3%) relative humidity conditions.

Keywords: *Onion Storage; Temperature; Relative Humidity; Respiration Rate; Nutritional Properties.*

INTRODUCTION

Onion (*Allium cepas L.*) is an important vegetable crop which is used both as a spice and a vegetable. It is grown in commercial quantity and forms part of daily diet in almost all households in Nigeria, throughout the year (Grema and Gashua, 2014). Due to its nutritive value, aroma, flavor and pungency, onion is an essential ingredient in many food preparations (Falayi and Yusuf, 2014). Onion is a good source of vitamins, minerals, dietary fibre and water, which aid digestion (NOA,, 2014). It provides many nutritive and medicinal benefits to its consumers (FAO, 2014). Its green leaves, immature and mature bulbs contain appreciable quantities of vitamins, minerals such as potassium, sodium, calcium, starch, sugar, proteins and vitamins A, C, D, and K (Kukanoor, 2005).

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Nigeria is among the world onion producing countries and the largest producing country in sub Saharan Africa, but due to non-availability of adequate storage facilities, onion supply to the local market does not generally meet national demand (Imoukhuede and Ale, 2015). Onion is a seasonal and perishable crop with low storability due to its high water content (Endalew et al., 2014). But due to its widespread consumption and constant demand throughout the year, farmers store onion from one harvesting season to the next or beyond, in order to extend its period of availability. Consequently, farmers encounter losses of large quantities of onion estimated at 50-76% (Denton and Ojeifo, 1990). The existing storage capacities are quite inadequate and most of the available units are traditional and unscientific. For fear of storage losses, farmers usually unload their entire stocks within a month of harvest. At this period, large quantities of onion flow into the market so much so that the market cannot absorb, leading to glut situations. During this period of seasonal glut, farmers are compelled to sell their onion stock immediately after harvest at very low prices (Sani and Jaliya, 2013; NABARD, 2011).

At the dormant stage, onion bulbs show no sprouting even though they possess the potential for sprouting. Depending on the cultivar and pre- and post- harvest treatments, onion bulbs can be stored at low temperatures (0-5°C) or high temperatures (25- 30°C), maintained at the relative humidity range of 55%-70%, to prolong the dormancy period of onion in storage (Singh, 2012). Low temperature storage is widely practiced in the developed countries as a technique for reducing the metabolic activity of onion bulbs and prolonging their dormancy period. Hence, temperature control between the period of harvest and consumption remains one most important factor in maintaining onion bulb quality. Cold storage facilities however require electricity to function, an input that is very expensive that cannot be afforded by farmers in the developing West African countries (Tarpaga *et al.*, 201 1). Most farmers in this region have no modern storage facilities and therefore rely on simple naturally ventilated structures such as *thatch covered-heap* (TCH), *thatch covered-straw bin* (TCSB) and *thatch roofed-mud hut* (TRMH) structures (Fumen *et al.*, 2015). The overall storage losses under these storage structures are high and generally increase with increase in storage temperature and period, with sprouting, rotting and weight loss as the main causes of losses in onion storages (Milenkovic *et al.*, 2009). During high-temperature storage, the bulbs are exposed to changes in environmental conditions such as gas (O2 and CO2) composition, temperature and relative humidity which can affect the respiration rate (O2 uptake and CO2) release) of the stored bulbs (Silva, 2015).

At the dormant state, the respiration rate remains low and continues to be low until dormancy breaks. As soon as dormancy is broken and sprouting begins the rate of dry-matter loss increases since the formation of sprouts requires energy, which is drawn from the carbohydrate reserves of the bulbs (FAO, 1998). The rate of water loss also increases and if it is in excess, the bulbs dry out allowing pathogens to penetrate the bulbs, leading total loss of the produce (Srivastava, 1993). During the respiration of stored onion, the carbohydrate reserves in the cells of stored onion bulbs oxidize (break down) into carbon dioxide (CO_2), water (H_2O) and heat energy (Silva, 2015, as expressed in Equation (1).

