Evaluation of a Low-cost Storage System for Shelf-life Extension of Fresh Onions

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Abstract

Onions, a major commercial vegetable crop, suffer losses during off-season storage due to sprouting and weight loss. This study examined the impact of different storage systems on the storability of onion bulbs under three storage conditions: a conventional onion storage system (COSS), the Nigerian Stored Products Research Institute's (NSPRI) solar storage system (NSCSS), and a low-cost onion storage system (LCOSS). 2,500 kg of fresh red onions were procured, sorted, and stored for a period of six months, between March and September. Samples were taken randomly every month to analyse their physical and chemical changes. Descriptive statistics and ANOVA were performed on the data recorded using SPSS at a significant difference of ($p<0.05$). It was observed that when relative humidity increases, particularly over 50%, there is a corresponding rise in the percentage weight loss of the stored onion. An average weight loss of 73.3%, 71.2%, and 85.6% was recorded at the end of the experiment for LCOSS, NSCSS, and COSS, respectively. A significant increase ($p<0.05$) in total polyphenols from 5.50 ± 0.55 GAE (mg/g) in all storage systems was observed during the study, with a steady increase (approximately 28.9%) in OSS, which is 37.7% higher than in other systems at the end of storage time. However, ascorbic acid declined significantly, with less than 50% retained beyond the third month. The dietary energy value decreased significantly ($p<0.05$) by 62.2%, 22.7%, and 32.8% in NSCSS, LCOSS, and Conventional, respectively. The study showed that LCOSS reduced sprouting. However, there is a need to modify both NSCSS and LCOSS to minimise weight loss.

Keywords:
Cold room, Conventional, Onion, Storage, Relative humidity

Introduction

One of the most significant commercial vegetables cultivated and consumed worldwide as a condiment is the onion (*Allium cepa*) (Ren & Zhou, 2021). It contains a high vitamin content (including vitamins A and C), flavour, and is used as an ingredient in herbal products. It is also found to contain approximately 86% water, 1.4% protein, 0.2% fat, 11% carbohydrates, 0.8% fibre, and 0.6% ash (Sangwan et al., 2010). According to Ojha & Michael (2006), onions are a seasonal and perishable crop with relatively low storability because of their high moisture content at harvest. *Allium cepa* possesses intriguing technological properties and exhibits positive health effects, including antioxidant, anticancer, and antimicrobial properties. Over 92.5 million metric tonnes are produced worldwide. Nigeria is ranked in the top ten globally, fourth in Africa (FAOSTAT, 2022), and experiences approximately 50% postharvest losses (Ogundele, 2022). The northern region of the nation produces the majority of it, with the states of Kano, Sokoto, and Kebbi being the leading commercial producers (Muhammad, 2018; Yunusa et al., 2023). In Nigeria, onions are mostly grown during the dry season from September to April. The harvesting season peaks between March and April. There is a steady demand for onions, and they are used throughout the year. Since onions are a

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seasonal crop whose price tends to rise during the off-season, efforts to store and reduce significant spoilage remain ineffective, particularly in Africa. Akbari (2022) reported that due to onions' high moisture content (≥80%), which allows for microbial infections, and unfavourable conventional storage conditions, such as high temperatures and high relative humidity, storing onions during the rainy season is challenging.

According to Kumar et al. (2015), the three main factors influencing the storage life of onions are physiological activity (including transpiration, respiration, senescence, and sprouting), biochemical activity (such as enzymatic reactions and tissue softening), and microbiological invasion (by fungi and bacteria). Onions are preserved under two different temperature and humidity regimes: 0–2 °C and 65–70% relative humidity, and 25–30 °C and 65–70% relative humidity (Tripathi, 2020). In tropical and sub-tropical nations, the second condition, 25–30 °C and 65–70% relative humidity, predominates, which promotes greater storage losses. The first approach has not been used in Nigeria as it is capital-intensive and power-dependent, with electricity remaining unpredictable**.**

The development of an artificially aerated onion structure (AAOS) and the development of natural & forced aerated structures are among the technologies that the Nigerian Stored Products Research Institute (NSPRI) has previously developed and studied to increase the shelf life of fresh onion bulbs (Adu et al., 2023) and (Ajiboye et al., 2022). The result highlights the need for further research, particularly the development of sufficient solar-powered cold storage facilities that are independent of the national grid, to ensure the commodity's year-round supply. The study also showed that forced aeration reduced sprouting but suggests the need to explore configurations that will also minimise weight losses. The purpose of this research is to assess a low-cost storage system (LCOSS) that can manage the bulk storage of fresh onions and determine its capability in extending the shelf life of fresh onions, thereby decreasing postharvest losses.

