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ORIGINAL RESEARCH ARTICLE

EVALUATION OF EVAPORATIVE COOLING STRUCTURE (ECS) AND ARTIFICIALLY AERATED ONION STRUCTURE (AAOS) FOR STORAGE OF FRESH RED ONION

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ABSTRACT

Storage of onion usually by cooling has been problematic due to poor electricity supply. Thus, this study assessed the effectiveness of artificially aerated onion structure (AAOS) and evaporative cooling structure (ECS) for the storage of fresh red onion. A total of 4650kg of red onion was stored for 7 months (March to October) and was monitored monthly to observe physiological and biochemical changes using AAOC and other standard methods. Data collected were subjected to descriptive statistics and t-test at significant difference of $P<0.05$ using SPSS. Increase in the percentage weight loss of the stored onion was observed as relative humidity increased especially when the relative humidity surpassed 50%. ECS had 27.03% weight loss recorded in May (2nd month of storage) while AAOS had 11.1% weight loss in July (Fourth month of storage). At the end of the experiment the average weight loss was 65.76%, 72.00%, and 76.12% for AAOS, Conventional method and ECS respectively. There was an increasing trend in the proteins, carbohydrates and oil contents of onion in AAOS and were significantly ($p < 0.05$) higher than the increase in conventional storage method and ECS. Declining trend was observed in ascorbic acids (AA) contents in the stored onions in all treatments leaving more retention (10.4% AA and 5.48% AA), in AAOS and conventional storage method respectively more than in ECS. Total polyphenolic contents increased from an initial 5.10±0.02 to 12.08±0.00, 9.95±1.03 and 8.97±1.03 GAE (mg/g) fresh weight in AAOS, conventional storage method and ECS respectively.

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1.0 Introduction

Onion (*Alluimcepa*) is one of the most important vegetables in Nigeria, belonging to the family *leliaceace* (Alabi and Adebayo, 2008). Its economic importance cannot be over-emphasized as it is an important vegetable crop whose distinctive flavour is appreciated globally. It is remarkably known for its aroma, taste and lachrymatory effects, it plays a significant role in the industries as constituents for moth repellent, beverages, expectorants, and condiments in biscuits (Sharma *et al*., 2005). Studies have shown

that bioactive onion molecules contribute to lowering bone re-absorption and preventing degenerative diseases due to ample polyphenols and potential antioxidants (Shahzadi *et al.,* 2005). One of the advantages of onion is that the bulbs can be harvested and sold either green in salads or as mature bulbs (Lannoy, 2001). Mature onion contains approximately: water (86%), protein (1.4%), fat (0.2%), carbohydrate (11%), fibre (0.8%) and (0.6%) (Anju *et al.,* 2010). The carbohydrate is principally in the form of sugar (FAO, 1998). More so, it is ranked as the second most important vegetable after tomato in Nigeria (Hussaini *et al.*, 2000). Over 64 million metric tonnes are produced worldwide; Nigeria is ranked among the top ten in the world and 4th in Africa with about 621,000 metric tonnes (FAOSTAT, 2010). About 50% of onions produced in 2010 under irrigation and rain-fed cultivation in Nigeria were from Kano State, Nigeria (KNARDA, 2011).

According to Pelter *et al.* (2000), cultivation of this crop has developed steadily in tropical areas for more than 40 years. Most of the onion produced in Nigeria comes from the Northern part of the country, such as Kano, Sokoto, Borno, Bauchi, Jigawa, Katsina and Zamfara (Inuwa, 2001). Onion consumption is spread throughout the year, and there is a constant demand for onion all year round. As a seasonal crop, price tends to skyrocket during the off-season, so attempts made to store and minimize huge spoilage of onion are still not very efficient, especially in Africa; this is due to the high moisture content (≥80%) of onion which allows for microbial infestations (Akbari *et al*., 2001) and unfavourable ambient condition for storage such as high temperature and high relative humidity during raining season.

The success of onions in adapting to most common storage techniques apart, from drying, is relatively poor, with storage losses reaching as high as 66% in some cases (Olusola *et al*., 2018). However, this essential commodity's sensorial and nutritional integrity depends on its freshness and wholesome state rather than in dehydrated form. Onion has comparatively low storage ability without cooling. Bulbs are usually stored until the next season's harvest or for a more extended period due to a seasonal glut in the market. Significant losses in quality and quantity of onion occur during storage. Therefore, the storage of onion bulbs has become a severe problem in tropical countries like Nigeria. The storage methods mainly adopted depend on the traditional knowledge, and commonly practised methods such as bags, room/stores, rhumbus, woven baskets, cribs, and the associated losses are pretty high. Sprouting, physiological loss in weight and microbial spoilage are often observed in storage. Three are two distinct storage approaches to storage of fresh onions one is cooling of storage space to 2^0C and control of humidity to 65-70% have been seen to be effective in the storage of fresh onions for up to 6 months, and the second is storage at ambient condition (Tripathi and Lawande, 2019). The first method has not been adopted in Nigeria as it is capital intensive and electricity-dependent, with electricity still erratic in the country. In contrast, the second condition prevails in tropical countries, which encourages more storage losses (Tripathi and Lawande, 2019).

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Hence, adequate storage facilities that do not depend on electricity from the national grid must be developed to ensure the supply of the commodity all year round. This study aims to evaluate low-cost onion storage structures that can handle bulk storage of fresh onions and ascertain their storage potential in extending the shelf life of fresh onions, thereby reducing post-harvest losses.

2.0 Materials and Methods

2.1 Experimental Location

The experiment was carried out at Nigerian Stored Product Research Institute, Kano, located in North Western Nigeria which has a semiarid climate (Figure 1). The experiment covers a period of 7 months, from March to October 2021.