$$C_6 H_{12} \quad + \quad 6O_2 \quad \rightarrow \quad CO \quad + \quad HO \quad + \quad heat \tag{1}$$

The knowledge of the physiology of dormancy and epidemiology of storage disease is essential long term storage of onion. Using the physical principles of temperature and humidity control, storage structures can provide long-term dormant conditions and suitable storage conditions unfavorable for spoilage development. Also in this process economic and technological constraints will have to be looked into. Thus, in view of the economic and technological constraints, high-temperature dormancy technology of onion bulbs and control of storage temperature at 30°C and above need to exploited. The physiological and pathological processes that proceed within a store of onion bulbs interact with the physical process of heat and water vapour exchange so as to mutually influence the environment within the store (FAO, 1998). In view all these, the present investigation was under taken to determine the effect of temperature and relative humidity on gas (O_2 and CO_2) composition and nutritional properties of onion in storage chambers under laboratory conditions.

METHODOLOGY

This study was carried out at the Department of Agricultural and Bio Resources Engineering, Federal University of Technology, Minna, Nigeria, between the months of December, 2014 and January, 2015.

Sample Preparation

A bulk sample of cured bulb of red onion variety (*Kano-red*) was obtained from a local market in Minna, Nigeria. The bulbs were cleaned, sorted and hand graded into three different sized grades (Abd-El Rahman and Ebeaid, 2009). Three kilogram (3kg) weight of medium sized grade (4.5-6.0cm dia.) bulbs was loaded into each of the 9 storage chambers

Experimental Set Up

The experimental setup (Plate I) comprised three galvanized aluminium cabinets (A, B and C), placed in the laboratory to avoid the effect of weather fluctuation on the selected storage temperature and relative humidity regimes. Each of the cabinets had three storage chambers of dimensions 400 x 400 x 400mm. The three cabinets, A, B and C were maintained at selected temperatures of 14°C, 27°C and 34°C, at ±2°C, respectively. The relative humidity within the 9 chambers were independently controlled, using saturated salt solutions of sodium chloride (NaCl), sodium nitrite ($NaNO_2$) and ammonium sulphate [$(NH_4)_2SO_4$] with predictable humidity levels of 64%, 75% and 80%RH, at ±1, respectively (Sabaragamuwa *et al.*, 2011). The storage chambers were partitioned into upper and lower compartments, demarcated at the centre by wire mesh laid with knitted thatch. Saturated salt solutions in plastic containers were placed in the lower compartments of the chambers, while 3kg weight onion bulbs were loaded on the thatch-laid wire mesh in the upper compartments. The bulbs were laid on the porous knitted thatch to allow free circulation of the fume or vapour of the saturated salt solution in the chambers. The saturated salt solution in each chamber was kept moist throughout the storage period to enable the solid phase of the solution to absorb water from the enclosed environment, while the water phase of the solution evaporates into the enclosed environment to generate and maintain the predictable relative humidity. The laboratory experiment lasted for a period of six weeks (42 days).

Data Collection

Gas (O_2 and CO_2) composition in each chamber was monitored on 7days intervals, using a gas analyzer (RASI 700 model). While at the intervals of 14 days, the nutritional properties of the stored onion were analyzed, using proximate analysis. The nutrient properties determined include moisture content (Mc), dry-matter content (Dm), carbohydrate content (CHO), crude protein (Cp) and vitamin C content (VC).

Proximate Analysis of Stored Onion Samples

The investigated properties were determined on dried ground or powder form (AOAC, 2003). Sampled bulbs from each chamber were prepared by removing the outer skins, root base and neck base of the bulbs, and washed in clean water to remove adhering debris. The peeled bulbs were sliced into chips and dried in an oven at a temperature of 60°C for 48 hours. The moisture content of the sample was determined as follows:

$$M(\%) = \frac{Wi-Wd}{Wi} \text{ x } 100 \qquad (1)$$

Where, Wi = initial weight of sample before drying

Wd = weight of sample after drying

After drying the chips were ground into fine powder, using a commercial blender. The powdered samples were used for determining carbohydrate, crude protein and vitamin C, as described by AACC (2000).