Materials and Methods

Experimental location

The experiment was conducted at the Nigerian Stored Products Research Institute (NSPRI), Kano Zonal Office, situated in the semi-arid region of North-Western Nigeria (Lat. 12.0063059, Long. 8.5650626). Kano has an average annual temperature of 26.4 °C. According to the Climate Graph for Kano, Nigeria, the average monthly relative humidity varies from 11% in March to 68% in August, with an average yearly relative humidity of 31.1% (Mohammed et al., 2019). The experiment period was six months, from March to September 2024.

Description and set-up of selected storage structure

Low-cost onion storage system (LCOSS)

The Low-cost onion storage system is a walk-in cool room system (a room) that has a total area of 11.02 m^2 with an internal dimension of length (3.33 m), width (3.33 m), height (3.04 m), and a volume of 34 m^3. A 1.5-horsepower air conditioner was fixed to the wall at 2.13 m above the floor level for cooling the room. The storage room is an air-tight structure, and the air conditioning was powered consistently for about 18 hours daily. The design idea was to utilise the cooling performance of an air conditioner for storing onions. It has been established that an air conditioner can reduce relative humidity by cooling air relatively below the dew point, causing water vapour to condense and be removed from the air, which is then drained away (Snidvongs & Vongsumran, 2020).

NSPRI solar cold storage system (NSCSS)

The solar cold storage system has an internal dimension of length (3 m), width (3 m), height (2.2 m) and volume of 20 m^3, comprising of the storage chamber, solar unit (PV panels, batteries, and charge controller connected with cables to generate and distribute electricity for the system), and the cooling units (water chiller bath housing the refrigeration cooling units for ice production, DC pump, and heat exchanger for transfer of cool air into the storage chamber). To improve the energy efficiency of the system, the cooling unit is divided into primary and secondary units, each with a dedicated solar unit that supplies the required electrical power to run the systems.

No-load evaluation of the NSPRI solar cold storage system

A no-load test was conducted on the NSPRI cold room. The hose that discharges the condensed water from the evaporator is within the storage chamber, which causes high relative humidity to be experienced. A simple modification involves tightly attaching a plastic bottle to the hose from the evaporator to collect the condensed water. A low temperature of 5 °C and relative humidity of 47 % were recorded against the conventional (29 ^{o}C and 65% RH) using a Temtop data logger (Temlog 20H), which were ideal conditions for onion storage. However, when it was loaded, the lowest temperature of 16 °C and almost 100% relative humidity was recorded.

Conventional onion storage system (COSS)

The conventional method of storage consists of a platform made of wood with a total surface area of 11.0 m^2, raised 1.5 m above the ground. Corn stalks were used to cover the top of the platform, allowing airflow and ventilation when onions are spread on it.

Experimental design

This experiment examined the impacts of three storage systems using a total of 2500 kg of onions: a conventional storage system (COSS), NSPRI solar cold storage system (NSCSS), and an air-conditioned room, which was employed as the low-cost onion storage system (LCOSS). Fresh red onions weighed an average of 125 kg per bag. A total of 1,000 kilograms of fresh onions were sorted, and 500 kg were stored in each of the storage systems. In the LCOSS, the onions were stored in 25 kg crates and stacked on pallets in the middle of the room (Figure 1a). The distance between the stack and the wall was 1.5 m, whereas for NSCSS, the onions were stored in 25 kg and 30 kg crates and were stacked on the crate rack (Figure 1b). In the Conventional storage system (COSS), the bulk of the onions was spread on corn stalks, and a representative quantity was stored in crates (Figure 1c). Physiochemical parameters measured include moisture content, ascorbic acid content, total carbohydrates, oil content, protein content, and total phenolic content. The percentage weight loss, percentage sprouting bulbs in storage, conventional and storage temperatures, and relative humidity were also recorded. The bulbs were sampled once a month to monitor the physiological and biochemical changes that occurred during storage.

