

Chemical Changes during Storage of 'Barhi' Dates under Controlled Atmosphere Conditions

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Abstract. Mature 'Barhi' dates (*Phoenix dactylifera* L.) were stored in air or under controlled atmosphere (CA) storage conditions with 5%, 10%, or 20% carbon dioxide concentrations (balance air) during storage at 0 °C. CA conditions extended date storability by maintaining fruit quality. Fruit quality was maintained for 26 weeks when stored in 20% CO₂, 17 weeks in both 5% and 10% CO₂, and 7 weeks in air. Treatment with 20% CO₂ maintained fruit color, firmness, SSC%, total sugar content, and total tannins. CO₂ treatment also reduced degradation of caffeoylshikimic acid (CSA), which is one of the major phenolic compound of date fruit. This study indicates that 'Barhi' dates could be stored under CA conditions in cold storage with good eating quality for 17 to 26 weeks.

Date palm (*Phoenix dactylifera* L.), the tree of life, is the major fruit tree in most Arabian countries and it is widely grown in the middle eastern countries. Some date fruit cultivars are consumed at full mature stage while others are consumed at ripening stage. 'Barhi', the most popular cultivar worldwide, is marketed and consumed at the full mature stage of development. However, its economical value decreases sharply when it ripens as surplus production has to be sold at lower prices. A strategy for producers could be to export dates to foreign markets, but requires application of modern technology to handle and store fruit at the full mature stage to delay fruit ripening. Few trials have been carried out to maintain fruit quality during storage of dates, including low temperature (Hassan and El-Sheemy, 1989; Hegazy et al., 2003), coating with polypropylene films (Thompson and Abboodi, 2003), or using polyethylene bags (Attia et al., 1997). However, responses of fruit quality to these treatments have been limited.

Fully mature soft dates initially have a high moisture content (Coggins and Knapp, 1969) that is comparatively much higher than the critical value of 23% for yeast fermentation and fungal attack (Rygg et al., 1953). In addition, dates at full mature stage are rich in antioxidants, especially phenol compounds (Modafar et al., 2000; Ramos et al., 1997). Tannin contents, which are the most dominant phenol compounds in date fruit, decline as the fruit ripen (Rouhani and Bassiri, 1976; Sawaya and Mashadi, 1983).

The use of elevated CO₂ in the storage atmosphere for maintaining fruit quality has

been described (Al-Redhaiman, 2002; El-Rayes and Ahmed, 2001; Kader, 1980). Optimal MA combinations have been developed for different species, and even cultivars within the same species (Kader, 1997). Although the effect of modified atmosphere (MA) treatments on quality preservation and control of nitidulid beetles of dried date fruit has been studied (Navarro et al., 1998), no information about responses of soft fully mature dates is available.

Our objective was to determine the possible use of carbon dioxide as a postharvest treatment to extend the storage period while maintaining the quality or the chemical composition of full mature 'Barhi' dates.

Materials and Methods

Plant material. Seven mature 'Barhi' date palms grown at the experimental research station, College of Agriculture, King Saud University, Buraidah, Al-Qassim, the Kingdom of Saudi Arabia, were selected for the study. All palms were almost of the same age and uniform in growth. The palms were in good physical condition, free from insect damage and diseases and were subjected to the same management treatments.

Fruit were harvested at full mature stage, according to skin color (the whole fruit should be yellow, and the yellowish green area should not exceed 10%) and soluble solids content (SSC) >28% (Hegazy et al., 2003). Immediately after harvest, fruit were transported to the postharvest laboratory where those of similar shape, color, and degree of development were divided into groups and were wiped free of dirt and kept immediately at 0 °C.

Treatments. Five replications of each treatment were stored in well sealed gas tight glass containers equipped with inlet and outlet valves, and CO₂ was injected from gas cylinders to provide concentrations of 5%, 10%, or 20% CO₂ in air. Supply and exhaust CO₂ gas composition

was monitored using a gas chromatograph (Carle analytical series S). Air storage was used as a control for all of the experiments. All containers were stored at 0 °C.

Analyses

Monthly samples (10 fruit per replication) were removed and frozen immediately for determinations of total tannin, sugars (reducing and nonreducing), and caffeoylshikimic acid (CSA) contents. Each treatment was terminated when the number of ripe fruits in each spike exceeded the number of the unripe fruit.

