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ORIGINAL RESEARCH ARTICLE



Revolutionizing onion preservation: A novel aerated storage approach

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ABSTRACT

The second goal of sustainable development is ending hunger, achieving food security improving nutrition, and promoting sustainable agriculture. Improved storage system is a part of sustainable agriculture. This research aimed to design and develop an aerated storage system for onions and examined the extent of losses to assess the efficacy of the storage system. Unseasonal rainfall and adequate storage facilities result in quick sales and spoilage of onions. A huge amount of onion is damaged due to a lack of proper post-harvest actions like storage, transportation, temperature control, and humidity control in our country. In this study, 40 kg of onion inside the storage and 10 kilograms outside the storage were stored for four weeks from 12 October to 8 November to observe parameters like percentage of moisture loss, sprouting, deterioration, and marketable onion. Temperature as well as relative humidity was observed throughout storage. After completing the research, it was found that the appropriate temperature was 27°C with 83% relative humidity resulting in minimum losses throughout four weeks of storage period. It was also observed that marketable onion bulbs for aerated storage systems was 97.536% on the other hand marketable onion bulbs for natural or open storage systems was 91.629% which was less than aerated storage systems. So, the aerated storage system is more effective for storing the onion than the natural or open storage system. Small-scale farmers will be benefited and the supply chain management will be maintained using this storage system. Additionally, stakeholders and families will benefit from reduced onion damage percentages when utilizing this storage solution.

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INTRODUCTION

Onions (*Allium cepa* L.) are bulbous vegetables that originate from the Liliaceae family. They are significant vegetable crops produced commonly for national consumption and distributed worldwide especially varieties grown for bulbs. (Halliru *et al.*, 2019). The onion is highly esteemed globally for its distinct flavor, taste, and pungent properties. Onions are abundant in sodium, phosphorus, calcium, and fiber. Its nutritional content can vary depending on various factors (Khokhar, 2019). Onions are enriched in nutritional substances like flavonoids. Flavonoids, organosulfur compounds, and fructans phytochemicals

are abundant in onions (Mahmood *et al.*, 2021). The demand for onions in Bangladesh is rising, but the available land for cultivation is shrinking, posing a challenge to meet the increasing demand. Currently, 459 thousand hectares are under onion cultivation (BBS, 2022).

Onions are a seasonal crop, and bulbs are frequently stored until the next harvest time or for a long period, especially during periods of market surplus. However, during storage major losses in both quantity and quality often occur. Subsequently, onion bulb storage has become a critical concern in tropical countries (Nassarawa and Sulaiman, 2019). Besides, onions are a type of crop with a long shelf life, but they can damage if not stored

properly due to problems such as sprouting, rotting, and physiological weight loss (Wang et al., 2019). Owing to endless loss of dry matter and water throughout storage conditions, onion bulbs are damaged their weight. Because of various bulbs rotting microorganisms, mostly significant loss arises in store (Ahsanuzzaman et al., 2017). In Bangladesh, predominant illnesses affecting onion include grey neck rot (*Botrytis allii*), black mold rot (*Aspergillus niger*), white rot (*Sclerotium cepivorum*), soft rot, and dry rot (*Macrophomina phaseolina*). Among these, at high storage temperatures and high relative humidity, black mold rot may become severe and result in a drastic loss (Ullah, 2020).

The production of onions in Bangladesh was 134000, 272000, 769000, 1159000, 1704000, 1867000, and 2517070 tons respectively in 1990, 2004, 2006, 2012, 2015, 2018, and 2022. From 2018 to 2022, onion production in the country increased by almost 1.5 times (BBS, 2022). In Bangladesh, the population is increasing rapidly. So, according to the demand for onion, the production of onion is not that much high. Sometimes, it is necessary to meet the demand by importation from another country. Moreover due to rotting, sprouting, black mold, and physical loss in weight, the quality and quantity of onion decrease during storage time. About 30-40% of onion is lost in the storage owing to several factors and up to 70-80% due to unsuitable and poor storage facilities (Bhasker et al., 2020). On the whole, weight loss 20 to 25 %, decaying 10 % to 12 %, and sprouting 4 % to 5 % were determined (Shankar et al., 2023). Many farmers bring their onions directly to the marketplace right after harvesting due to insufficient storage facility. The current storage facilities are unsatisfactory, and maximum of the existing storages are conventional and based on irrational design (Kumari et al., 2022).

