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STORAGE OF DATES UNDER CARBON DIOXIDE ATMOSPHERE FOR QUALITY PRESERVATION

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ABSTRACT

Dates grown in Israel served as a model to demonstrate the feasibility of storing dried fruit under CO_2 atmosphere. A controlled atmosphere of 60-80% $CO_2$was used within a 151 m^3 plastic chamber partially filled with 30 tonnes of dates stacked in crates on pallets. The dates were stored in the chamber in bulk (in boxes of 10 kg or crates of 400 kg on pallets) or packed (250 g capped plastic cups) on pallets containing dates of vars. 'Hallawi', 'Hadrawi', 'Zahidi', 'Derei' and 'Ameri'. Dates were sampled before closing the chamber, after one month and after 4.5 months at the end of storage. The following were investigated: presence of insects and molds; skin sloughing; sugar formation; water activity (a_w); and color changes (only on var. Zahidi). At the initial purge phase the desired CO_2 concentration was obtained in the chamber within one hour by introducing the gas under high pressure. An intermittent maintenance phase was then applied for 4.5 months using approximately 0.8 kg CO_2 per day. At the end of storage, quality of the treated dates was compared to controls stored at -18° C. No significant difference was found between the treated dates and controls. The insect population was effectively controlled. This technology is proposed for the treatment of stored dates to control pests and maintain quality.

INTRODUCTION

Dried fruits are subject to infestation by insect pests during and after harvest. Several species of nitidulid beetles are particularly associated with dried fruits because they are both field and storage pests. Fumigation of dried fruits with methyl bromide (MB) upon arrival at the packing plant effectively controls infestation and also causes a high proportion of larvae and adults to emigrate from the fruit before they succumb (Donahaye *et al*. 1991; Navarro *et al*. 1989). The mechanism causing this emigration is not understood, though it clearly involves the delayed action of MB on insects which differs from other fumigants that have an anesthetic effect (Price, 1985) .

In recent years, reliance upon fumigation as an overall solution to infestation problems in durable agricultural products has become questionable. The chemical action of fumigants upon commodities and the environment has necessitated the withdrawal of many fumigants from the market. Of the two still widely used, phosphine is characterized as a slow acting fumigant with the ability of insects to develop resistance to it (Winks 1987), whereas MB is under severe scrutiny because of its involvement in ozone depletion and as such the international community has decided to phase out its use (UNEP, 1998).

The influence of different controlled atmospheres (CAs) in causing emigration of *Carpophilus* spp. larvae from dates was compared with that of MB by Navarro *et al.* (1989) and Donahaye *et al.* (1991). The influence of low O_2 or high CO_2 atmospheres as alternatives to fumigation of dried fruits has been investigated (Soderstrom, 1984; Soderstrom *et al.* 1986; Tarr *et al.* 1994). Recommended dosages to obtain mortality of most stored-product pests using high carbon dioxide (CO_2) CAs require exposure to >60% CO_2 for at least 11 days (Navarro *et al.* 1990).

Generally, soft-fruit date cultivars contain mainly glucose and fructose and little or no sucrose, whereas date cultivars with a firm and dry texture contain a high percentage of sucrose. The sugar that accumulates in the unripe fruits is sucrose and only at a later stage is it inverted. Kanner *et al.* (1978) studied the activity of the invertase enzyme during the last stages of date maturation and found that the maximum invertase activity was much higher in soft-date than in dry-date cultivars. They also discussed the role of invertase in causing sucrose inversion in dates. In soft date cultivars, which contain high amounts of reducing sugars in the ripe fruits, non-enzymatic browning induces development of a "caramel"-like taste (Kanner, 1967). Both accumulation of sugar on the date surface and changes in color are factors that affect date quality during storage (Rygg, 1957).

In Israel, the conventional method of date conservation after harvest is cold-storage at -18°C. This is the most suitable method for the sensitive soft-fruit cultivars, but it is highly energy consuming. In contrast to studies carried out on CAs for insect disinfestation, only very limited work has been carried out to determine the influence of CAs on date quality. Studies under laboratory conditions (Navarro, 1988) and in field tests at ambient temperatures (Navarro *et al.* 1992, 1995) showed that CO_2 significantly delayed browning and sugar formation on dates, and extended shelf life. On the basis of these earlier studies aimed at providing a non-toxic alternative to MB fumigation at ambient temperatures and to extending the shelf life of dates, it was decided to study the application of CA technology to date storage on a commercial scale. This study describes the use of a gastight plastic liner especially designed for the CA storage of dates in Israel.

