Forced Ambient Air Storage of Different Onion Cultivars

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Summary. No systematic curing and storage techniques are currently used with onions in Honduras; postharvest losses occur rapidly. The objective of this study was to evaluate the use of storage bins (maximum capacity 7t) that use forced ambient air ventilation to manipulate the atmospheric conditions around the onions. The desired storage conditions were 26 to 30°C and 60% to 75% relative humidity. Ventilation regimes were manipulated in an attempt to obtain these conditions. The rate of deterioration in four varieties of onions over a 3-month period was determined and compared with onions stored under normal ambient conditions. Marketable onions in the forced-air storage bin compared to the controls stored under ambient conditions after 13 weeks were 82% vs. 37% for 'Granex 33'; 71% vs. 40% for 'Granex 429'; 63% vs. 31% for 'Granex 438'; and 90% vs. 44% for 'Texas Grano 502'. This represents a significant increase in the number of marketable onions after storage. All losses were increased by rain and tornado damage after 1 month of storage. The methods used to maintain uniform temperature and humidity conditions in the storage bin are discussed together with the problems encountered. The construction and operating costs are given together with the market prices and the required returns to cover the bin costs.

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No systematic curing and storage techniques are currently used with onions in Honduras, and postharvest losses are reported to occur rapidly. Red onions and traditionally produced yellow onions are sold locally immediately after harvest from March to July. Volume is limited, and storage is not normally required for local markets if rapid sales are made. Significant volumes of new yellow cultivars have been introduced for export, with the excess being sold in the local market from January to July. Storage will be required to minimize oversupply and reduced prices. During the remaining months, onions are imported from Guatemala and the United States.

The storage life of onions is dependent on the cultivar and the storage conditions, together with other factors, including harvest and postharvest management, cultural practices, and weather. Temperature and humidity affect the rate of bulb decay, sprouting, root development, and water loss. After curing, low-temperature storage at 0 to 5°C is normally used for large-scale commercial onion storage for long-day onions, with the temperature being reduced slowly (Voss, 1979). Onions stored at low temperature have to be heated to prevent moisture condensation on the surface when removed from the store (Pacific Northwest Extension Publication, 1985). For the short-day cultivar Texas Grano 1015Y, 15C was recommended (Pike et al., 1989). However, under long-term storage at this temperature, sprouting is likely to occur (Thompson et al., 1972). When it was more profitable to minimize rotting and sprouting rather than reduce water loss, optimum storage conditions were 30°C, 75% to 80% relative humidity (RH) (Stow, 1975). Assessment of the development of *Aspergillus niger* over a range of humidities showed that growth increased with RH above 80% (Maude et al., 1984). Studies carried out in Yemen to test a controlled forced ambient air ventilation store showed that, after 31 weeks, 83% of the onions were marketable compared with 11% stored traditionally in 25-kg net sacks placed on pallets (25 to 30 sacks) in an open-sided building (Bisbrown et al., 1991).

Forced-air storage bins under ambient conditions offer a cheaper alternative to temperature-controlled

cold rooms, although they may not be as efficient at reducing storage losses and sprouting. The objectives of this study were to use high-temperature storage of onions, evaluate the effects of forced ambient air ventilation on maintaining onion marketability, and determine the technical and economic viability of the system.

Methods

Forced-air store construction. The design given by Bisbrown (1991) was used as a basis for the forced-air storage bin construction. The storage bin was built using tongue-and-groove wood panels, sealant was placed at all joints, and plastic sheeting was used to line all walls to reduce air loss through the walls. Storage bin size was ≈ 2.2 m square and 3.0 m high, with a slatted floor over a plenum chamber to which was connected a fan via a triangular duct. The floor was made of wooden slats 50 mm wide, with gaps of 40 to 50 mm, and was raised ≈ 20 cm above ground level. A fan with a delivery of $0.586 \text{ m}^3\text{s}^{-1}$ @ 375 N/m^2 was used, based on recommendations from the Natural Resources Institute, U.K. The total construction cost of the forced-air storage bin (7-t capacity) was between Lps 3500 and 4000 (\$640 to \$730), depending on the materials used. The fan cost Lps 2000 (\$360). If maintained correctly, the storage bin will last a minimum of 3 years.