Effective storage facilities for onions are crucial during the off-season so that serious losses are prevented. Different storages of onions were studied. A developed modern onion storage structure named Makani Model was compared with traditional storage and Makani model was found beneficial aspect of overall losses (Halliru et al., 2019). An onion storage and dryer was developed and evaluated and the efficiency was observed year round to give reliable results. This dryer was adaptable to the situation such as moisture level and temperature in the area, particularly during cooking activities and this model was satisfied the household users (Moradas & Sealongo, 2022).

Some storage structures like the traditional double row storage structure, modified bottom ventilated storage structure, modified bottom ventilated storage structure with chain-linked side walls, traditional single row storage structure, modified bottom ventilated single row storage structure, top and bottom ventilated storage structure with mud-plastered walls and bottom ventilated single row low-cost thatched roof storage structure were designed and built to decrease storage losses and found that bottom ventilated structures were efficient (Tripathi and Lawande, 2016). An experiment found that the efficiency of a wooden structure on a raised platform packed with ventilation on all sides was better to diminish the onion bulb deterioration

during three months of storage (Soomro et al., 2016).

To continue the accessibility of high-quality onions in the marketplace and stabilize prices between harvest seasons, operative storing is crucial (Bukar et al., 2023). Usually, harvested onion bulbs are stored in locally manufactured traditional structures in our country. However, due to inadequate aeration losses range from 50 to 60 percent (Yadav & Yadav, 2011). Researchers described a significant rate of physiological weight loss under naturally ventilated structures in the first four weeks. The results fluctuate with the environmental conditions (Eriballo et al., 2021). Physiological weight loss is greater than before as the storage period proceeded (Kumar & Dhankhar, 2023). Therefore, farmers are frequently bound to sell their yield immediately after harvest at minimum value. Although the progress in new storage constructions initiated in developed counties, the system of onion storage is still primitive in Bangladesh. Nowadays restaurant business is thriving, and they have to make food look delicious and also make different kinds of food items so that people get interested. For all of these, the food makers need tons of vegetables and spices, onion is one of them. A proper storage system will help to reduce the wastage percentage of onions before sending these to the business chain. To eliminate the problems of onions, there is a vital prerequisite to developing a storage structure that has minimum sprouting, rotting, and weight losses. Aerated storage is one of them through which anyone can easily store onions for a long time. The study was done to find out the suitable aerated storage system for onions for storing and using them in the off-season. Therefore, the study aimed to design and fabricate an aerated storage system for onions and to identify the appropriate temperature and relative humidity suitable for onion storage during that experimental period.

MATERIALS AND METHODS

The fabrication and testing were conducted at Engineering Workshop, Department of FPM Bangladesh Agricultural University to develop an aerated storage system for onions.

Design of onion storage system

For this study, a 3D figure was designed for storage with the software Autodesk AutoCAD-2017 following which a structure was made by a 12 mm MS rod for the stand, a 5mm MS rod for support, an 8mm MS rod for making a round shape at the workshop with the help of the workshop workers. The height of the storage was 5 feet making a clearance of 1 foot from the base 1st chamber was set and after the second chamber 2 feet gap was taken and set in the 2nd chamber after that making 2 feet gap the shelter was set with a hole in the middle for setting up an exhaust fan. 3D design and measurement of the storage are shown in Figure 1.

Fabrication of storage system

At first, all the materials were bought from the local market and

brought to the Engineering workshop. After bringing those to the workshop the measurement by steel tape of 5 feet height into the 12mm rods and 3 feet diameter into the 8mm rods was taken for the cylindrical shaped storage and cut those rods into pieces by the rod cutter, then 10mm rods were bent to make 4 pieces of circle shape of 3 feet diameter. After cutting into pieces those rods were joined with the help of a welding machine to build the structure. Beginning from circle-shaped pieces, 6 bolster bars of 5mm were joined into each of the three circle-shaped pieces. At that point bolster for the debilitate fan with a 5mm pole was joined into the fourth piece of the circle shape. After that two of them were wrapped with the steel net so that they could be utilized as an onion holding chamber than on the 6 joining focuses of the base circle 12mm poles were joined for standing at the capacity of 5 feet tall with the welding machine. When 6 stands were joined with the base circle, the moment circle was joined 1 foot over the base which was 1st chamber, and from the 1st chamber third circle was joined 2 feet over the 1st one which was 2nd chamber, and after that, over 2 feet of the 2nd chamber, the fourth circle was joined which was used as the shield of the capacity additionally holding the exhaust fan as well. Hence the structure was made at that point the exhaust fan was set up with the switchboard and settled onto the beat with the assistance of a cable tie at that point the total capacity

was wrapped with the steel net official with the steel wire. The capacity was prepared at that point for the try.