MATERIALS AND METHODS

Description of the gastight flexible structure (cube)

The flexible structure was erected on a shaded asphalt-paved site and was subjected to the ambient temperatures prevailing in the Bet-Shaan valley in Israel. The completed structure resembled a cube and is therefore referred to as a "cube" in this paper (Fig. 1). It was built up *in-situ* by capping a stack of date crates placed on a floor-liner of PVC sheeting, and then welding the sections into place. It was equipped with a ball valve welded to the lower front side for the introduction of CO_2

and a screw-on valve 100 mm diam. welded at one corner at the top for pressure release. The cube measured 4.2 m high by 6 m wide and 6 m long and had a volume of 151 m^3. These dimensions enabled the storage of 72 crates on pallets each measuring 1 m x 1 m x 2.1 m high.

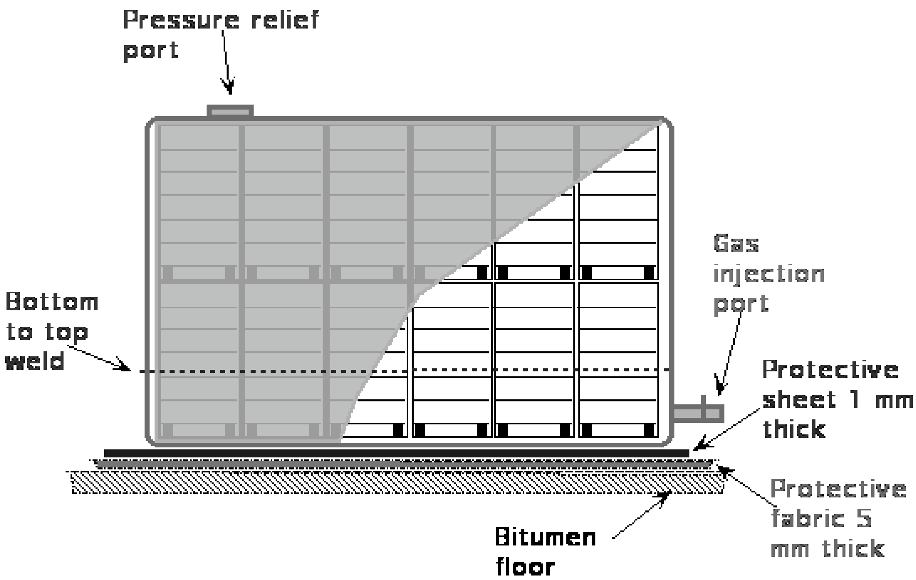

Fig. 1. Cut-away of cube showing crates on pallets inside cube of 151 m^3 capacity.

Test for gastightness

The initial tests for gas tightness were carried out before the cube was loaded with dates, but containing 72 empty crates on pallets so as to enable the shape of the structure to be retained. In this manner, the cube was tested without dates three times with improvements in the gastight seal made between each test, and then once again with the dates inside. A suction fan was used to create a negative pressure, thus enabling gastightness to be tested using the pressure decay method (Annis and van Graver, 1991). A "Celesco" transducer was used to monitor the pressure. The tests were carried out by creating an initial negative pressure of 40 to 60 mm water column, after which the ball valve was closed and the rate of rise in pressure was measured.

Quantity of dates stored in the cube

The dates were stored in the cube in bulk (in boxes of 10 kg or crates of 400 kg on pallets), or packed (250 g capped plastic cups) on pallets . To load the dates into the preformed cube the top section was cut and separated in order to enable removal of 30 empty pallets, which were then replaced with 30 pallets containing dates of the following varieties: Hallawi, Hadrawi, Zahidi, Derei and Ameri. Thus the cube was partially loaded with 30 tonnes of dates and then sealed, while the remaining space in the cube was filled with 42 pallets without dates.