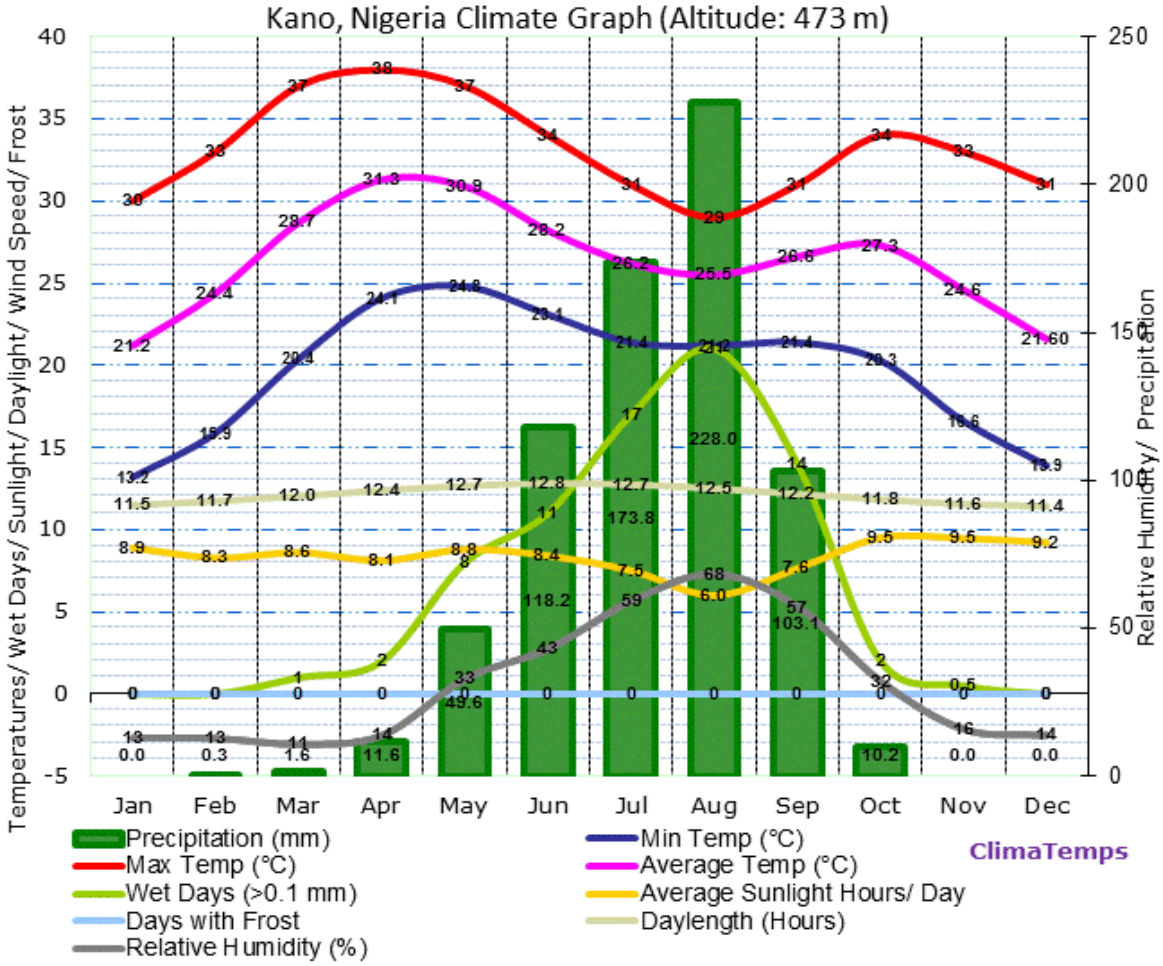

Figure 1: Average climatic condition of Kano, North-West Nigeria (Altitude 473m)
Source: http://www.kano.climatemps.com/graph.php

2.2 Experimental design

A comparative study of the effect of three storage methods; (i) Artificially aerated onion structure (AAOS), (ii) Evaporative cooling structure (ECS) and (iii) the conventional storage method on the physical and biochemical parameters of the stored onion carried out. A total of 4650kg of onions was used for this experiment. The average weight of a bag of fresh red onion was 125kg and 12.5bags (1550kg) was stored in each storage

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methods and replicated three times. The bulbs were monitored monthly to observe physiological and biochemical changes in storage. Parameters measured include ambient and storage temperatures and relative humidity, percentage weight loss, percentage of sprouted bulbs in storage, moisture content, ascorbic acid content, total carbohydrates, oil content, protein content, total phenolic content and total carotenoids.

2.3 Description of selected storage structures

2.3.1 Artificially aerated onion structure (AAOS)

The AAOS is expected to handle bulk storage of fresh onions. The frame of the onion storage structure was made from metal square pipe (2" x 2") for durability, and the body is made of embossed plywood, as seen in picture 1. The structure has a dimension of 8' x 8' x 4' and was set up inside a warehouse to achieve air tightness on all sides except at the open top. Interlock block was arraigned at the base to create an elevation of about 15cm (Figure 2) upon which wire mesh is laid. The wire mesh was welded to angle iron on all sides for rigidity. A standard-size drum opened on both ends was attached to the wire mesh's centric middle, and an AC axial fan (180W) was attached to the drum at the top. The fan is powered by a solar power assembly (Figure 2) which includes six (160W) photovoltaic cells, a 60A charge controller, a 1.5kVa power inverter and a 220Ah tubular battery. The operation of the ventilating system is to exhaust high humidity air, thereby preventing condensation from occurring on the onions and eliminating local heating within the onion bulk. During the holding period, onions maintained a ventilation airflow rate of 1 m^3/min/m^3 (1 cfm per cubic foot).

Figure 2: Artificial Aerated Onion Structure with solar power setup

2.3.2 Evaporative cooling structure (ECS)

ECS is a low-energy, environmentally friendly cool chamber made from locally available materials that utilise evaporative cooling principles. The evaporative cooled storage structure has proved to be useful for short-term, on-farm storage of fruits and vegetables in hot and dry (Amrat *et al*., 2013). Evaporative cooling is an efficient and economical means for reducing temperature and increasing the relative humidity of an enclosure and has been extensively tried for to enhance the shelf life of horticultural produce (Jha and Chopra 2006; Dadhich *et al*., 2008; Odesola and Onyebuchi 2009), which is essential for maintaining the freshness of the commodities (Dadhich *et al.,* 2008). Evaporative cooling is an environmentally friendly air conditioning system that

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operates using induced heat and mass transfer processes where water and air are working fluids (Camargo 2007).

2.4 Performance Evaluation of the Structure

2.4.1 Sample Collection and Preparation

Red onion bulbs, locally known as Yan-Gashua in the Hausa language, were purchased from onion Farm gate in Kura, Kano state. After curing, the onions were carefully bulk loaded into AAOS, ECS using crates (Figure 3 and 4) and conventionally (Single layer spreading in a ventilated dark room) for a seven-month storage period. A representative sample using randomization was taken from each storage method every two months for Physical and biochemical analysis. Experimental analyses were in triplicates in all cases.

Figure 3: Loaded AAOS

Figure 4: Loaded ECS

2.4.2 Analysis of Physical Properties

Physical properties evaluated were storage temperature, storage relative humidity, percentage weight loss and percentage sprouting. The storage and ambient temperature and relative humidity were measured using Temtop data logger, model: Temlog 20H with temperature accuracy of ±0.5^{o}Cand Humidity accuracy of ±3%RH.