RESULTS AND DISCUSSION

Effect of Temperature and Relative Humidity on Gas Composition in Storage Chambers

The results of effect of temperature and relative humidity on gas (O_2 and CO_2) compositions in the storage chambers are presented in Figures 1 and 2.

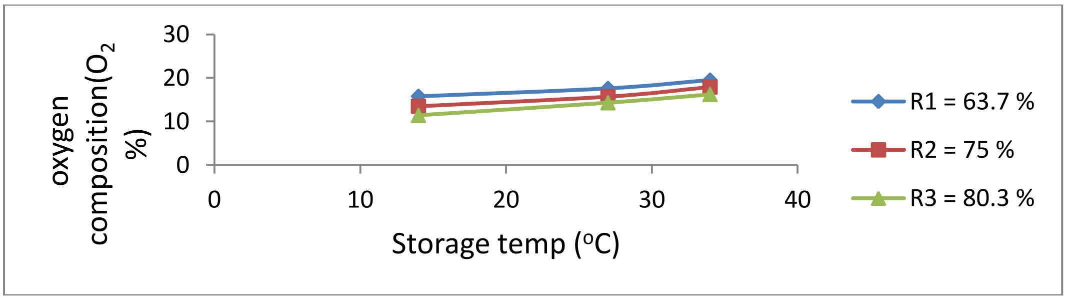

Figure 1: Temperature and Relative Humidity Effect on Oxygen (O_2) Composition in Storage Chamber.

The result of the effect of temperature and relative humidity on the composition of O_2 in the storage chambers in Figure 1shows that the gas composition was significantly influenced by the conditions of the storage chambers. The highest composition of 19.5% was obtained in a chamber maintained at the low relative humidity of 63.7% and a high temperature (34°C), while the lowest gas composition of 11.4% was recorded in a storage chamber with a storage temperature of 14°C and a high relative humidity of 80.3%. This result shows that high storage temperature with low relative humidity showed increase in oxygen composition in the chambers. Respiration is temperature dependent; thus, increase in storage temperature leads to increase in O_2 up take (Kader (2000). To maintain low O_2 composition in a storage environment, it requires that the store atmosphere is kept cool and gas-tight. Wills *et al.* (1998) also reported that respiration rate in living tissues is temperature dependent; thus, as temperature decreases, oxygen composition in a storage environment also decreases.

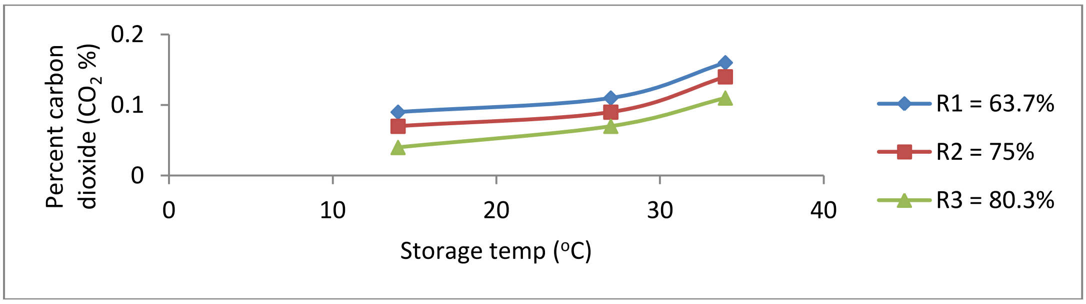

Figure 2: Temperature and Relative Humidity Effect on Carbon Dioxide (CO_2) Level in Storage Chambers