Experimental data collection

After making the structure, it was moved to a windproof room. 50 kg of onion for the experiment was bought. 20 kg was put in each chamber which means 40kg to the two chambers and 10kg was kept outside the chamber in that room. After storing those onions in that chamber one data logger inside the storage was set and another data logger outside the storage was set. After that, the experiment was held October 12th to November 8th 2022. During the period, several weights such as total weight, deteriorated onion weight, sprouting onion weight, rotten onion weight, and marketable onion weight were taken and the rotten onions were removed from the inside and also from the outside 7 days interval. After taking those data we measured some parameters to find out whether the storage was better than outside or not. Throughout the time of research, the regular temperature as well as relative humidity was documented 24 times a day by a Data logger. Some activities of data collections are shown in figure 2.

Estimation of storage parameters

Percentage of moisture loss

To determine the moisture loss was simple in terms of weight basis; the weight of the total onion was taken after a certain period and divided the difference from the initial weight by the initial weight. The calculation formula is shown in (eqⁿ.1) (Soomro et al., 2016):

$$ML (\%) = \frac{W_i - W_N}{W_i} \times 100$$

Where, W_i = Initial weight, kg; W_N = Weight after N days, kg

Percentage of deterioration

Percentage of deterioration on required days after storing was calculated by taking the weight of rotting, sprouting, and affected onions after certain period and then divided by the initial weight of the onion. The calculation formula is shown in (eqⁿ.2) (Hatem et al., 2014):

$$DP (\%) = \frac{W_d}{W_i} \times 100$$

Where, W_i = Initial weight, kg; W_d = Weight of deteriorated onion after N days, kg

Percentage of sprouting

To assess the percentage of sprouting on required days after storing, the bulbs were detached from the trial lots and weighed using an electronic balance. The weight of the bulb sprouted was calculated with the equation shown in (eqⁿ.3) (Hatem et al., 2014):

$$SP (\%) = \frac{W_s}{W_i} \times 100$$

Where, W_i = Initial weight, kg; W_s = Weight of sprouting onion after N days, kg

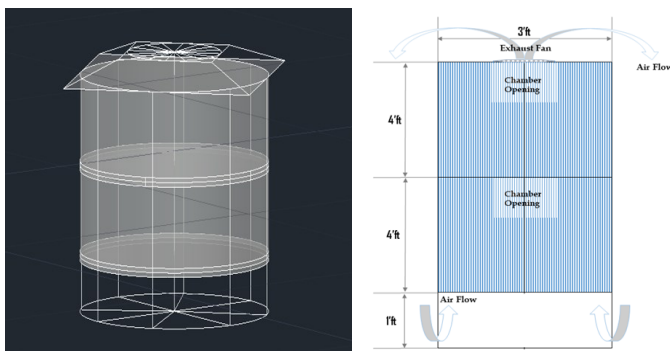


Figure 1. 3D view with schematic view.



(a) Measurement with Data logger.

(b) Manual Checkup.



(c) Pushing inside air to outside.

Figure 2. Activities during data collection.

Marketable onion bulbs

During the study, the perished defected as well as shrinkage bulbs were removed and the weight of healthy bulbs was observed. To determine the marketable bulbs the eqⁿ. 4 was used (Hatem et al., 2014):

$$MB (\%) = \frac{W_n}{W_i} \times 100$$

Where, W_i = Initial weight, kg; W_n= Weight of healthy onion after N days, kg

Average temperature and relative humidity

Average temperature along with relative humidity was calculated with the help of Microsoft Excel but those might be calculated with the equation shown in (eqⁿ.5) and (eqⁿ.6) (Hatem et al., 2014):

$$Avg. T = \frac{T_n}{n} \times 100$$

Where,

Avg. T = Average temperature; T_n= Sum of 'n' number temperature value, (°C); n = Number of temperatures

$$Avg. \%RH = \frac{RH_n}{n} \times 100$$

Where, Avg. %RH = Average relative humidity; T_n= Sum of 'n' number relative humidity value, (%); n = Number of relative humidity

RESULTS AND DISCUSSION

Parameters of onion quality like percentage of moisture loss, deterioration along with percentage of sprouting, marketable onion were assessed and other factors such as temperature along with relative humidity was monitored for storing onion under two dissimilar storage environments.