SSC was measured with a temperature-compensated refractometer (RFM 110; Bellingham + Stanley LTD, Lawrenceville, Ga.). Reducing and non-reducing sugars were determined colorimetrically according to Dubois et al. (1956) using a spectrophotometer (Ez301; Perkin Elmer, Shelton, Conn.). Total tannin content was determined according to the Association of Official Agricultural Chemists (1975).

CSA extraction was carried out using Soxhlet extractor (Electrothermal-Ectromantle ME, England) at 40 °C for 6 h using 10 g of sample powder (samples were ground three times for 15 s in an analytical mill (Grindomix GM200; Retsch, Haan, Germany), and 200 mL of ethyl acetate solvent. The crude solvent extracts were filtrated through Whatman No. 1 filter paper and then dried using a vacuum rotary evaporator (Buchi 011; Buchi, Switzerland) below 40 °C. CSA was measured by using HPLC system consisting of a Consta METRIC 4100 series pump, spectra series AS-100 auto sampler, spectra system FL 3000 fluorescence detector. Column used was a reversed-phase water Spherosorb ODC-2 (3 µm; 150 mm × 4.6 mm i.d., Alltech). The HPLC conditions were as follows: injection volume = 20 µL, detector = Fluorescence Ex 250 to 400 nm, mobile phase = 12 methanol : 88 ammonium acetate (v/v at pH 5.4), and flow rate = 1 mL·min⁻¹.

Statistical analysis. Data were analyzed using a complete randomized block design with five replicates per treatment, using the Student-Newman-Keul's test. The least significant differences were used to compare means at $P \leq 0.05$ according to the procedure outlined by Snedecor and Cochran (1980). The experiment was carried out for two successive seasons.

Results and Discussion

Storage period. Elevated CO₂ extended the storage period of fully mature 'Barhi' date fruit (Table 1) by retarding ripening and senescence.

Table 1. Storage period of 'Barhi' date fruit stored at 0 °C under different carbon dioxide concentrations.

CO ₂ concn (%)	Storage period (weeks)
0.03	7 a
5	17 b
10	17 b
20	26 c

Means in the same column with different letters are significantly different ($P \leq 0.05$). Each value in the table is the mean of five replications, and three measurements were conducted for each replication.

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Control fruit started to lose their eating quality after 7 weeks of storage and were discarded after two months. A CO₂ concentration of 20% extended the stored period of fruit 3.71 times that of control fruit. The effect of CO₂ was proportional to its concentration.

Sugar content. The total sugar content in the fruit at the beginning of the experiment was 75.3% (dry weight basis) and increased at different rates during storage depending on the treatment (Fig. 1A). The highest rate of change occurred in control fruit while the lowest increase occurred in fruit stored in 20% CO₂.

Nonreducing sugar contents were relatively low at the beginning of the storage period, (6.5% on a dry weight basis). Contents decreased slightly in fruit from all treatments during the first month of storage (Fig. 1C). However, as the storage period proceeded, they dropped very rapidly in air-stored fruit to undetectable levels. CO₂ in the storage atmosphere reduced this loss, the greatest effect being observed at 20% CO₂.

In contrast reducing sugar contents increased rapidly in air stored fruit and this increase was inhibited by elevated CO₂ (Fig. 1B).

A decrease in the sucrose content at the later stage of maturity and the increase in the reducing sugars values are synchronized with the rising activity of the invertase enzyme which is a characteristic of all date cultivars (Sawaya and Mashadi, 1983). The action of CO₂ on these processes may be associated with lower rates of respiratory metabolism.

Total tannin contents. The more advanced stage of ripening, the lower the fruit tannin contents decreased as fruit ripening advanced and these changes were delayed by elevated CO₂ (Fig. 2A).