The effect of temperature and relative humidity on CO_2 composition in the storage chambers, as given in Figure 2, was significantly affected by the temperature and relative humidity of the chambers. The chamber maintained at the highest humidity level of 80.3% and moderate temperature of 14°C recorded the lowest CO_2 composition (0.04%). The highest gas composition of 0.11% was observed in a chamber with a moderate relative humidity (63.7%) and a higher (34°C) temperature. This result conforms to the report by Silva (2015) that the respiration rate in living tissues is temperature dependent; thus, at high temperature oxygen uptake increases, leading to increase respiration rate and increase in carbon dioxide composition in the storage environment. This also agrees with the report by FAO (1998) that the rate of respiration of stored produce is assessed either by measuring the uptake of O_2 or the quantity of CO_2 released. Since CO_2 is a product of respiration, it would be expected that respiration rate would decrease as CO_2 concentration in the store atmosphere increases. Kubo et al. (1990) reported that at high CO_2 concentration, succinic acid accumulates and the activities of enzymes involved in its metabolism decrease, thereby inhibiting respiration.

Effect of Temperature and Relative Humidity on Nutritional Properties of Stored Onion

The results of effect of temperature and relative humidity on moisture content (Mc), dry-matter (Dm), carbohydrate (CHO), crude protein (Cp) and vitamin C (VC) are given in Figures 3-7.

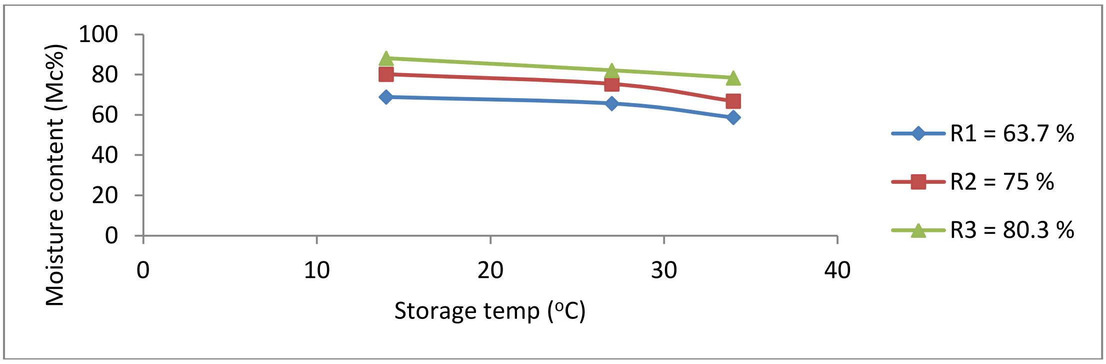

Figure 3: Temperature and Relative Humidity Effect on Moisture Content of Stored Onion.

The effect of temperature and relative humidity on the moisture content of stored onion, as presented in Figure 3, reveals that temperature and relative humidity within the storage chambers significantly influenced the moisture content of the stored onion. The lowest percent moisture content of 58.74% was obtained in a chamber maintained at 63.7% relative humidity and 34°C temperature. The highest percent moisture content of 88% was observed in a storage chamber with 80.3% relative humidity and 14°C. This implies that to minimize moisture loss from stored onion, the bulbs should be kept in a cool and humid environment. This result is in conformity with the report that moisture loss from fresh fruit, vegetable, root, tuber and bulb crops depends on the difference between the water vapour pressure within the commodity and the water vapour pressure of the surrounding air, with the moisture moving from the higher pressure to the lower (FAO, 1998). Where there is significant difference between the temperature of the commodity and the surrounding air, temperature has the most significant effect, but when both are at similar temperatures, the relative humidity has the most significant effect.