Performance evaluation of the structure

Sample collection and preparation

Red onion bulbs (known locally as *Yan-Gashua* in Hausa) were purchased from the Onion Farm gate in Kura, Kano State, on March 27, 2024. Following curing, sorting, and weighing, the onions were carefully bulk loaded into LCOSS and NSCSS (Figure 1a & b) and conventionally stored for the six-month storage period. Representative samples were taken randomly from each storage system each month throughout the storage period for physical and biochemical evaluation. Samples were taken in triplicate from all storage systems and analysed.

Figure 1a: Loaded LCOSS

Figure 1b: Loaded NSCSS

Figure 1c: Loaded COSS

Monitoring and determination of storage parameters

The assessed physical properties included percentage weight loss and sprouting, as well as storage temperature and relative humidity. A Temtop data logger, model number Temlog 20H, with a temperature precision of ±0.5 °C and a humidity accuracy of ±3 % RH, was used to measure the temperature and relative humidity of both the conventional and storage structures.

Percentage weight loss

The technique outlined by Soomro & Ibupoto (2017) was used for measuring the percentage of weight loss. A digital weighing scale (Camry dual display, Accuracy: ±1 kg, Range: 0–150 kg) was used to determine the physiological weight loss of the onion per month. Among the physiological alterations noted were the incidence of sprouting and the proportion of weight loss. Equation (1) was used to compute the percentage weight reduction.

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

Where; WL = Weight loss, %, W_o = Initial weight, kg and W_n = Weight after n months, kg

To determine the percentage of sprouting during storage, sprouted bulbs were separated and weighed using an electronic weighing scale. The rate of sprouted bulbs was determined using Equation 2, Hatem et al. (2014):

$$SP\ (\%) = \left(\frac{W_s}{W_i}\right) \times 100 \qquad 2$$

Where: SP = Percentage Sprouted; W_s = Weight of sprouted onion after N Months; W_i = Initial weight of onion bulbs, kg.

Biochemical analysis

The biochemical analysis was conducted to determine the ascorbic acid content, total carbohydrate content, oil content, protein content, and total phenolic content, following the AOAC (2019) method.

Data analysis

The data collected was analysed statistically using Excel and SPSS (Version 26) for the ANOVA and descriptive statistics (mean value, standard deviation, and percentage).

Results and Discussion

Storage temperature and relative humidity of the selected storage systems

The two most significant environmental factors that impact the storage of onion bulbs are temperature and relative humidity. The average periodic temperature of the various onion storage methods is shown in Figure 2 compared with the conventional temperature over the March–September storage period. The LCOSS system's mean temperature was observed to be 25.7 °C, the NSCSS mean temperature was 21.6 °C, and that of the COSS was 29.1 °C. The periodic mean relative humidity throughout the various onion storage methods is shown in Figure 3. The LCOSS had a mean relative humidity of 56%, NSCSS had a mean relative humidity of 83%, while the mean relative humidity in the COSS was 72.10%.

The average monthly recorded conventional temperature and relative humidity indicate that the hottest days occur between late March and early June, when the relative humidity is low. Figures 2 and 3 suggest that the relative humidity began to increase in June, coinciding with the onset of the rainy season. The conventional storage had the highest average temperature and relative humidity (RH), while the NSCSS had the lowest average temperature and higher relative humidity. These factors had a significant impact on sprouting loss, physiological loss in weight (PLW), and rotting loss, ultimately affecting the overall weight loss in the stored onion bulbs.