2.4.2.1 Determination of Percentage Weight Loss

This was measured using methods described by Nicoli (2012). The weights of the onions were measured monthly using a digital weighing balance. The physiological changes observed included percentage weight loss and sprouting incidence. The Percentage weight loss was calculated using equation (1)

$$WL\ (\%) = \left(\frac{W_o - W_n}{W_o}\right) x\ 100 \qquad (1)$$

Where $\mathrm{WL} = \mathrm{Weigth\ loss\ (g)}$,
$\mathrm{W_n} = \mathrm{Weight\ after\ n\ months\ (g)}$,
$\mathrm{W_o} = \mathrm{Initial\ Weight\ (g)}$

2.4.2.2 Determination of Percentage sprouted

The incidence of sprouting of onion was measured by manual counting and expressed as a percentage. After each counting, the sprouted onions were discarded to avoid double counting. Bulbs that were sprouted and rotted due to sprouting were considered sprouted. The Percentage sprouted was calculated using equation (2)

$$NL\ (\%) = \left(\frac{N_o - N_n}{N_o}\right) x\ 100 \qquad (2)$$

Where:

$\mathrm{NL} = \text{Percentage Sprouted},$

$\mathrm{N_n} = \text{Number of onion bulbs after n months, and}$

$\mathrm{N_o} = \text{Initial number of onion bulbs}$

2.4.2.3 Determination of Moisture Contents

Moisture content was determined according to AOAC hot-air oven method of 2016. 5.0g of onion sliced was weighed into pre-weighed moisture dishes and kept in an oven set at 105°C for four hours. After a constant weight was recorded three times, the difference in weight of the moisture dishes were then weighed again post-drying. The moisture content was calculated using equation (3):

$$(\%)MC = \left(\frac{(\text{weight of wet sample+ pan}) - (\text{weight of dried sample + pan})}{(\text{Weight of wet sample + pan}) - (\text{weight of pan})}\right) x\ 100 \qquad (3)$$

2.4.3 Biochemical analysis

The biochemical parameter of the stored onion determined include ascorbic acid content, total carbohydrate, oil content, protein content, total phenolic content, and total carotenoids

2.4.3.1 Determination of Ascorbic Acid Content

Vitamin C content was determined according to titration method (AOAC, 2016 and Nielsen, 2017). About 2.0g of macerated sample was weighed into 10ml distilled water.7.0ml of extraction solution containing 15g Metaphosphoric acid, 40ml acetic acid glacial in about 500ml distilled water was dispensed to 2.0 ml of sample aliquot. 2-3 drops of thymol blue indicator (0.1g thymol blue in 10.75ml of 0.03M NaOH diluted in 250ml water) was added to aliquot and then titrated with indophenol standard solution to rosy pink at end-point. Standard ascorbic acid solution prepared by dissolving 0.05 g in 50ml in extraction solution was then titrated in similar ways to samples. It was calculated using equation (4)

$$\text{Vitamin C (mg/100g)} = \left(\frac{\text{Average titre (sample} - \text{blank)}}{\text{Average titre of standard}}\right) x\ 100 \qquad (4)$$

2.4.3.2 Determination of Total Carbohydrates

About 1g of macerated sample was placed in 25ml conical flask containing 10ml distilled water which was shake vigorously and followed by 15ml of 52% perchloric acid. After 30 minutes of votexing, mixture was filtered and about 1.0ml of filtrate was was

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mixed with Anthrone reagent in a test tube and absorbance taken at wavelenght 620nm using a PG-T80 Spectrophotometer. The total soluble carbohydrates was then estimated using the standard curve of glucose (Mansfield 2020 and Pearson e*t al.,*1976).

2.4.3.3 Determination of Oil content

Oil content was determined using soxhlet extraction method according to AOAC (2016). 3.0g of pulverized onion sample was weighed into a thimble. The thimble was placed in the extraction unit of the soxhlet apparatus. About 230ml of petroleum ether was poured into a pre-weighed round bottom flask. The apparatus was set to boil at 80°C for 4 hours after continuous reflux of condensed solvent through the sample in the extraction thimble. It was calculated using equation (5):

$$\text{Oil content (\%)} = \left(\frac{\text{weight of oil extracted}}{\text{weight of sample}}\right) x\ 100 \qquad (5)$$

2.4.3.4 Determination of Protein Content

Crude Protein Content was determined as described by Kjedhal procedure in AOAC (2016). Approximately 0.5g of pulverized sample was weighed into digestion tube, followed by addition of Kjedhal table (catalyst) then 15ml of concentrated hydrochloric acid was added. The mixture was digested at 420°C on digest stove. After digestion (clearly solution), a 40% sodium hydroxide solution was suctioned into it; then a distillation process involving the solution mixture and boric acid was made through continuous flow of distilled water in the distillation set-ups. After about 50ml of distillate was collected into the boric acid, the distillate was then titrated with 0.05M HCl using mixed indicator of bromo-cresol green and methyl red. It was calculated using equation (6):

$$\text{Protein content (\%)} = \left(\frac{\text{(A}-\text{B) x 0.05 x 1.4007 x 6.25}}{\text{Weight of sample used (0.5g)}}\right) x\ 100 \qquad (6)$$

Where:
A = titer value of sample (ml);
B = titer value of blank (ml),
Molarity of HCl used = 0.05M;
1.4007 = equivalent of atomic mass of Nitrogen,
6.25 = conversion factor of nitrogen.

2.4.3.5 Determination of Total Phenolic Content

2.4.3.5.1 Extraction of aliquot

About 500mg of pulverized onion sample was added to 25ml of methanol-water (80:20v/v) and then sonicated for 1hour. The mixture was then centrifuged at 3000g rpm for 30minutes and extract was collected twice after being spun for the second time into Eppendorf tube and completely wrapped with aluminium foil ready for analysis (Albuquerque *et al.,* 2017).

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2.4.3.5.2 Gallic Acid Standard Preparation

12.5mg of gallic acid crystal was weighed and dissolved in 50ml volumetric flask made up to mark methanol-water (50:50) to produce a stock solution of 250mg/L which was then used to produce solutions of 50, 100, 150 and 200mg/L (Nirmala *et al.,* 2020).

2.4.3.5.3 Determination of Total Phenolic Contents

Total polyphenols contents (TPC) were determined by method used by Lachman *et al.* (2003) and expressed in mg gallic acid equivalent (mg/dl) of dried weight matter. 0.25ml of 500mg/L solution of each sample was added to 2.5ml Folin-Ciocalteu Reagent (FCR) followed by 2.0ml of 1M sodium carbonate. Likewise, 0.25ml of each of the gallic standard solutions were used in lieu of sample to obtain calibration curve; while 0.25ml of methanol-water (50:50) was used as blank in place of sample. The reaction mixes were allowed to stand at room temperature for 15minutes in a dim light room where the absorbance was then measured spectrophotometrically at 765nm using a T80 PG-UV/Vis spectrometer. TPC was expressed as gallic acid equivalent (GAE) mg/g fresh weight (FW) of sample.

2.4.3.6 Determination of Total Carotenoids

The total carotenoids were evaluated by the spectrophotometric method described by Astrid *et al.* (2012) and Chan and Cavaletto (1982). About 6g of pulverized onion sample was mixed with 5.0g of celite and 15ml Methanol (70%V/V) and then filtered using Whatman filter paper. The residue was extracted up to three times using 20ml of 1:1 acetone-petroleum ether (v/v). The extract was then transferred to 500ml separating funnel where a 5ml of 10% KOH (v/v) in methanol was added and mixture allowed standing for 90minutes. Partition achieved following the addition of 15ml petroleum ether and 20ml NaCl (20%w/v) was separated as the hypophasic layer were discarded while the epiphasic (upper) layer was washed three times with 20ml of distilled water to remove excess acetone. It was then filtered through a funnel plugged with 3.0g anhydrous sodium sulfate to remove residual water. The filtrate was made up to 100ml petroleum ether and absorbance was measured at 450nm wavelength. The total carotenoids content (µg/g) was calculated using Beer-Lambert's Law as shown in equation (7)

$$A = ECL \qquad (7)$$

Where: A = absorbance,

E = Extinction coefficient of carotenoids = 1.25x104 µg/L;

C = Concentration and

L = path length of cuvette (1cm)

Onions have been evaluated for considerable nutritional value such as lipid, protein, reducing sugar, iron, calcium, vitamin C (Anju, 2010), phenolic contents as well as antioxidant activity (Cheng *et al.,* 2013). Bulb onions varieties are the red Tropicana, Bombay red (brown onion), white onion among others (Nuutila e*t al*., 2003). Artificial aeration of onion storage structure provides a more conducive surrounding temperature and relative humidity that slows deteriorations especially in a long-term storage.