Temperature and relative humidity

If temperature increases, the action of water increases and consequently affects the quality of the onion. Figure 3 presents average temperature of the dissimilar onion storage environments throughout the period. It could be seen that the average

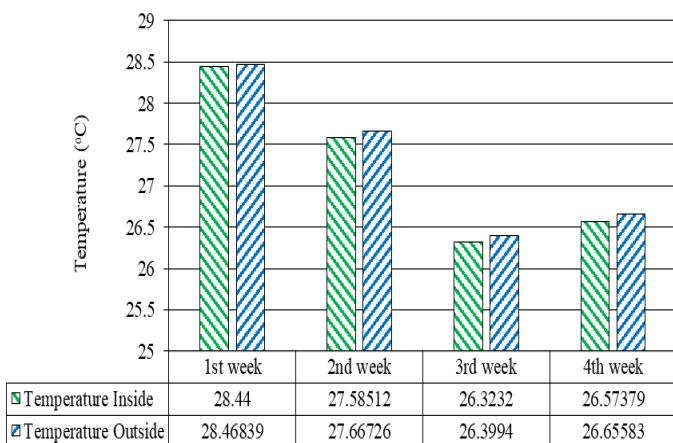


Figure 3. Variation of temperature for storage and outside or natural.

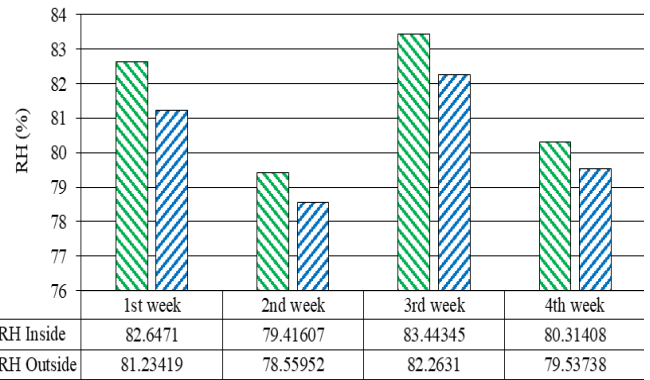


Figure 4. Variation of relative humidity for storage and outside or natural.

temperature in the aerated storage system was from 28.44 to 26.57°C, while, it transformed from 28.46 to 26.65°C in the natural storage system. A regression analysis was conducted to find a connection between the temperatures as a function of the experiment period (1st – 4th week). The suitable form was as follows:

$$\text{Temperature Inside } (\hat{C}) = -0.0037(t) + 28.475 \quad (R^2) = 0.2492$$

$$\text{Temperature Outside } (\hat{C}) = -0.0036(t) + 28.511 \quad (R^2) = 0.2439$$

If relative humidity increases, the microbial actions of the onion affect its texture of the onion. Figure 4 shows the average relative humidity of the dissimilar onion storage environments throughout the storage time. It could be observed that the average relative humidity in the aerated storage system was from 82.64 to 80.31%, while it changed from 81.23 to 79.53% in the natural storage system. A regression analysis was conducted to discover a connection between the relative humidity as a function of the experiment period (1st – 4th week). The suitable form was as follows:

$$\%RH \text{ Inside} = -0.002(t) + 82.085 \quad (R^2) = 0.0056$$

$$\%RH \text{ Outside} = -0.0011(t) + 80.727 \quad (R^2) = 0.0022$$

A study showed two temperature conditions have been identified for minimum losses with low-temperature storage (0-20 °C) and high-temperature storage (25-30°C). Optimum results in both temperature conditions were achieved by maintaining humidity at 65 to 70% (Kakade et al., 2023). So, the result of the study was compatible.

Onion quality

Several weights were taken at 7 days intervals on the basis of moisture loss, deteriorated percentage, sprouting percentage, and marketable bulbs with the help of electronic balance.

Percentage of moisture loss

The percentages of moisture losses were 0.635, 1.931, 2.126, and 3.95% in 1st, 2nd, 3rd, and 4th weeks, respectively for the onion stored inside and 0.9, 7.01, 7.7, and 11.907% in 1st, 2nd, 3rd and 4th weeks for onion stored outside the aerated storage. 1st-week data for both inside and outside of the storage observed the minimum moisture loss percentage which was possibly because of less transpiration and respiration.