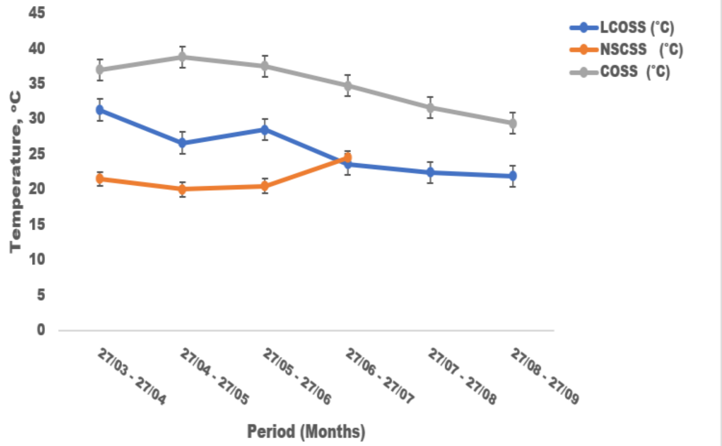

Figure 2: Periodical average temperature during March to September, 2024

Low-Cost Onion Storage System (LCOSS), NSPRI Solar Cold Storage System (NSCSS), and Conventional Onion Storage System (COSS). Error bars indicate the standard deviation (±SD) of mean temperature readings.

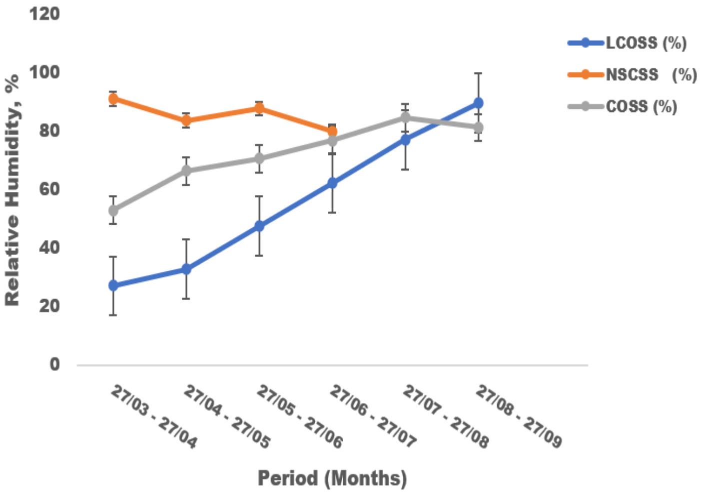

Figure 3: Periodical average relative humidity from March to September 2024

Low-Cost Onion Storage System (LCOSS), NSPRI Solar Cold Storage System (NSCSS), and Conventional Onion Storage System (COSS). Error bars indicate the standard deviation (±SD) of mean temperature readings.

Effect of storage method on percentage weight loss and percentage sprouting

Figure 4 shows the percentage weight loss of onion bulbs over a six-month storage period. The weight loss increased with the storage period in all the structures. Weight loss in all structures was not significantly different ($p<0.05$) during the first month (March to April). However, weight loss in NSCSS was significantly higher than in structure LCOSS and COSS during the first three months of storage ($p<0.05$). The weight loss in LCOSS increased in the fifth month (August) to 35.8% from 16.0% in June, while in COSS it increased to 47.3% from 27.1% respectively. In contrast, NSCSS showed 61.2% weight loss in July (the third month of storage). The LCOSS and COSS recorded the lowest percentage weight loss. These losses may be due to the moisture loss during respiration of onion bulbs during the storage period. A similar result was obtained by Mishra et al. (2018) when they compared two low-cost onion storage structures (two-row ventilated and single-row ventilated) with the chali method, and observed that physiological weight loss increased gradually across all systems due to temperature and humidity fluctuations. Spoilage loss was initially low in the improved structures (0.1 to 0.67% at 15-30 days), but it rose to 12.66% after 90 days. The chali method performed best, with only 5.22% spoilage loss after 90 days. Soomro & Ibupoto (2017) showed that physiological weight loss was minimal in the improved structure at 2.43% early in storage, compared to 3.14% to 3.45% for other structures. After one month, the weight loss increased sharply to 13% for floor-stored onions, while the chali and improved structure had a weight loss of 6.53% to 6.82%. After three months, the improved structure and chali showed 13% weight loss, while floor-stored onions had the highest loss at 19.5% to 20.72%. The Nasarpur variety stored on an open floor had 19.38% weight loss after three months and 4.98% after 15 days.