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2.5 Data Analysis

Data collected was subjected to appropriate statistical analysis such as descriptive statistics (mean value, Standard deviation and percentage) and t-test using Excel and SPSS. Table values are data expressed as mean ±SD of three replicates. Different superscript in the same column were used to indicates significant difference at $P<0.05$ between treatments.

3.0 Results and Discussion

A summary of the result of physical measurements and biochemical changes of the stored onion was discussed in this section.

3.1 Storage temperature and relative humidity of the selected storage facilities

Figures 5 and 6 show the average three-hourly temperature and relative humidity for the selected storage facilities, respectively, and it should be noted that conventional storage condition is ambient condition. The temperature within the ECS was observed to be lower and relative humidity higher than in the other two storage methods, which can be attributed to the evaporative cooling effect in the ECS. AAOS has a slightly lower temperature and relative humidity as compared to ambient due to the aeration from the fan blowing through the bulk onion bulbs. Furthermore, it was observed that the temperature and relative humidity of the selected storage methods follows the same trend as that of ambient condition; that is, they are influenced and respond accordingly to changes in ambient condition. Furthermore, the average monthly measured ambient temperature and relative humidity show that the hottest days lie from late March to early June with low relative humidity. The relative humidity started rising in June at the onset of rainy season as seen in Figure 7. Data represented in Figure 7 is important as it has been established from Figures 5 and 6 that the temperature and relative humidity of the evaluated storage methods mirrors that of the ambient condition.

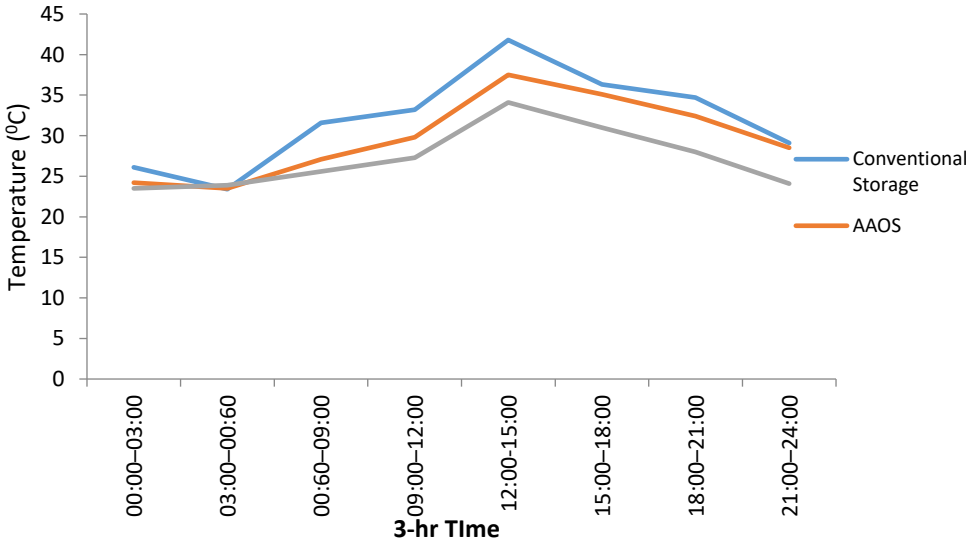

Figure 5: Average 3-hr Temperature (^{0}C) recorded in the three storage methods

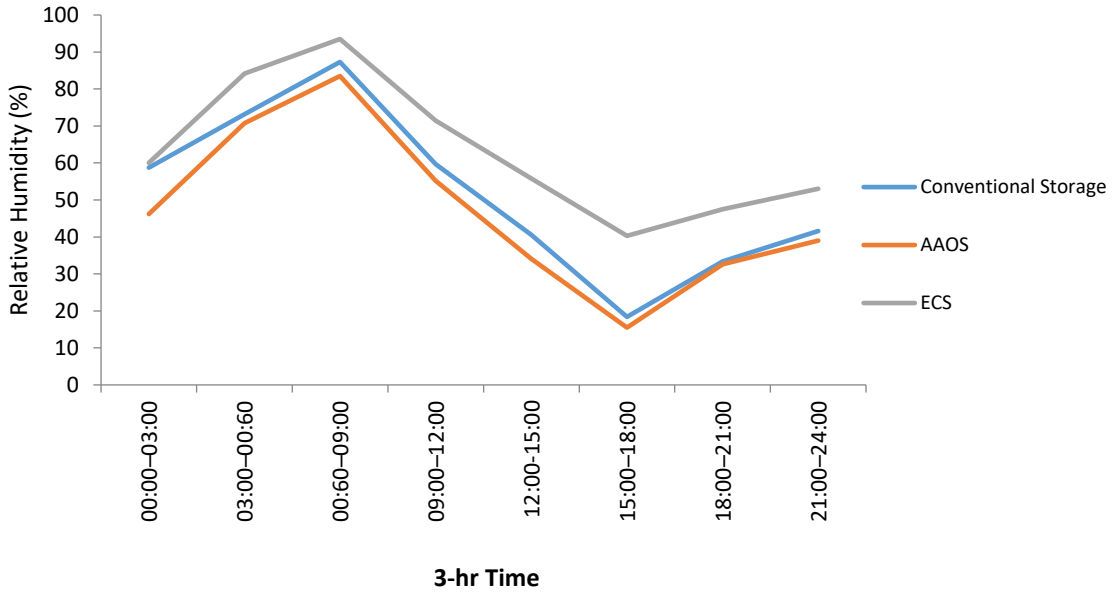

Figure 6: Average 3-hr Relative Humidity (%) recorded in the three storage methods