CA treatments - CO_2 gas purge and maintenance

Four trials were carried out on the purge and maintenance of the CO_2 concentration in the cube without dates and one trial was carried out after loading the cube with dates. In this paper only the trial on the cube with dates is reported. During the purge phase the upper valve was opened in order to prevent build-up of gas pressure. Liquid CO_2 was allowed to flow into the cube from the lower valve, which was connected to one of a series of inverted 24 kg capacity CO_2 gas cylinders (each one emptied into the cube within 4 min). The vaporized gas, entering from the bottom, expelled the air inside the cube upwards and out of the opening at the top (Fig. 2 (A)). Preliminary experiments indicated that uniform CO_2 concentration could be obtained within 48 h of termination of purge. These results are not reported in this paper, but they are schematically shown in Fig. 2 (B). During the maintenance phase the gas was metered into the cube to compensate for small losses through the plastic and through any undetected holes.

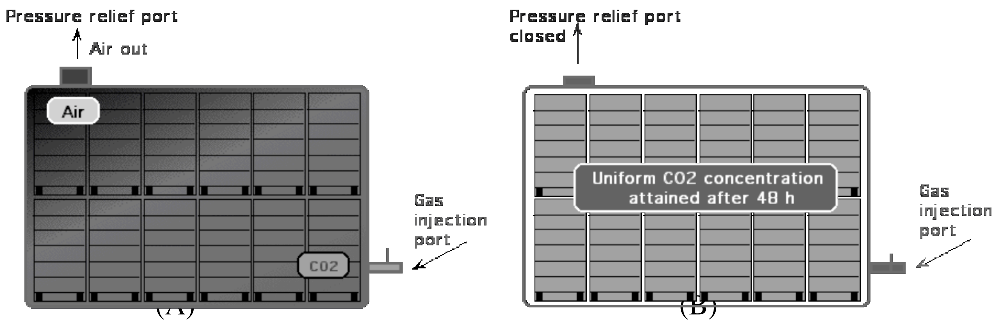

Fig. 2. Cross section of cube to show gas distribution from bottom at start of purge (A) and gas distribution 48 h from start of purge.

Control and monitoring of gas concentrations

The CO_2 concentration during the maintenance phase was controlled using a "David Bishop" O_2 analyzer equipped with control relays capable of operating in the presence of high concentrations of CO_2. The analyzer was set to activate a solenoid valve attached to the CO_2 cylinder when the CO_2 concentration within the cube rose above the set point. The rate of CO_2 flow was determined using a pressure regulator set at a flow-rate between 450 and 940 mL/min. In addition to continuous measurement of O_2 concentration, the CO_2 concentration was measured daily with a portable "GOW-MAC" gas analyzer equipped with a TC detector.

Sampling and test of date quality

Dates were sampled before closing the cube, after one month, and after 4.5 months at the end of storage. Tests included: i) presence of insects and molds according to Israel standard 1251 (Dried Fruits -Dates); ii) skin sloughing; iii) sugar formation; iv) water activity (a_w); and v) color changes (only on var. Zahidi).

RESULTS AND DISCUSSION

Degree of gas-tightness

The results of tests for gas-tightness of the cube are presented in Fig. 3. After the second test there was a slight improvement in gas-tightness. But still the half-life pressure decay was 4.5 min. Following a major repair, after the main leak source was detected, two gas-tightness tests were carried out, one prior to filling the cube with dates, on March 7, 1995 and the other after loading dates, the next day. These tests showed extended half-life pressure decay of 28 and 16.5 minutes, respectively.