The findings in Figure 5 show that sprouting increased in all structures over the storage period. Sprouting observed in the structures did not differ significantly after the first two months ($p < 0.05$). Sprouting first appeared in NSCSS in May (12%), and by June, all the structures recorded sprouting, with NSCSS having 17% compared to LCOSS (13%) and COSS (15%). In July, NSCSS reached its peak at 29%, while LCOSS and COSS recorded moderate increases (16% and 18%, respectively). From August onwards, COSS displayed the highest sprouting, rising to 41% in August and 48% in September. LCOSS also increased steadily, reaching 31% in August and 41% in September. At the end of the storage period, sprouting recorded in LCOSS was significantly lower than in other structures ($p < 0.05$). Figures 6 and 8 show the sprouted onions in LCOSS and COSS after three months in storage, while Figure 7 shows onion sprouting in NSCSS after two months of storage. Similar findings were reported by Adu et al., (2023), where an increase in the rate of weight loss was observed in the fifth month (August) for onion stored in Artificial Aerated Onion Structure (AAOS) and conventional storage reaching 28.27% from 10% in July and 38% from 24% in July, respectively, while in Evaporative Cooling System (ECS), 39.36% weight loss was already observed in June (third month of storage. The result is also in agreement with Petropoulos et al. (2016) who reported sprouting as one of the major factors responsible for in onions during long-term storage.

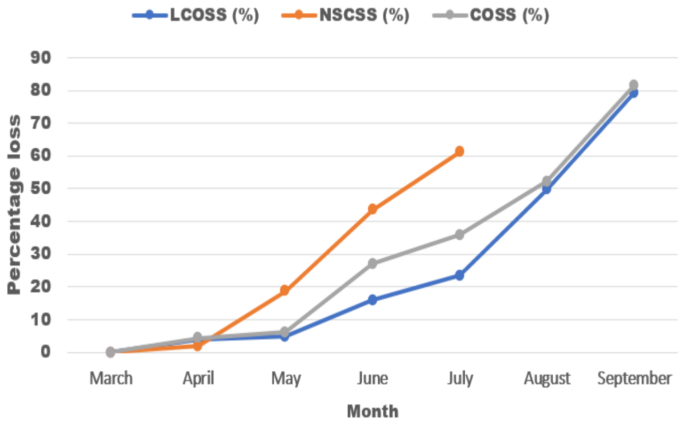

Figure 4: Percentage weight loss of the onion in three different storage structures.
Low-Cost Onion Storage System (LCOSS),
NSPRI Solar Cold Storage System (NSCSS), and
Conventional Onion Storage System (COSS).

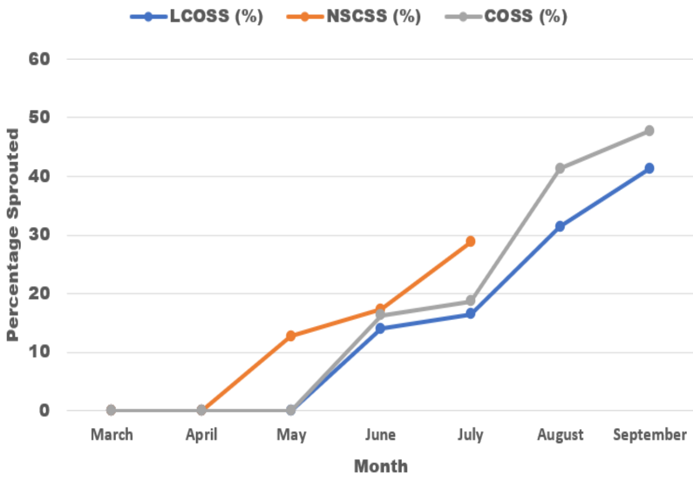

Figure 5: Percentage sprouting of the onion in three different storage structures.
Low-Cost Onion Storage System (LCOSS),
NSPRI Solar Cold Storage System (NSCSS), and
Conventional Onion Storage System (COSS).