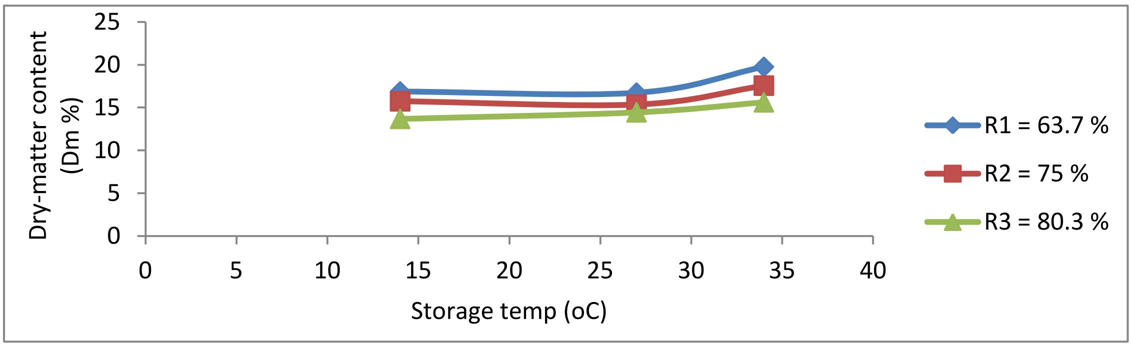

Figure 4: Temperature and Relative Humidity Effect on Dry-Matter Content of Stored Onion.

Storage temperature and relative humidity effect on dry-matter content of stored onion, as given in Figure 4, shows that the dry-matter content of the stored onion was influenced significantly with variation in the storage conditions. The highest dry-matter content of 19.75% was obtained in the onion bulbs stored in a chamber maintained at 63.7% relative humidity and 34°C, while the lowest dry-matter content of 13.68% was recorded in a chamber with 14°C temperature and 80.3% relative humidity. This result conforms to the report that under high-temperature storage of onion over a period of time, the dry-matter content of stored onion increased significantly (Patil and Kale, 1998).

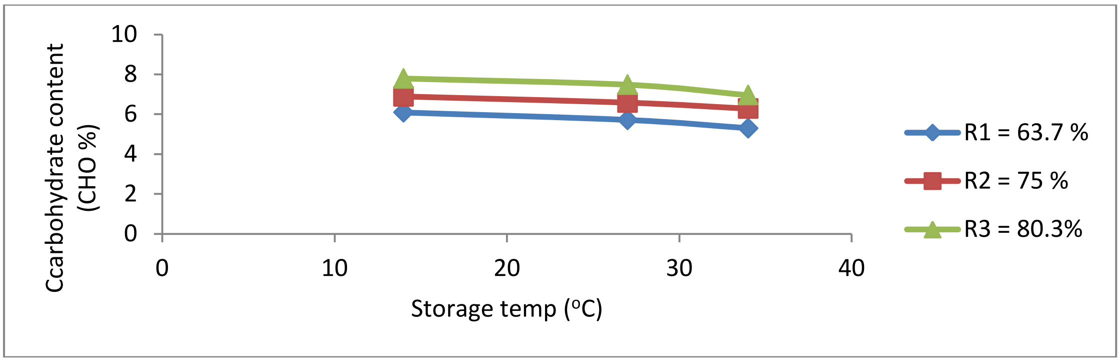

Figure 5: Temperature and Relative Humidity Effect on Carbohydrate Content of Stored Onion

Figure 5 shows the effect of temperature and relative humidity on the carbohydrate content of the stored onion. Increase in temperature reflected increase in the carbohydrate content. The lowest carbohydrate content of 5.29% was obtained in a storage chamber maintained at 63.7% relative humidity and 34°C temperature, while the highest carbohydrate content of 7.79% was obtained in a chamber with 80.3% relative humidity and 14°C temperature. This result agrees with the report by Kumar and Sreenarayan (2000) that the carbohydrate contents of the stored bulbs increased with storage temperature.

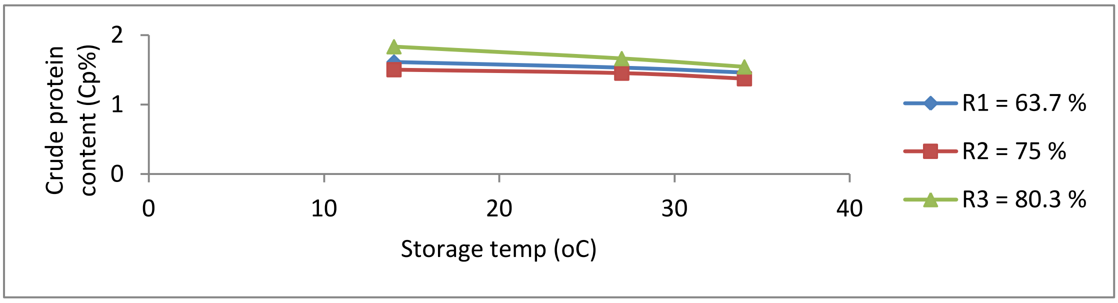

Figure 6: Temperature and Relative Humidity Effect on Crude Protein Content of Stored Onion