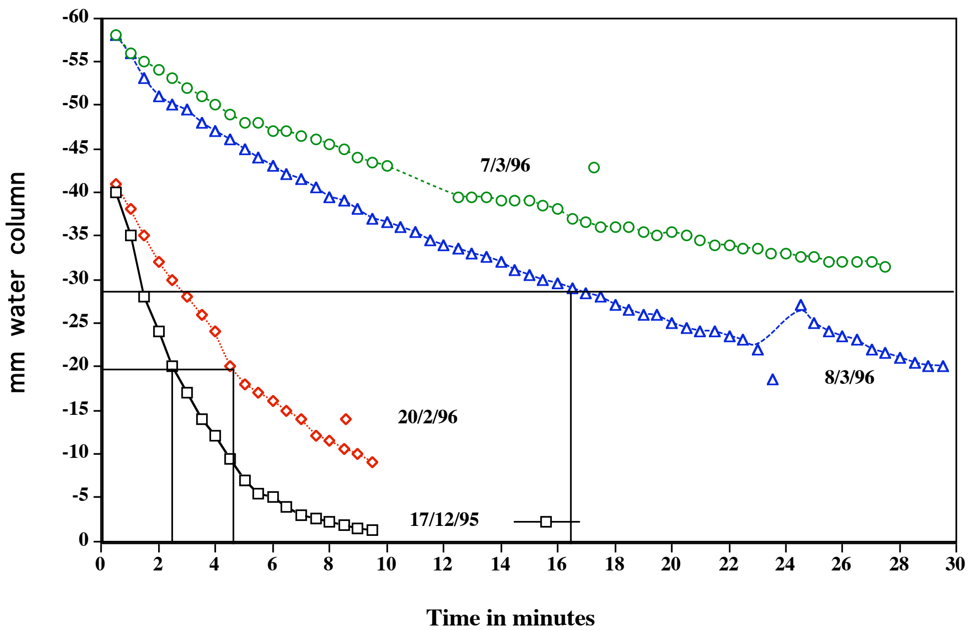

Fig. 3. Pressure decay tests (in mm water column) to evaluate the gas-tightness of the 151-m^3 capacity plastic storage enclosure. The vertical bars indicate the half-life time of pressure decay in each test.

Gas concentrations in the cube

Recordings of CO_2 concentrations in the cube without dates were used to compare the degree of CO_2 loss at different gas-tightness levels as the sealing of the cube was improved after each test. These results are not reported in this paper. Fig. 4 shows the CO_2 concentrations within the cube containing dates over a period of about 4.5 months. The level of CO_2 remained at ~ 85% for the first 10 days and decreased to ~ 60%, while the O_2 level was about 4% at the outset and rose to 7%. These O_2 concentrations were used as set-points for the monitoring system.

Quantity of gas required to create the CO_2 based controlled atmosphere

To create the CO_2 enriched atmosphere 180 kg CO_2 (equivalent to 98.6 m^3 of gas at 30ºC) were used in the trial with dates. This is equivalent to an initial CO_2 concentration of 92%. Actually, at the outset an average concentration of 87.8% was recorded in the cube. The difference between the calculated (92%) concentration and the measured average (87.8%.), could have been caused by the absorption of the gas by the dates, the wooden pallets, and the plastic boxes.

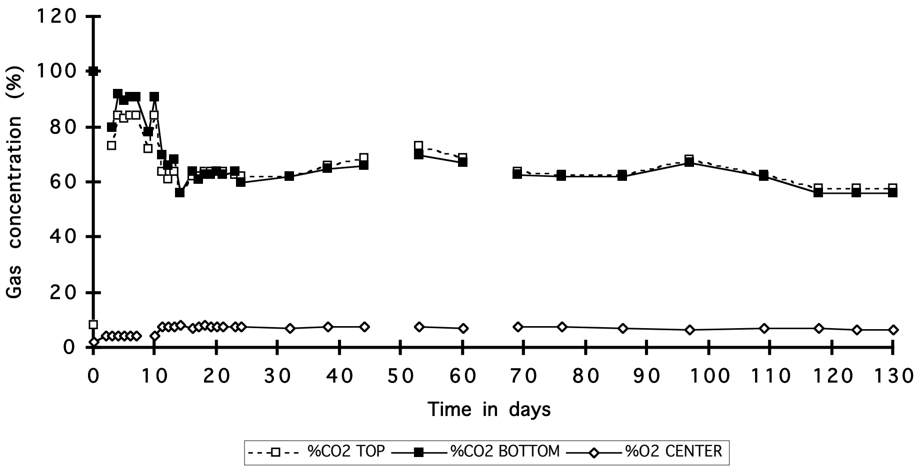

Fig. 4. Changes in carbon dioxide concentration in the 151 m^3 capacity plastic storage enclosure containing 30 tonnes of dates stored for 4.5 months.