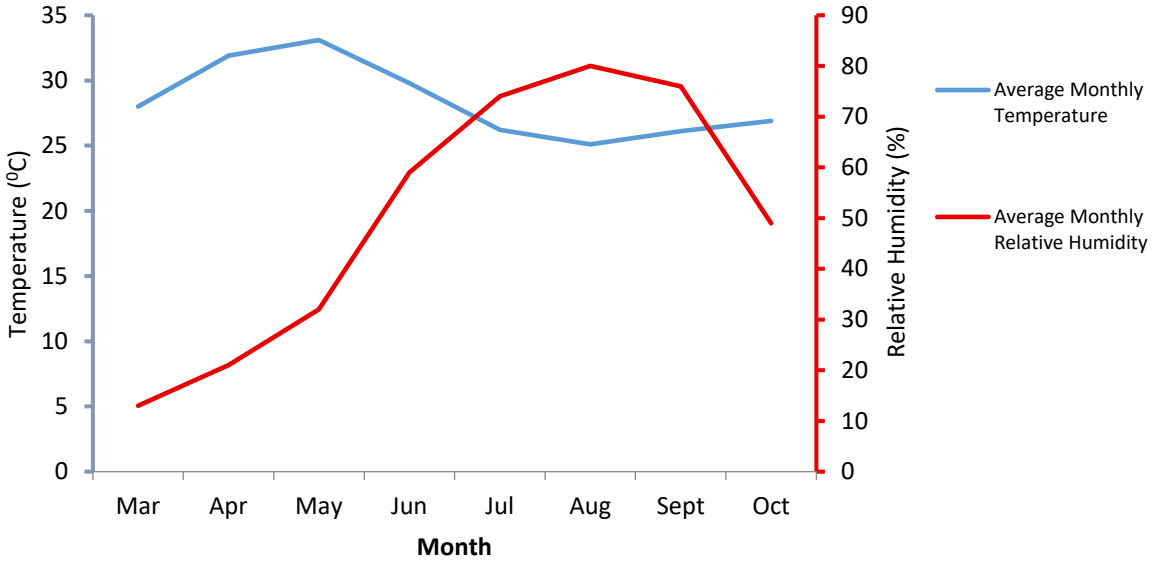

Figure 7: Average monthly recorded ambient temperature and relative humidity

3.2 Effect of storage method on percentage weight loss and sprouting

The percentage loss in weight is as shown in Figure 8 below. For storage of fresh onions, Tripathi and Lawande (2019) and Walter *et al*. (1985) stated that the best holding temperature is at or near 6°C, with a relative humidity between 60 and 70 percent, emphasizing that higher humidity above 70 percent promotes sprouting and bulb decay. This desired temperature and humidity can only be achieved through refrigeration which requires electricity. Therefore, with the premise that the selected storage methods do not use electricity and are influenced by ambient conditions, this study observed that the effect of temperature on the shelf life extension of onion is not

as critical as the effect of relative humidity. This was seen when Figures7 and 8 were compared, as it was observed that there was a rapid increase in the percentage weight loss as the relative humidity increases, especially when the relative humidity surpasses 50% from July to October, but that cannot be said of temperature. From Figures 2 and 3, ECS was seen to be better than AAOS and conventional storage methods in lowering the temperature but, poor in lowering of relative humidity and, as such, perform least in preventing rottenness and sprouting of the onion bulbs in storage.

AAOS and the conventional storage method had their first visible sprouting observed in July (the fourth month of storage) which were sparsely distributed at the top of the stored onions as seen in Figures 9 and 10while sprouting was observed in May (the second month of storage) in the ECS. It kept increasing in occurrence till the termination of the storage experiment. It was observed from Figures 8 and 11that sprouting is responsible for about half of the percentage loss in weight. Vintila *et al.,* (2014), observed that sprouting was common to all varieties of onion stored at different temperatures and Kukanoor, (2005) reported that sprouting caused shrivelling of bulbs, consequently onion bulbs lost marketable quality. An increase in the rate of sprouting was observed at the fifth month (August) for onions stored in AAOS and conventional storage reaching 11.7% and 18% respectively while in ECS 21.6% sprouting rate was already observed in June (third month of storage). As seen in Figure 1, August has the highest level of precipitation in Kano and consequently the highest levels of relative humidity which encourages sprouting.

An increase in the rate of weight loss was observed in the fifth month (August) for onion stored in AAOS and conventional storage reaching 28.27% from 10% in July and 38% from 24% in July, respectively, while in ECS, 39.36% weight loss was already observed in June (third month of storage). As seen in Figure 1, August has the highest level of precipitation in Kano and consequently the highest levels of relative humidity, which result in rottenness and sprouting of the bulbs. Conditions inside the ECS are such that due to wetting of the padding sand, humidity within the chamber was higher than needed for the shelf-life extension of fresh onion. Thus, a higher level of loss was recorded. The nature of weight loss observed during the experiment is a physiological loss in weight, rottenness and sprouting of the onion bulbs.

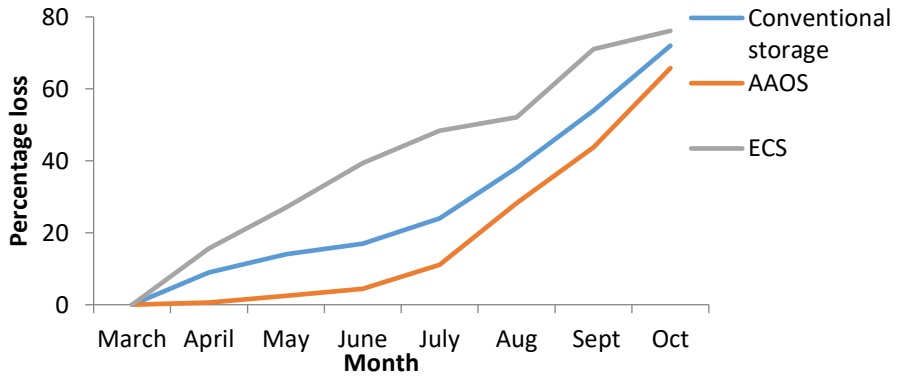

Figure 8: Percentage Weight Loss of onion in three different storage methods

Figure 9: Onions stored in AAOS showing sprouting after the fourth month in storage

Figure 10: Onions stored conventionally showing onset of sprouting after fourth month in storage

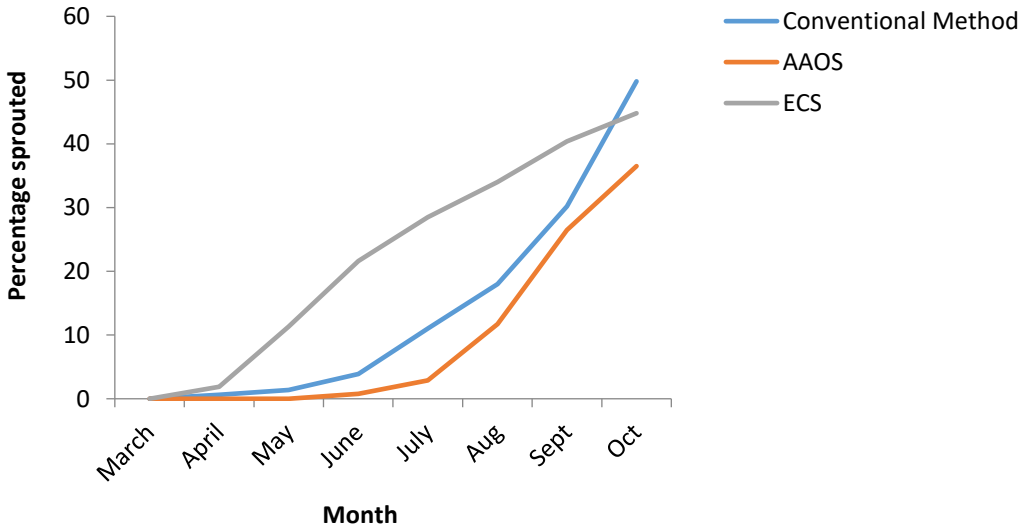

Figure 11: Percentage monthly loss due to Sprouted onion in three different storage methods