Onion preparation and bin loading. Onion cultivars grown in two sites in Comayagua ('Granex 33', 'Granex 429', 'Granex 438', and 'Texas Grano 502') were harvested when 60% to 70% of the leaves had died back; irrigation was stopped at least 10 days before harvest. Bulb diameter for each of the varieties ranged from 5 to 8 cm. After harvest, the onions were windrowed and left in the field for 1 day. They were field-graded to remove damaged, diseased, or double bulbs, then transported to a packing area and trimmed. They were then cured in ventilated plastic field crates in a ventilated shaded area under a roof for up to 9 days. After curing, the onions were packed in 23-kg polypropylene net bags normally used for export. The bags were loaded in the forced-air storage bin in an alternate stacking design so that gaps in one layer were covered by the layer above. Where gaps were unavoidable, they were plugged with empty mesh bags to pre-

vent the escape of air and to force it through the bags that contained the onions. The forced-air storage bin was dated on a concrete base under a roof with open sides, where it was fully protected from rain and sunlight. The different cultivars were distributed randomly in the forced-air storage bin; initial total weight for 'Granex 33' was 562 kg; 'Granex 429', 3109 kg; 'Granex 438', 674 kg; and 'Texas Grano 502', 218 kg. The control onions (125 kg for each cultivar) were placed in net sacks and stored to four layers deep, adjacent to the bins, protected from rain and sun. and subjected to only natural ventilation.

Temperature and RH measurement. Ten temperature sensors (thermistors) were placed in the net bags indifferent positions in the forced-air storage bin during loading, in the four corners and center, and at varying heights [0.5, 1.0, 1.5 and 1.9m (top)]. Two RH probes were used, one under the top layer of onions in the center and one by the ventilation unit. All probes were connected to a Squirrel Data Logger 1200 (Grant Instruments, U.K.) programmed to collect data every 10-min, calculate the means every hour, and record the hourly data on a continuous basis. The data were analyzed weekly.

Ventilation regimes. The ventilation regimes used in the trial were based on the prevailing ambient conditions. To achieve a relatively stable temperature and RH in the storage bin, it was not ventilated continuously. For example, if the ambient temperature was below the desired conditions of the storage bin, then no ventilation was applied. If, however, the temperature in the storage bin was above the desired value, it could be reduced by ventilation during the early morning or early evening when ambient temperature was relatively low. A similar argument follows for the humidity, but it was often necessary to compromise between conflicting requirements.

The overall aim of the system was to maintain the temperature and humidity within the storage bin between 25 and 30°C and 60% to 75% RH. This was achieved by ventilating when ambient conditions were within these ranges of temperature and humidity. Fan operation was controlled by a switching mechanism linked to a timer control unit measuring the ambient

temperature and humidity. When the timer, temperature, and RH were all in the desired range, the fan switched on; when one or more of the Parameters was outside of the set range, the fan did not operate. The ranges for fan operation could be increased or decreased using minimum and maximum settings on the control unit. In general, the ventilation was used early to midmorning and then again late afternoon to early evening. Initial temperature and RH ranges set for fan operation were 25 to 33°C, and 55% to 70% RH.

Quality assessments. The forced-air storage bin was unloaded for assessment at 4-week intervals. Each bag was graded to remove all unmarketable onions, such as those showing fungal or bacterial infection; the marketable onions were repacked, weighed, and loaded back in the storage bin on the original level. The percentage loss (by weight) was calculated for each of the varieties. No differentiation was made between losses due to disease and those due to water loss, as the producers' concerns were directly towards the amount of product available for sale.

Results and discussion

Onion quality during storage.

After 13 weeks under ambient conditions in an open-sided building, the control onions stored without forced ventilation showed losses for 'Granex 33' of 82%; 'Granex 429', 71%; 'Granex 438', 63%; and 'Texas Grano 502', 90%. Losses in the forced-air storage bin in an open-sided building with forced ventilation were lower, showing losses of 37% for 'Granex 33', 40% for 'Granex 429', 31% for 'Granex 438', and 45% for 'Texas Grano 502'. Data given in Table 1 show the progressive loss in total weight of marketable onions with increased storage time. All losses were probably increased by rain and tornado damage after 1 month of storage.