Balance of the CO_2 losses during storage

To maintain a constant concentration over 4.5 months of storage 4 CO_2 cylinders per day were required, equivalent to a consumption of 0.8 kg CO_2/day (438 L/day). When liner specification for CO_2 permeability, and the calculated surface area of the cube are taken into account, loss of CO_2 through the plastic cover was calculated to be 202 L/day. The difference between the theoretical amount of gas to be supplied (202 L CO_2/day), and the actual amount required to maintain the target concentration

(438 L/day) indicates the existence of leaks that were not discovered and through which the gas escaped.

The relation between the degree of gastightness and CO_2 losses

To express gastightness in terms of half-life time of pressure decay, the average CO_2 losses per day were calculated after each purge. The results given in Fig. 5, are values for half-life pressure decay plot against the daily % CO_2 losses. It should be pointed out that this test is dependent on the free volume of the structure. From the shape of the curve, it is possible to conclude that in structures of similar size, a half-life pressure decay of less than 10 min can be regarded as critical, since less gastight structures would require the use of large amounts of CO_2 to maintain a constant concentration.

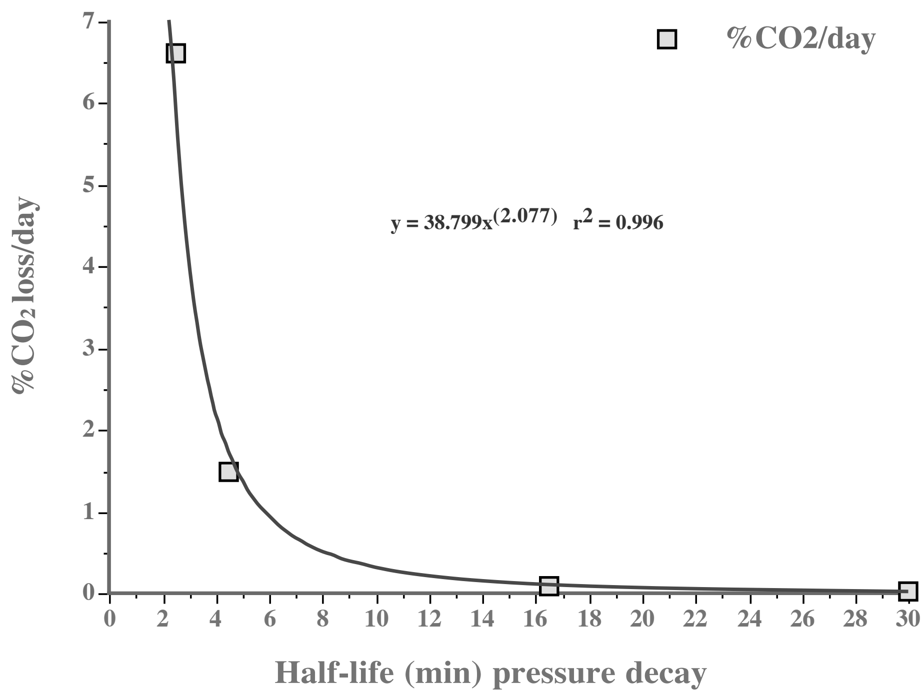

Fig. 5. Degree of gastightness expressed in half-life (min) pressure decay and daily percentage carbon dioxide loss from the 151-m^3 capacity storage enclosure.

CA storage for quality preservation of dates

In this trial date quality was preserved under CA at temperatures ranging between 22 and 28ºC. Tests for presence of insects and molds revealed no development during storage in the cube. Water activity of dates remained low from beginning to end of storage in the range of 0.55 to 0.64 a_w.

No significant change in sloughing of peel, or in sugar formation on the date surface was observed after 4.5 months of storage. These results support data obtained in a previous study of Zahidi, Ameri and Hallawi dates stored under a CO_2 enriched CA, namely that there was no negative influence as regards increase of sugars, even after 8 months of storage (Navarro *et al*. 1992; 1995).

CONCLUSIONS

Our results showed: i) that the use of CA storage without cooling is feasible; ii) it was found necessary to supply 0.8 kg/day of CO_2 to maintain a concentration of 60 to 80% in the cube; iii) to prevent further CO_2 loss the degree of gas tightness should ensure a half-life pressure decay of not less than 10 min; iv) the level of moisture in the dates did not change and no reduction in quality was observed throughout the 4.5 month storage period.

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