Soluble solid content. SSC was not affected

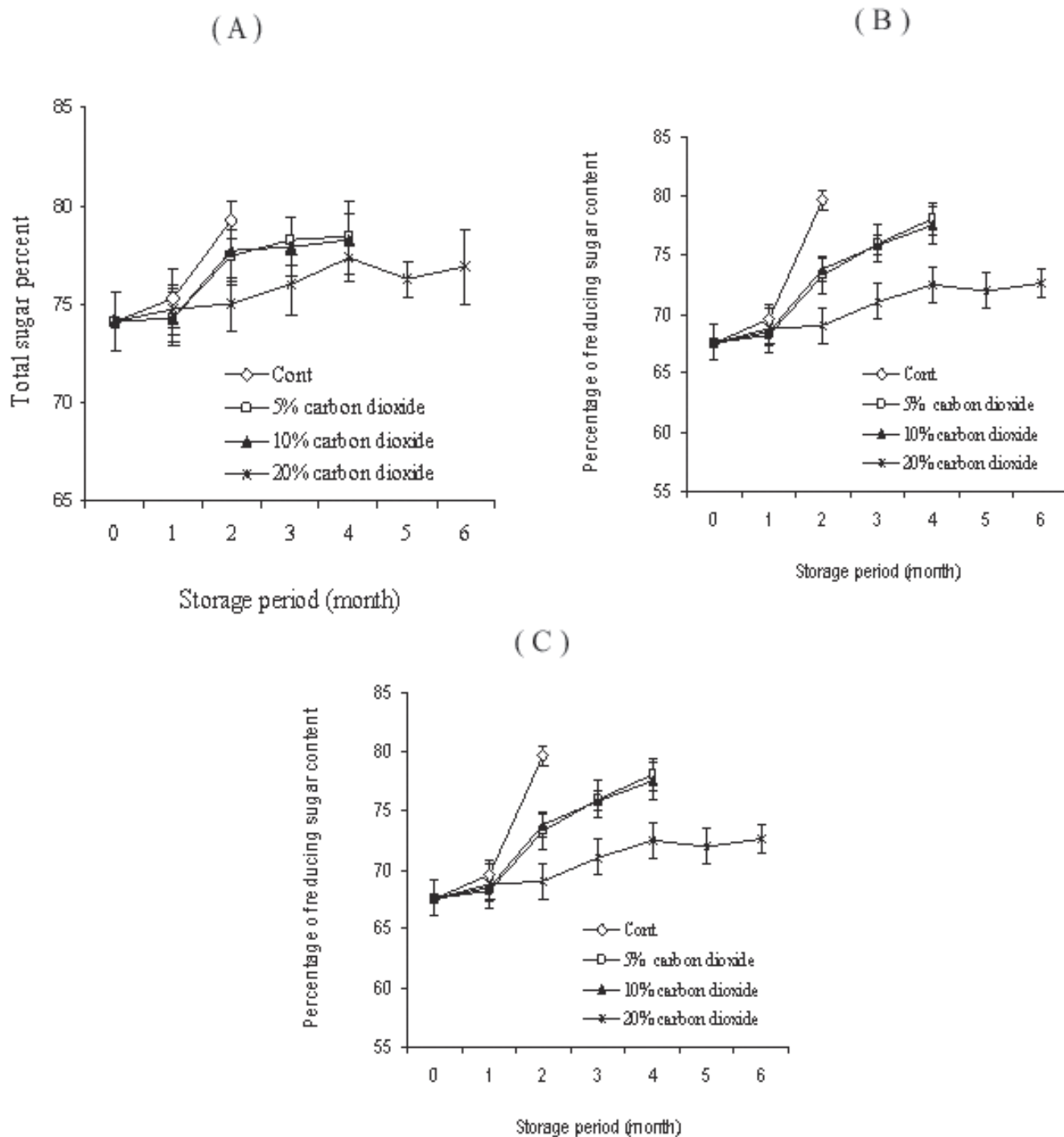


Fig. 1. Effect of different CO₂ treatments on (A) total sugars (%), (B) reducing sugars (%), and (C) nonreducing sugars (%) of 'Barhi' dates stored at 0 °C. Vertical bars show SE values of five replications. Three measurements were conducted for each replication.