Losses to rots were due to black mold (*Aspergillus niger*), neck rot (*Botrytis*), soft rot (*Erwinia*), and slippery skin (*Pseudomonas*). No incidence of sprouting or rooting was found.

The first indication of disease problems occurred in the forced-air stored onions located at the base of the storage bin where mechanical damage had occurred from the slatted floor; in addition, onions in each sack under-

neath the central label on the net bags were normally the first to show disease problems. No localized diseased areas were noted during unloading.

The varieties used in the trial are known to have relatively short storage lives compared to other short-day onions, but were used in the trial due to increases in commercial production of these varieties for the export market.

Temperature and RH control.

Temperature maintenance in the forced-air storage bin was achieved with daily fluctuations during the weekly assessments of between 1 and 3°C, compared to 10 and 13°C for the nonventilated onions. During the initial 5-week storage period, control of relative humidity in the forced-air storage bin was achieved within the 65% to 75% range, while the RH in the control onions under ambient storage ranged from 30% to 90%. During this period, optimum ventilation was found to be from 7:00 to 10:00 AM and 6:00 to 10:00 PM. Data given in Figs. 1 and 2 for week 4 (25 May 1992) give an example of the ventilation periods related to the ambient temperature and humidity conditions, with ventilation occurring between the ranges of 22 to 33°C, and 50% to 85% RH. During the later stage of the trial, due to high levels of rainfall, the ambient humidity was frequently between 80% and 100% and reductions in the store humidity was not possible. Temperature in the storage bin was maintained between 26 and 28°C, compared to 20 to 34°C under ambient conditions. In an attempt to reduce the humidity, the ventilation cycle was increased to 7:00 AM to 12:00 PM to use the midday air of lower humidity, but of higher temperature. However, the forced-air storage bin humidity was reduced only marginally. Conditions in the control bags followed those of the prevailing ambient conditions.

The percentage of marketable onions in the control treatment was considerably lower than those in the forced-air storage bin; assessment of the storage bin conditions indicates that the average weekly temperatures were different by only 2 to 3°C. The main differences in the conditions were in the fluctuations in both temperature and RH and the higher RH in the first 5 weeks of the control ambient-stored onions. All three factors are likely to have contributed to the rapid losses shown in the control onions, although

Table 1. Percentage weight loss in four onion varieties during 3 months of storage in a forced-air ambient ventilation store.

Cultivar	Storage time (weeks)			
	4	5 ²	9	13
Granex 33				
Control	11	44	62	82
Forced air ¹	5	7	3	2
Granex 429				
Control	4	18	47	71
Forced air	4	14	30	40
Granex 438				
Control	5	15	31	63
Forced air	5	15	25	31
Texas Grano 502				
Control	11	69	84	90
Forced air	6	19	33	44

²Assessments carried out early as the bin was damaged by a tornado.

¹Initial weights in store for 562 kg for 'Granex 33'; 3109 kg for 'Granex 429'; 674 kg for 'Granex 438' and 218 kg for 'Texas Grano 502'. All ambient weights commenced with 125 kg.

it is believed that the reduction in the wide fluctuation in both temperature and RH are the major contributors to reducing the losses in the onions in the forced-air storage bin.

Storage conditions. Measurements were made in various sections and heights in the forced-air storage bin to determine temperature variation over 1-week periods; similar temperature and RH conditions were found indifferent positions in the storage bin. Temperature and RH were maintained relatively constant in the

forced-air treatment compared to the widely fluctuating ambient conditions (Figs. 3 and 4).

Capital and operating costs.

Average onion returns (Table 2) in 1992 to the producer during the period increased from Lps 0.45/lb (\$0.08) in May to Lps 1.20/lb (\$0.21/lb) in October (Lps 5.80 = \$1.00). The construction and operating costs were as follows:

Capital cost: Lps 4000, US\$690
Temperature/humidity meter: Lps 1500, \$119

Electricity: Lps30.00/week, \$6.00/week

The storage bin capacity is 7 t (15,400 lb). Market prices obtained for 1992 showed that returns on immediate sale after harvest in May would be Lps 7000 or \$1207 (≈ Lps 0.45 or \$0.08/lb). To cover the storage bin capital and operating costs based on a 3-year depreciation, plus the original value of the onions, a sales return would be required of Lps 0.60 or \$0.10/lb. This can be obtained from May onward, and would be most profitable from August onward, particularly at the beginning of September, when onions are normally imported from the United States and returns would approach Lps 1.00 to 1.50 or \$0.17 to \$0.26/lb. Although the onion price differentials between June and July are minimal, the results suggest that store construction would not be viable unless storage was carried out for more than 1 month. Profitability could be increased with further reduction in losses. Further economic analyses on a commercial level will be required.