Figure 6: Onions stored in LCOSS showing sprouting after three months in storage

Figure 7: Onions stored in NSCSS showing sprouting after three months in storage

Figure 8: Onions stored conventionally showing sprouting after three months in storage

Effect of storage method on nutritional content

Table 1 illustrates the impact of storage structures on the nutritional composition of onions over a six-month period. At the start of storage, there were no significant differences ($p>0.05$) in crude protein, total carbohydrate, or oil contents among the Conventional Onion Storage System (COSS), Low-Cost Onion Storage Structure (LCOSS), and NSPRI Solar Cold Storage System (NSCSS). However, by the second month, significant differences ($p < 0.05$) were observed, with COSS and LCOSS maintaining higher protein (2.19% and 2.07%) and carbohydrate (15.59% and 14.14%) values compared to NSCSS (1.85% protein and 13.44% carbohydrate). The oil content also increased significantly ($p < 0.05$) in COSS (1.28%) and LCOSS (1.21%), whereas NSCSS recorded lower values. From the third month onward, nutrient losses became more pronounced, particularly in NSCSS, where the crude protein and carbohydrate contents declined significantly ($p < 0.05$) to 1.23% and 12.99%, respectively. LCOSS maintained significantly higher protein levels (2.02%) than both COSS and NSCSS, while COSS preserved oil content better (2.11%). By the fifth and sixth months, reductions were evident in all systems, with COSS and LCOSS retaining relatively higher values, while NSCSS data were unavailable due to deterioration. A similar result was reported by Adu et al. (2023).

Effect of storage method on dietary energy value

The dietary energy value, as a derivative of three major metabolic fuels of protein, lipid, and carbohydrates, was significantly ($p<0.05$) different in terms of storage structure over the storage time, as shown in Figure 9. There was a steady decline in energy values in samples of both NSCSS and COSS from the initial 79.03 Kcal/100g by about 23.3% and 16.82% at the end of the fourth and sixth months of storage, respectively. Samples in LCOSS maintained a rise in energy value until the end of the fourth month (July), after which a sharp decline set in. The decreasing trend could be due to the corresponding decrease in the values of macromolecules of energy potentials. This may be due to increased relative humidity, which enhances many biochemical changes associated with sprouting processes and microbial activities (Mitra et al., 2012; Bala et al., 2021).

Effect of storage method on total polyphenols and ascorbic acid

Table 2 depicts a significant increase ($p<0.05$) in total polyphenols from 5.50±0.55 GAE (mg/g) across onion samples in all storage structures as extrapolated from $y = 0.0021x + 0.0276$ (Figure 9). The increase was steady throughout the storage period from 5.50±0.55 mg/g GAE to 7.54±0.55 mg/g GAE and 8.73±0.15 mg/g GAE in AMB and LCOSS, respectively, except in the NSCSS system, where it declined along with the physical deteriorations and sprouting at the fourth month; thus, leading to termination of the experiment in NSCSS storage.

Table 1. Estimated values of dietary energy macromolecules of onions in the three storage structures