3.4 Effect of storage method on nutritional compositions

Onion to many is just a spice for food delicacies. However, its nutritional compositions cannot be over emphasized. Macromolecules such as proteins, carbohydrates, lipid (oil) contents which are precursors of total derivable energy value for any form of food substance also constitute a profile of nutritional exigencies in onion bulbs. From Tables1 and 2 , the observed increase in carbohydrates was quite more than it was observed in protein and oil contents. Many food substances have shown an increase in protein and carbohydrates as moisture contents declines due to concentrated linkages in the amino groups and glycolytic bonds, respectively (Tao and Linchun, 2008).The decreasing moisture content was due to tissue respiration of onion bulbs and was more observed with the AAOS due to steady aeration of the storage environment.

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Table 1. Some Nutritional Parameters of Fresh Red onion in Storage

Storage Time (Month)	Moisture (%)			Protein (%)			Total Carbs (%)		
	ASOS	CS	ECS	ASOS	CS	ECS	ASOS	CS	ECS
0th	78.39 ±0.01^{e}	78.39 ±0.01^{e}	78.39 ±0.01^{e}	1.95 ±0.1^{g}	1.95 ±0.10^{g}	1.95 ±0.10^{g}	15.35 ±1.0^{h}	15.35 ±1.00^{h}	15.35 ±1.00^{h}
2nd	71.10 ±0.0^{g}	75.02 ±0.01^{d}	76.05 ±0.01^{d}	2.27 ±0.1^{d}	2.22 ±0.06^{b}	2.11 ±0.06^{b}	15.99 ±2.0^{d}	15.63 ±1.50^{a}	15.53 ±1.50^{a}
4th	65.17 ±0.83^{f}	69.91 ±0.1^{a}	71.94 ±0.1^{a}	2.47 ±0.0^{e}	2.35 ±0.06^{c}	2.26 ±0.06^{c}	16.80 ±2.0^{e}	15.88 ±1.9^{b}	15.72 ±2.0
6th	61.79 ±0.01^{b}	65.03 ±0.0^{f}	68.22 ±0.0^{f}	2.58 ±0.0^{a}	2.47 ±0.01^{f}	2.33 ±0.01^{f}	17.34 ±0.0^{c}	16.22 ±0.0^{c}	16.16 ±0.0^{c}

Values are data expressed as mean ±SD of three replicates. Different superscript in the same column indicates significant difference at P<0.05.

The onion bulbs initially collected for this research were estimated to have an energy value of 80.17kcal/100g which steadily increased during the storage periods to 92.26kcal/100g, 82.26kcal/100g and 84.34kcal/100g in the AAOS, ECS and in the conventional storage method (control) respectively (Table 2).

Table 2. Oil and Energy Value of Fresh Red onion in Storage

Storage Time (Month)	Oil (%)			Energy Value (Kcal/100g)		
	ASOS	Control	ECS	ASOS	Control	ECS
0th	0.93±0.0^{a}	0.93±0.01^{a}	0.93±0.01^{a}	80.17	80.17	80.17
2nd	1.13±0.0^{e}	0.96±0.01^{h}	0.95±0.01^{h}	83.21	79.55	79.12
4th	1.18±0.0^{c}	1.02±0.02^{g}	0.99±0.02^{g}	87.70	81.83	80.53
6th	1.22±0.01^{f}	1.06±0.01^{c}	1.02±0.01^{c}	92.26	84.34	82.26

Values are data expressed as mean ±SD of three replicates. Different superscript in the same column indicates significant difference at P<0.05.

3.5 Effect of storage method on bioactive compositions

The onion for this current research was analysed only for ascorbic acids, total polyphenolics and carotenoids from many known bioactive compounds of onion bulbs. Prior to storage, the onions were analysed to determine to have 6.21±0.05 mg/100g, 5.10±0.02GAE (mg/g) Fresh weight and 1.02±0.00 µg/g contents of Ascorbic acids, total polyphenols and total carotenoids respectively as seen in Table 3. Fruits and vegetables with less moisture content due todehydration tends to increase some bioactive compounds (Jayeeta, *et al*., 2012; Bala *et* al., 2021). However, the composition and concentration of any bioactive compounds are depend on certain intrinsic and extrinsic factors such as genetics and cultivars, soil and growing conditions, maturity status and postharvest storage conditions (Jaffery *et al*., 2003; Chaudhary *et al.,* 2018)**.** Ascorbic acids have been reported to be thermo-labile and photo-sensitive, which are prone to degradation during thermal processing and storage (Jayathunge *et al.,* 2019).

Table 3. Some Bioactive Parameters of Fresh Red onion in Storage

Storage Time (Months)	Ascorbic acid (mg/100g)			Total polyphenols (GAE mg/g) FW			Total carotenoids (µg/g)		
	AAOS	Control	ECS	AAOS	Control	ECS	AAOS	Control	ECS
0th	6.21 ±0.05^{a}	6.21 ±0.05^{a}	6.21 ±0.05^{a}	5.10 ±0.02^{a}	5.10 ±0.02^{a}	5.10 ±0.02^{a}	1.02 ± 0.00^{b}	1.02 ± 0.00^{b}	1.02 ± 0.00^{b}
2nd	5.40 ±0.11^{c}	5.00 ±0.02^{g}	4.70 ±0.02^{g}	5.61 ±0.11^{b}	5.65 ±0.05^{d}	5.52 ±0.05^{d}	0.77 ±0.01^{e}	0.77 ±0.01^{e}	0.74 ±0.01^{e}
4th	4.80 ±0.00^{e}	4.31 ±0.05^{d}	4.01 ±0.05^{d}	9.04 ±0.05^{e}	6.09 ±0.11^{e}	5.90 ±0.11^{e}	0.53 ±0.12^{f}	0.53 ±0.00^{f}	0.50 ±0.00^{f}
6th	3.20 ±0.05^{d}	2.86 ±0.11^{e}	2.55 ±0.11^{e}	12.08 ±0.00^{d}	9.95 ±1.03^{b}	8.97 ±1.03^{b}	0.07 ±0.05^{a}	0.069 ±0. 05^{a}	0.064 ±0. 05^{a}

Values are data expressed as mean ±SD of three replicates. Different superscript in the same column indicates significant difference at P<0.05. ASOS = Artificially Aerated Onion Structure; CS= Conventional Storage, ECS = Evaporative Cooling Structure.