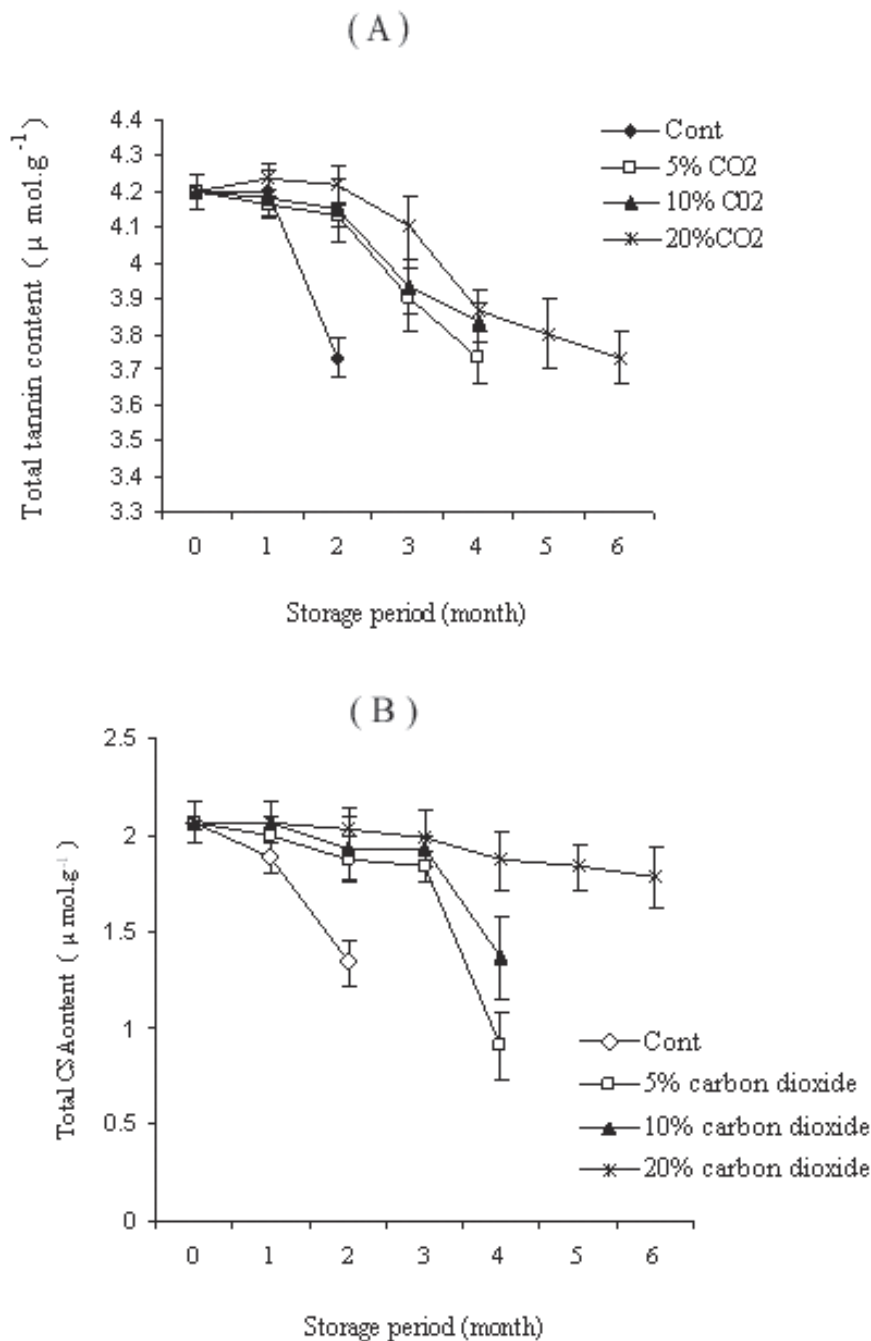


Fig. 2. Changes in (A) total tannin content ($\mu\text{mol}\cdot\text{g}^{-1}$) dry weight) and (B) caffeolshikimic acid (CSA) content ($\mu\text{mol}\cdot\text{g}^{-1}$) in 'Barhi' dates stored at $0\text{ }^{\circ}\text{C}$ under different CO_2 concentrations. Verticle bars show SE values of five replications. Three measurements were conducted for each replication.

by treatment (data not shown), perhaps because this factor was only slightly affected by ripening; the overall average SSC for mature unripe and ripe fruit was 28% and 30%, respectively. At the third and fourth month of the storage period, a slight increase in SSC occurred in most treatments after 3 and 4 weeks of storage. This increase could be due to the conversion of some insoluble compounds into soluble compounds (such as the conversion of proto pectin into pectin), or as a result of greater weight loss of fruit and thus lower moisture content as shown by Thompson and Abboodi (2003).

Fruit caffeoylshikimic acid content. CO_2 treatments increasingly retarded loss of SCA

as storage periods increased (Fig. 2B). CSA contents are associated with fruit ripening with maximum concentrations occurring at full mature stage and lowest content occurring in fully ripe fruit (Regnault et al., 1987).

Conclusion

The postharvest storage period possible for 'Barhi' date fruit can be markedly improved by exposure to elevated CO_2 concentrations up to 20% CO_2 . These conditions maintained tannin contents of the fruit but did not affect SSC of the fruit. Overall, these results suggest that a modified atmosphere system could be devel-

oped for mature date fruit to retard ripening and senescence and allow shipping of fruit to distant markets with acceptable quality.

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