Although the sales returns do not appear to generate significant earnings compared with direct sale after harvest, there are several points that re-

Fig. 1. Onion storage, Comayagua, Honduras, daily temperatures, week of 25 May 1992.

Fig. 2. Onion storage, Comayagua, Honduras, daily humidities, week of 25 May 1992.

quire consideration and that favor the use of the forced-air storage bin. The original market value of the onions, given as Lps 7000 (\$1207), assumes

that all the onions can be sold immediately; depending on the market conditions, this is not always the case. Similarly, it is assumed that the onions in

storage are all sold at the same time. Storage allows flexibility in marketing to take advantage of market shortages, as all the onions need not be sold at the

Fig. 3. Onion storage, Comayagua, Honduras, temperature fluctuation, week of 25 May 1992.

Fig. 4. Onion storage, Comayagua, Honduras, humidity fluctuations, week of 25 May 1992.

same time. The calculations are based on storage losses incurred in the trials; these were, in fact, enhanced by multiple loading and unloading during the trial and by tornado damage to the store and wetting of the onions.

Future store modifications.

Onions were loaded into the forced-air storage bin in mesh bags used for export; these include a label strip across the center, which restricted the flow of air through the center part of the bag. For further use of this storage method,

mesh bags with no barriers to air flow should be used, although these have only recently been developed in the United States. This should also assist in reducing some of the storage losses. Alternatively, plastic field crates may be used, or the onions maybe bulk-loaded into the bin. Bulk loading may cause mechanical damage to the onions that are at the base of the storage bin. Air drying through selective heating may also improve the storage characteristics, particularly during humid periods. The

increased cost and benefits of this system would require evaluation.

The trial was carried out using different cultivars in the same forced-air storage bin. It is possible that the different morphological characteristics may affect the air flow movement and therefore the storage life. However, in this study, it is likely to be negligible compared with the damage caused by the tornado. Future storage bins should contain only one cultivar.

As the storage bin was placed under a roof with open sides, the temperature and RH of the ambient air used for ventilation varied considerably. If the storage bin is placed in a closed building, the ambient conditions would show less variation, particularly in relation to humidity. Less fluctuations would be shown in storage bin conditions and the onions should show improved storage characteristics, particularly with 3 months of storage or more.

Conclusion

The ventilated ambient air storage system reduced losses compared to ambient storage and may enable growers in developing countries to store onions without cold storage, allowing for an extended and more-

Table 2. Estimated returns¹ from onions after storage, Comayagua, Honduras, 1992 (\$).

	Initial value	Freed cost	Operating cost	Sales return
Original value (\$ O. OS/lb)	\$1207			\$1207
June(\$0.11/lb)				
Forced air (95% of original)	\$1640	\$316	\$21	\$1303
Control (92% of original)	\$1468			\$1468
July(\$0.12/lb)				
Forced air (70% of original)	\$1264	\$316	\$41	\$953
Control (45% of original)	\$810			\$810
August(\$0.16/lb)				
Forced air (60% of original)	\$1434	\$316	\$62	\$1056
Control (23% of original)	\$552			\$552
September(\$0.20/lb)				
Forced air (50% of original)	\$1527	\$316	\$83	\$1128
Control (0% of original)	\$0			\$0

¹Assumptions: onions are harvested in mid-May; store capacity 15,000 lb; capital cost of store devalued over 3 years; operating costs of \$5.17/week. Loss calculations are based on 'Granex 33' and 'Granex 429' after 1, 2, and 3 months storage. September values are estimated.

flexible marketing period. Storage for 1 or 2 months with continuous marketing would provide the required financial benefits. Storage for 3 months or more would be advisable only if the optimum storage bin conditions could be maintained throughout the entire period, as the present design cannot reduce the storage bin RH if ambient RH is very high, such as during rainfall. For longer-term storage, modifications to the storage bin design and studies with intermediate-day-length cultivars are recommended.

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