Table 3 above shows the initial estimated value of ascorbic acids to be 6.21±0.05 mg/100g prior to storage. However, there was a steady decline from this initial value to 3.20±0.05 mg/100g, 2.55mg/100g and 2.86mg/100g in the AAOS, the conventional storage and the ECS, respectively. This indicated that ascorbic acid declined more in the ECS. This difference could be due to higher humidity in the ECS than in the other storage methods, resulting in lower moisture loss of onions in the ECS, as seen in Table1. Similarly, total carotenoids were initially estimated to be 1.02±00µg/g before storage, and there was a continuous decline in the total carotenoid contents of the onion during the storage periods but no significant (p>0.05) difference in the AAOS, ECS and Convention method. Carotenoids are less affected than ascorbic acid levels during the storage of fruits and vegetables (Jayeeta, *et al*., 2012). The total polyphenol contents of the onions were extrapolated from the equation: y= 0.0053x+ 0.0023; R^2 = 0.9986) of gallic acid standard as shown in Figure 12. It was observed that total polyphenolic content increased from the initial estimate of 5.10±0.02GAE (mg/g) fresh weight prior to storage to 12.08±0.00 GAE (mg/g) FW, 8.97±1.03GAE (mg/g) FW and 9.95±1.03GAE (mg/g) FW in the AAOS, conventional method and the ECS respectively. There was a significant difference (p<0.05) in the value of total polyphenols in each periodic analysis from all the storage methods evaluated. The AAOS retained 41.8% more of the total polyphenols than the conventional method, while ECS retained less than the conventional method. This could be attributed to lower moisture content and lower temperature difference in the AAOS than in the conventional method. In contrast, ECS could be attributed to higher moisture content than the conventional method.

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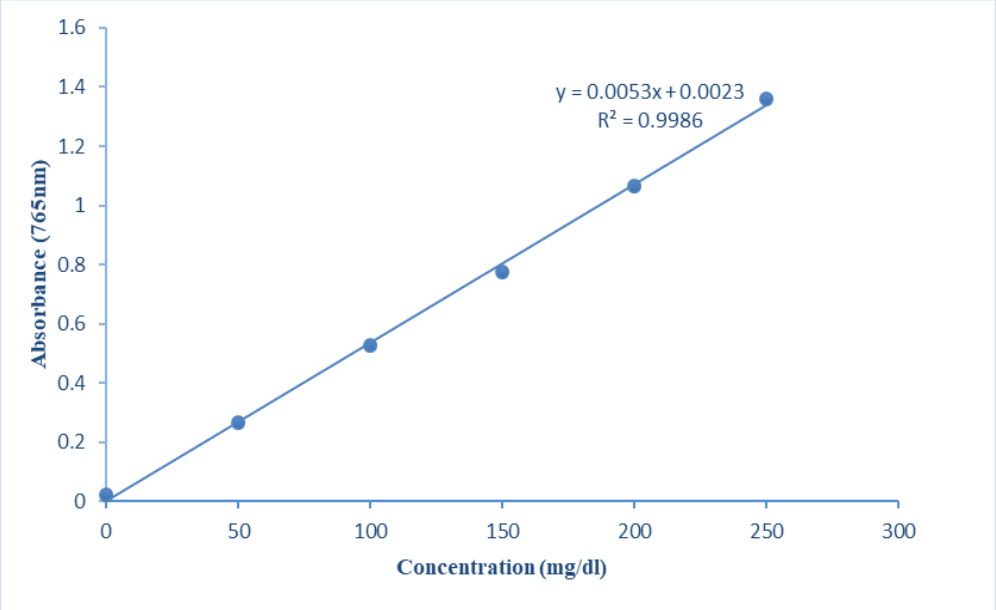

Figure 12: Plot of Gallic Acid Standard Absorbance (nm) Against Concentration (mg/dl).

4. Conclusions

Based on the finding of the study, temperature and the relative humidity of AAOS, ECS and conventional storage methods follows the same trend as the ambient condition, that is, they are influenced and responded accordingly to changes in ambient temperature and relative humidity though at different degrees. Temperature in the ECS was lower than in AAOS and in AAOS it was lower than ambient while relative humidity in the ECS was higher than ambient and ambient was higher than in AAOS. There was increase in the percentage weight loss of the stored onion as relative humidity increases especially when the relative humidity surpasses 50%. There was an increase in the rate of weight loss at the fifth month (August) for onion stored in AAOS and conventional storage reaching 28.27% from 11.1% and 38% from 24% in July respectively while in ECS 39.36% weight loss was already observed in June (3rd month of storage). Percentage weight loss in October (7th month) which is the end of the experiment were 65.76%, 72%, and 76.12 for AAOS, Conventional method and ECS respectively. There was a continuous declining trend in ascorbic acids (AA) and total carotenoids (TC) content in the stored onion for all the treatments leaving a 10.4% (AA), 0.59% (TC) and 5.48% (AA), 4.90% (TC) more retention in AAOS and control respectively than in ECS. Total polyphenolic contents increased from an initial 5.10±0.02 to 12.08±0.00, 9.95±1.03 and 8.97±1.03 GAE (mg/g) fresh weight in AAOS, control and ECS respectively.

From the findings of this research, AAOS is recommended for storage of fresh onion for 4 months with consideration to the time of the year and agro-ecology of the region, as it was found to be more desirable to curb the enormous wastage during glut and for better retention of nutritional and bioactive compounds prior to use at home or industry.

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References

Akbari, SH., Patel, NC. and Joshi, DC. 2001. Studies on Dehydration of Onion. ASAE International Annual Meeting. Sacramento, California, USA.

Alabi, OO. and Adebayo, CO. 2008. Net income analysis of onion producers in Zara Local Government Area of Kaduna state Nigeria. Proceeding of 10th Annual National conference of Nigeria Association of Agriculture Economics (NAAE), pp.4-48. University of Abuja, Abuja Nigeria.

Albuquerque, J., Júnior, L., Netio, D., Andrade, M., Matias, J., Simões, A., and Júnior, A., 2017. Adequacy of the extract aliquot for determining the activity of polyphenoloxidase in sweet potato varieties. Amazonian Journal of Plant Research, 1: 20 - 23. 10.26545/b00002x.

Amrat, B., Samuel, DVK. and Beera, V. 2013. Evaporative cooling system for storage of fruits and vegetables - a review. Journal of Food Science Technology, 50(3):429–442. OI 10.1007/s13197-011-0311-6

Anju, S., Kawatr, A. and Salil, S. 2010. Nutritional Evaluation of onion powder dried using different drying methods. Journal of Dairying Foods,29 (2):151-153.

AOAC 2016. Official methods of analysis . Calculations of Moisture: method 934.06 Fruits, Vegetables, and their Products, Association of Analytical Communites, Gaithersburg.

Astrid Garzón G., Carlos-Eduardo N., Rachel E K., Andrew MB., Kenneth MR., and Steven A, 2012. Determination of Carotenoids, Total Phenolic Content, and Antioxidant Activity of Arazá (Eugenia stipitate McVaugh), an Amazonian Fruit. Journal Schwart. Agric. Food Chemistry. 60(18): 4709–4717. https://doi.org/10.1021/jf205347f

Bala, I., Ahmad, FU., Yerima, AK., Said, SS. and Ibrahim, AT. 2021. Nutritional Quality Evaluation of Stored Onion (*Allium cepaL*) Powder in Transparent and Amber Colourfed Jars. Nigerian Journal of Basic and Applied Science, 29(2): 09-16.