A regression analysis was conducted to discover a connection between the moisture losses as a function of the experiment period (1st – 4th week). The suitable form was as follows:

$$\begin{aligned} \text{Inside ML (\%)} &= 1.017(t) - 0.3845 & (R^2) &= 0.9212 \\ \text{Outside ML (\%)} &= 3.3711(t) - 1.5485 & (R^2) &= 0.9206 \end{aligned}$$

In comparison with the results of studies it was found that moisture loss percentage in forced ventilated wooden structure was 14.8% (Chattha et al., 2020). The physical weight loss was observed 4.19% in wooden packed structure with all sides ventilation (Soomro et al., 2016). The result was close to the study.

Percentage of deterioration

Figure 5 presents the effect of dissimilar storing environments (aerated storage and outside or natural storage system) on the percentage of deterioration loss of onion bulbs throughout four weeks of storing time. The percentages of deterioration were 6.125, 1.23, 0.337, and 0.632% in 1st, 2nd, 3rd, and 4th weeks respectively for the onion stored inside and 11.7, 6.185, 0.669, and 1.701% in 1st, 2nd, 3rd and 4th weeks respectively for onion stored outside the aerated storage. The maximum deterioration percentage in both storage environments could be because of high temperature along with relative humidity related to the other systems presented in figure 3 and 4. An analysis named regression was conducted to discover a connection between the deterioration percentages as a function of the experiment time (1st – 4th week). The suitable form was as follows:

$$\begin{aligned} \text{Inside DP (\%)} &= -1.7462(t) + 6.469 & (R^2) &= 0.6907 \\ \text{Outside DP (\%)} &= -3.5513(t) + 13.942 & (R^2) &= 0.8306 \end{aligned}$$

A bottom ventilated thatched roof with single row low cost onion storage structure had 10.88% deterioration percentage (Tripathi & Lawande, 2016). Another study revealed that the rotting of the bulb was found 7.4% in forced ventilated wooden structure (Chattha et al., 2020).

Percentage of sprouting

The sprouting percentages were 1.65, 0.673, 0.285, and 0.344% in 1st, 2nd, 3rd, and 4th weeks respectively for the onion stored inside and 2.5, 4.123, 0.223, and 0.6% in 1st, 2nd, 3rd and 4th

weeks respectively for onion stored outside the aerated storage. The maximum percentage of sprouting in both storage environments could be because of inadequate ventilation which might cause the build-up or humidity pockets inside the stored onion and aid to stimulate sprouting and also allow the constant growth of these sprouts. An analysis named regression was conducted to discover a connection between the percentages of sprouting as a function of the experiment time (1st – 4th week). The suitable form was as follows:

$$\begin{aligned} \text{Inside SP (\%)} &= -0.4306(t) + 1.8145 & (R^2) &= 0.7749 \\ \text{Outside SP (\%)} &= -0.96(t) + 4.2615 & (R^2) &= 0.4703 \end{aligned}$$

This result was found better compared to a study that found 7.8% of the sprouting percentage of the bulb in forced ventilation structure (Chattha et al., 2020) but another study recorded 1.47 % which was lower than this result (Hatem et al., 2014). The result of the study was close to them.

Marketable onion bulb (Healthy)

A marketable onion bulb means an onion with good outer and inner surface structure, texture, and chemical composition that is ready to cook or eat. Data showed the effect of dissimilar storage environments (aerated storage and outside or natural storage systems) on the marketable percentage of onion bulbs throughout four weeks of storage time. The marketable percentages were 95.75, 96.746, 97.536, and 95.413% in 1st, the 2nd, 3rd, and 4th weeks for the onion stored inside and 87.4, 86.804, 91.629, and 86.39% in 1st, 2nd, 3rd and 4th weeks for onion stored outside the aerated storage. An analysis named regression was conducted to discover a connection between the percentages of marketable onion bulb as a function of the experiment time (1st – 4th week). The suitable form was as follows:

$$\begin{aligned} \text{Inside MB (\%)} &= 0.7279(t) + 93.917 & (R^2) &= 0.2512 \\ \text{Outside MB (\%)} &= 0.1798(t) + 87.607 & (R^2) &= 0.0092 \end{aligned}$$

The mean percentage of marketable bulbs in a study was 85.31% (Hatem et al., 2014).