Storage Time (month)	Storage Structure	Nutritional Parameters Crude Protein (%)	Total Carbohydrate (%)	Total Oil (%)
0th	COSS	2.01±0.05^{a}	15.52±0.74^{a}	0.99±0.12^{a}
	LCOSS	2.01±0.05^{a}	15.52±0.74^{a}	0.99±0.12^{a}
	NSCSS	2.01±0.05^{a}	15.52±0.74^{a}	0.99±0.12^{a}
1st	COSS	2.10±0.19^{a}	15.75±1.20^{a}	1.02±0.04^{a}
	LCOSS	2.01±0.10^{a}	15.04±0.09^{a}	1.05±0.06^{a}
	NSCSS	1.99±0.13^{a}	14.05±0.04^{a}	1.10±0.06^{a}
2nd	COSS	2.19±0.15^{a}	15.59±0.67^{a}	1.28±0.11^{a}
	LCOSS	2.07±0.06^{ab}	14.14±1.11^{a}	1.21±0.04^{ab}
	NSCSS	1.85±0.50^{c}	13.44±1.25^{b}	1.05±0.03^{b}
3rd	COSS	1.80±0.13^{a}	14.28±1.05^{a}	2.11±0.04^{a}
	LCOSS	2.02±0.05^{b}	14.00±1.15^{b}	1.08±0.03^{b}
	NSCSS	1.23±003^{c}	12.99±0.05^{b}	0.91±0.03^{c}
4th	COSS	1.78±0.14^{a}	14.02±1.15^{a}	2.16±0.04^{a}
	LCOSS	1.87±0.14^{b}	12.79±1.10^{b}	0.79±0.10^{a}
	NSCSS	1.15±0.06^{b}	12.02±1.05^{c}	0.88±0.04^{c}
5th	COSS	1.33±0.13	13.02±1.05	1.89±0.04
	LCOSS	1.20±0.06	11.60±1.01	0.53±0.04
	NSCSS	NA	NA	NA
6th	COSS	1.38±0.06	11.37±1.03	1.12±0.05
	LCOSS	1.09±0.03	11.05±1.15	0.50±0.03
	NSCSS	NA	NA	NA

Values are data expressed as mean ±SD of three replicates. Different superscript in the same column indicates significant differences at p<0.05. NA = Not Available, COSS= Conventional Onion Storage System, LCOSS=Low-cost Onion Storage Structure, NSCSS=NSPRI Solar Cold Storage System

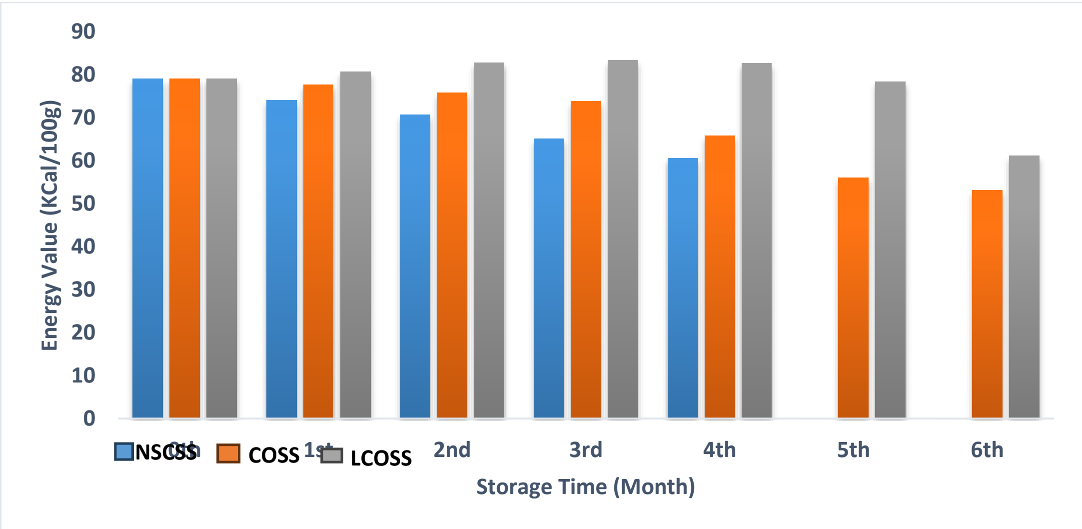

Figure 9. Dietary energy potential of stored red onion bulbs in three storage structures

Table 2. Level of total polyphenols (GAE (mg/g) FW) in fresh red onion bulb during storage

Storage Structure	Storage Time (Month) 0^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
NSCSS	5.50±0.03^{a}	5.88±0.03^{a}	6.55±0.08^{a}	6.50±0.05^{a}	4.04±0.02^{a}	NA	NA
COSS	5.50±0.03^{a}	5.83±0.02^{a}	6.80±0.30^{b}	6.91±1.75^{a}	7.00±0.06^{b}	7.03±0.06	7.54±0.04
LCOSS	5.50±0.03^{a}	5.99±0.04^{b}	6.65±0.05^{a}	7.52±0.03^{a}	7.97±0.03^{c}	8.62±0.12	8.73±0.02

Values are data expressed as mean ±SD of three replicates. Different superscript in the same column indicates significant differences at p<0.05. NSCSS = NSPRI Solar Cold Storage System; LCOSS Low-cost onion storage system; COSS = Conventional Onion Storage System**.** NA =Not available. FW = Fresh weight.