Camargo, JR. 2007. Evaporative cooling: water for thermal comfort. An Interdisciplinary Journal of Applied Science, 3: 51–61.

Chan, HIJR. and Cavaletto, CG. 1982. Aseptically Packaged Papaya and Guava Puree: Changes in Chemical and Quality During Processing and Storage. Journal of Food Technology, 47: 1164-1169.

Chaudhary, P., Sharma, A., Singh, B. and Nagpai, AK. 2018. Bioactivities of phytochemicals present in tomato. Journal of Food Science Technology, 55: 2833-2849.

Cheng, A., Chen, X., Jin, Q., Wang, W., Shi, J., and Liu, Y. 2013. Comparison of Phenolic Contents and Antioxidant Capacity of Red and Yellow Onions. Journals of Food Sciences, 31(5): 501-508.

Dadhich, SM., Dadhich, H. and Verma, RC. 2008. Comparative study on storage of fruits and vegetables in evaporative cool chamber and in ambient. International Journal of Food Engineering, 4(1):1–11.

FAO. 1998. Food composition Table for use in Africa. F.A.O and U.S.A

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FAOSTAT 2010. CROPS: Statistics for Countries. United Nations, New York. Available online: http://www.fao.org/faosta/en/#data/QC (accessed 2022).

Hussaini, MA.,Amans, EB. and Ramalan, AA. 2000. Yield, Bulb size distribution and Storability of Onion (Allium cepa) under Different Levels of N fertilization and Irrigation Regime. Tropical Agriculture (Trinidad), 77(3): 145-149.

Inuwa, BBD. 2001. A study of issues arising from the production of garlic (Allium Sativum) in Nigeria. A paper presented at the training workshop on improving and accelerated garlic production for local and export needs in Nigeria at food crops production technology transfer station (FDA), Dan Hassan, Kano.

Jaffery, EH., Brown, AF., Kurilich, AC., Keek, AS., Matusheski, N. and Klein, BP. 2003. Variation in Content of Bioactive Components in Broccoli. Journal of Food Composition and Analysis, 16: 323-330.

Jayathunge, KG., Stratakos, AC. and Delgado-Pando, G. 2019. Thermal and Non-Thermal Processing Technologies on Intrinsic and Extrinsic Quality Factors of Tomato Products: A Review. Journal of Food Processing and Preservation, 43: e13901.

Jayeeta, M., Shanker, LS. and Pavuluri, SR. 2012. Onion Dehydration: A Review. Journal of Food Science and Technology, 49(3): 267-277.

Jha, SN. and Chopra, S. 2006. Selection of bricks and cooling pad for construction of evaporatively cooled storage structure. Institute of Engineers (I) (AG), 87:25–28.

Kano Agricultural and Rural Development Authority 2011.Press Release on Onion Farming through Irrigation. Hadejia Road, Kano, Nigeria.

Kukanoor, L. 2005.Post-Harvest Studies in Onion. Department of Horticulture, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad, 19-144.

Lachman, J., Pronek, A., Helmtankova, A., Dudjak, V., Pirec, K. and Faitova, C. 2003. Total Polyphenols and Flavonoids Antioxidants in Different Onion Varieties. Journal of Horticulture Science, 30(4): 142-147.

Lannoy, GD. 2001.Vegetable crops in Tropical Africa. 395-511. In: Raemaeks R. H. (Editor). Crop production in Tropical Africa. 1540pp. Directorate General for International Cooperation (GDIC) Belgium.

Mansfield, SD. 2020. Determination of Total Carbohydrates. In: Bärlocher, F., Gessner, M., Graça, M. (eds) Methods to Study Litter Decomposition. Springer, Cham. https://doi.org/10.1007/978-3-030-30515-4_14

Nicoli, MC. 2012. Shelf Life Assessment of Food. C.R.C. Press, Boca Raton, pp. 302.

Nielsen, SS. 2017. Vitamin C determination by indophenol method, In: Food analysis laboratory manual. Springer, Cham, pp. 143-146.

Nirmala P., Pramod KJ, Pankaj PR, and Sangeeta R. 2020. Total Phenolic, Flavonoid Contents, and Antioxidant Activities of Fruit, Seed, and Bark Extracts of *Zanthoxylumarmatum* DC. The Scientific World Journal, 2020: Article ID 8780704, 1-7, https://doi.org/10.1155/2020/8780704

Nuutila, A., Puupponen-Pimia, R., Aarni, M. and Oksman-Caldentey, KM. 2003. Comparison of Antioxidant Activity of Onion and Garlic Extracts by Inhibition of Lipid

Peroxidation and Radical Scavenging Activity. Journal of Food Chemistry, 81(4): 485 – 493.

Odesola, IF. and Onyebuchi, O. 2009.A review of porous evaporative cooling for the preservation of fruits and vegetables. Pacific Journal of Science and Technology, 10(2): 935–941.

Olusola, SJ., Sanusi, SN., Oluranti, ML., Mopelola, AS. and Isaac, BO. 2018. Monitoring the changes in chemical properties of red and white onions (Allium cepa) during storage. Journal of Stored Products and Postharvest Research, 9(7):78-86 https://doi.org/10.5897/JSPPR2018.0263.

Pearson, D., Melon, HK. and Ronald, S. 1976. Chemical Analysis of Food, 8th Edition. Churchill Livingstone, pp. 5-63.

Pelter, GQ., Sorensen, EJ., Thornton, RE. and Stevens, R. 2000. Dry bulb onion production in the Columbia basin. Bull. EB1693. Western Washington State University, Crop Extension, Pullman.

Shahzadi, N., Butt, MS., Rahman, SU. and Sharif, K. 2005. Chemical Characteristics of Various Composite Flours. International Journal of Agriculture and Biology, 7(3): 105-108.

Sharma, S., Deya, E., Frau, M. and Rossello, C. 2005. Simple Modelling of Air-Drying Curves of Fresh and Osmotically Pre-dehydrated Apple Cubes. Journal of Food Processing and Engineering, 3(3):139-150.

Tao, W. and Linchun, M. 2008. Influences of Hot Air Drying and Microwave Drying on Nutritional and Odorous Properties of Grass Carp (*Ctenopharyngodonidelius*) Fillets. Journal of Food Chemistry, 110(3): 647-653

Tripathi, PC. and Lawande, KE. 2019. Onions storage in tropical region: A review. Current Horticulture, 7(2): 15-27

Vintila, M., Niculescu, FA.andRomas, M. 2014.Technical Aspects Regarding the Preservation of Dry Onions in Different Storage Conditions. Bulletin UASVM, Food Science and Technology, 71.

Walter, E., Matson, NS. and Daryl, GR. 1985. Onion Storage Guidelines for Commercial Growers.Pacific Northwest cooperative Extension bulletins PNW 277

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