Appropriate temperature and relative humidity

Among the four weeks, the lowest moisture loss percentage is found in the 1st week (12th – 18th Oct) of the experiment inside the aerated storage. Average temperature and relative humidity of the 1st week inside the storage is, T = 28.44°C and %Rh = 83.308%, respectively. So, 28.44°C is the temperature and 83.308% is the relative humidity for the lowest moisture loss percentage inside of the storage. The percentage of moisture loss in the 1st week is 0.625 %. Among the four weeks, the lowest deteriorated; sprouting percentage and the highest marketable onion bulb percentage is found in the 3rd week (26th Oct – 1st Nov) of the experiment inside the aerated storage. Average temperature and relative humidity of the 3rd week inside the storage is, T = 26.332°C and %Rh = 83.423%, respectively. So,

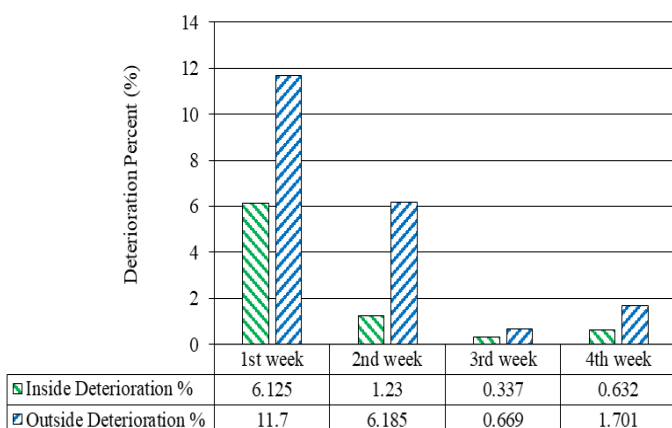


Figure 5. Variation of deterioration percentage inside and outside.

26.332°C is the temperature and 83.423% is the relative humidity for the lowest deteriorated, sprouting percentage, and highest marketable bulb percentage inside of the storage. The percentage of deteriorated, sprouting and marketable onions was 0.337%, 0.285%, and 97.536%, respectively in the 3rd week. Between the 1st and 3rd week's average temperature and relative humidity, 27.386°C \approx 27°C is the appropriate temperature and 83.365% \approx 83% is the appropriate relative humidity for the aerated storage system of onion on the period of the experiment to have the longest shelf-life. So, onions are stored a long time in this system with the recommended temperature and relative humidity.

Conclusion

The conducted study concluded that the aerated storage was better than the different structures of onion storage that were studied previously. The research explored the influence of various storage environments on onion quality, showing specific results. The average temperature throughout the storage period fluctuated between 28.44 to 26.57°C for the inside of the aerated storage system, where it fluctuated between 28.46 to 26.65°C for outside the aerated storage system. The average relative humidity throughout the storage period fluctuated between 82.64 to 80.31% inside of the aerated storage system, where it fluctuated between 81.23 to 79.53% outside the aerated storage system. The minimum moisture loss was observed 0.625% inside the aerated storage system, while the minimum moisture loss was observed 0.9% outside the aerated storage system. The bulbs stored inside the aerated storage and outside the aerated storage system showed that the minimum percentage of deterioration was 0.337% and 0.669%, respectively. The lowest sprouting percentage was observed 0.285% inside the aerated storage system, while the lowest sprouting percentage was observed 0.223% outside the aerated storage system. The bulbs stored inside the aerated storage showed the highest percentage of marketable onion bulbs 97.536%, while outside the aerated storage system showed the highest percentage of marketable onion bulbs 91.629%. The study suggests that growers or businessmen can adopt the aerated storage system for storing onions with minimum losses.

DECLARATIONS

Authors contribution

Conceptualization, A.A.M. and M.H.I.; Methodology, A.A.M. and M.H.I.; Software, A.A.M.; Validation, A.A.M., M.H.I., A.H. and I.Z.; Formal analysis, A.A.M.; Resources, A.A.M. and M.H.I.; Data curation, A.A.M.; Writing original draft preparation, A.A.M., M.H.I.; A.H. and I.Z.; Writing—review and editing, A.H. and I.Z.; Visualization, A.A.M. and M.H.I.; Supervision, M.H.I. All authors contributed to the article and approved the submitted version.

Conflict of interest: The authors declare no conflict of interest.

Ethical approval: Not applicable.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

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