The total polyphenol levels in onions contribute to an onion's antioxidant potential, supportive of the body's physiology and overall wellness (Bala et al., 2021). Lowering the moisture content may increase the total polyphenolic content of the onion bulb during storage (Bala et al., 2021; Cheng et al., 2013). According to (2018), several internal and external factors, including genetics and cultivars, soil and growing conditions, maturity stage, and postharvest storage conditions, affect the concentration and content of bioactive chemicals.

Table 3 shows that ascorbic acid declined significantly ($p < 0.05$), with less than 50% retained after the third month of storage in all storage systems. However, more retention of ascorbic acids was in the LCOSS, while most of the decrease was observed in the NSCSS structure, followed by the COSS. The conventional effect of ascorbic acid could be attributed to periodic dry hot-air circulation through the windows and door vents between the first and third months (>50% reduction); this was the peak of the hot season in Kano state. The decline in ascorbic acid in onion bulbs during storage is similar to the research work of Adu et al. (2023) and also in consonance with the research works of Nuutila et al. (2003) and Cheng et al. (2013) regarding antioxidant and total polyphenolic content.

Table 3. Level of ascorbic acids (mg/g) in fresh red onion bulb during storage

Storage	Storage Time (Month)						
Structure	0th	1st	2nd	3rd	4th	5th	6th
NSCSS	6.19±1.31[a]	5.15±0.04[a]	1.95±0.10[a]	1.33±0.05[a]	1.06±0.07[a]	NA	NA
LCOSS	6.19±1.31[a]	5.87±0.09[b]	3.00±0.50[b]	2.89±0.06[c]	2.62±0.04[c]	2.00±1.32	1.88±0.07
COSS	6.19±1.31[a]	5.00±1.50[a]	2.55±0.06[ab]	2.22±0.06[b]	1.89±0.05[b]	1.62±0.04	1.43±0.06

Values are data expressed as mean ±SD of three replicates. Different superscript in the same column indicates significant differences at P<0.05. NCR = NSPRI Cold Room; LCOSS Low-cost onion storage system; COSS = Conventional Onion Storage System. NA =Not available.

Conclusion

This research evaluated three onion storage systems — namely, the Conventional Onion Storage System (COSS), the NSPRI Solar Cold Storage System (NSCSS), and the Low-Cost Onion Storage System (LCOSS) —over a six-month period. The findings underscore the critical impact of temperature and relative humidity on storage performance. The LCOSS, with an average temperature of 25.7°C and relative humidity of 56%, demonstrated higher performance by minimising weight loss (27.9%), delaying sprouting, and better retaining nutritional attributes, including crude protein, carbohydrates, oil, and ascorbic acid, up to the fourth month. Conversely, the NSCSS, despite achieving a cooler temperature of 21.6 °C, was compromised by high humidity (83%), resulting in early sprouting and spoilage by the fourth month. The modification on the NSCSS was ineffective in reducing the relative humidity during the storage period. The COSS, recorded temperature of 29.1°C and a relative humidity of 72.1%, exhibited the highest weight loss (32.5%), particularly during the rainy season.

Additionally, LCOSS supported a notable increase in total polyphenols, enhancing the antioxidant capacity of stored onions. By utilising conventional air-conditioning, LCOSS proved to be an efficient system for onion bulb storage, ensuring both physical preservation and nutritional retention. Its use of conventional air conditioning makes it a practical option for low-income producers aiming to reduce postharvest losses at a minimal energy cost. Since the experiment aimed to minimise postharvest losses of red onion bulbs, there is a need to modify the NSCSS and LCOSS to achieve the desired weight loss.

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