The effect of temperature and relative humidity on crude protein content of stored onion, as given in Figure 6, shows that the protein content decreased with increase in temperature and decrease in relative humidity. The highest percent protein content of 1.83% was recorded in a storage chamber maintained at the lowest temperature of 14°C and the highest relative humidity of 80.3%, while the lowest percent protein content of 1.37% was obtained in a chamber maintained at the highest storage temperature of 34°C and the lowest relative humidity of 63.7%. This result agrees with the report that onion stored under different storage conditions after six months period of storage, showed that crude protein content decreased with increase in storage temperature and storage period (Kukanoor, 2005).

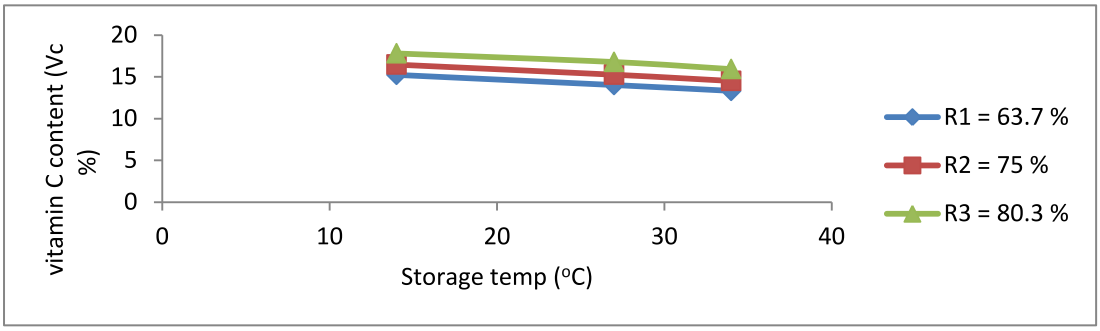

Figure 7: Temperature and Relative Humidity Effect on Vitamin C Content of Stored Onion

In Figure 7, the result of the effect of temperature and relative humidity on vitamin C content of the stored onion shows that the vitamin C content of the stored onion significantly decreased in storage chambers with high temperature and low air relative humidity surrounding the onion bulbs. The highest per cent vitamin C content of 17.81% was observed in a chamber maintained at moderate temperature (14°C) and high *relative* humidity (80.3%), whereas the lowest per cent vitamin C contents of 13.31% was recorded in a chambers maintained at high temperature (34°C) and low relative humidity (63.7%). This result confirms the report by Bankeblia and Selselet (1999), which stated that the vitamin C content of onion decreased with storage temperature and period of storage.

CONCLUSION

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

i. Temperature and relative humidity significantly influenced the gas (O_2 and CO_2) composition and the nutritional properties of onion bulbs in the storage chambers.
ii. Oxygen (O_2) and carbon dioxide (CO_2) compositions increased in storage chambers with high temperature and low humidity, agreeing that respiration in onion bulbs is temperature dependent.
iii. Moisture, carbohydrate, crude protein and vitamin C contents of the stored onion decreased in onion bulbs stored in chambers with low temperature and high relative humidity, while the dry-matter content increased in bulbs stored in chambers with high storage temperature and low relative humidity.
iv. The storage chamber maintained at low (63.7%) relative humidity and high (34°C) temperature conserved the highest dry-matter content in the stored onion.

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Plate 1: Three Galvanized Aluminium Cabinets for Determining the Effect of Temperature and Relative humidity on Onion Storage

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