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# Extension of Postharvest Life of 'Mission' Figs by $CO_2$-enriched Atmospheres

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*Additional index words.* controlled atmosphere, quality, decay, respiration, ethylene, ethanol, acetaldehyde, *Ficus carica*

***Abstract.*** **Good quality of fresh 'Mission' figs *(Ficus carica* L.) was maintained for up to 4 weeks when kept at 0, 2.2, or 5C in atmospheres enriched with 15% or 20% $CO_2$. The visible benefits of exposure to high $CO_2$ levels were reduction of decay incidence and maintenance of bright external appearance. Ethylene production was lower, and fruit softening (as measured with a deformation tester) was slower in the high-$CO_2$-stored figs than in those kept in air. Ethanol content of the $CO_2$-treated fruit increased slightly during the first 3 weeks and moderately during the 4th week, while acetaldehyde concentration increased during the first week, then decreased. The results may be applicable to the transport and storage of fresh 'Mission' figs, as high $CO_2$ extended their postharvest life, especially near 0C.**

Figs are grown commercially in most Mediterranean countries, as well as in California. Most of the production is used as dried figs because the high perishability of fresh figs makes them difficult to store and/or ship to expand the potential markets. The fig has been reported to be a climacteric fruit (Biale and Young, 1981; Marei and Crane, 1971), although Claypool and Ozbek (1952) observed no respiratory climacteric peak, and Ryall and Pentzer (1982) classify them as nonclimacteric. Several studies have shown the effectiveness of ethylene in enhancing fig maturation and ripening (Crane et al., 1970; Marei and Crane, 1971; Maxie and Crane, 1968).

Very little research has been done to identify the optimum environmental conditions for extending postharvest life of fresh' figs. The most important cause of deterioration is incidence of microbial molds and rots that take advantage of the easily damaged epidermis and the high sugar content of figs. Claypool and Ozbek (1952) showed the effectiveness of storage temperatures below 5C in reducing the metabolic activity. Several authors (Condit, 1947; Hardenburg et al., 1986; Ryall and Pentzer, 1982) recommend a storage temperature of 0C to achieve a 7- to 10-day postharvest life. Claypool and Ozbek (1952) reported that storage in atmospheres containing up to 60% $CO_2$ at 20C was of little value, but an initial 36-h pretreatment with 100% $CO_2$ at 5 and 10C delayed the growth of microorganisms.

During the 1986, 1987, and 1989 seasons, studies were conducted to evaluate the effectiveness of holding fresh 'Mission' figs in a $CO_2$-enriched atmosphere to extend their postharvest life and maintain fruit quality. Since the results were similar in the three seasons, we report here only the 1989 data on the effects of temperature and $CO_2$ level on postharvest physiology, decay control, and quality attributes of fresh 'Mission' figs.

*Materials and treatments.* Fresh, ripe 'Mission' (also known as 'Black Mission') figs were harvested from a commercial orchard in Winters, Calif., on 29 Aug. 1989 and transported within 1 h to the laboratory in Davis. On the same day, the figs were sorted to eliminate those with defects, and matched samples were selected for the various treatments. For measuring respiration and $C_2H_4$, production rates, 10 fruit were placed into a 2-liter glass jar as one replicate, with three replicates used per treatment. The jars were then placed at 0, 2.2, and 5C and ventilated with a continuous flow of humidified air or air enriched with 15% or 20% $CO_2$. For quality evaluations, 20 fruit were placed in a 10-liter glass jar as one replicate, with three replicates used per treatment. The jars were kept under the same conditions as mentioned above.

*Gas analysis.* The desired $CO_2$ concentrations were verified daily by analyzing 10-ml gas samples with a Carle gas chromatograph (EG&G Chandler Engineering, Tulsa, Okla.) equipped with a thermal conductivity detector. Measurements of $CO_2$ production rates of fruit kept in air were made on alternate days using a model SX-2 Horiba infrared $CO_2$ gas analyzer (Horiba Instruments, Irvine, Calif.). Ethylene production rates for all the treatments were measured on alternate days by analyzing 10-ml gas samples using a Carle gas chromatograph equipped with a flame ionization detector.

*Quality evaluation.* Quality attributes, evaluated on separate samples initially and after 1, 2, 3, and 4 weeks in storage, included overall visual appearance, flesh firmness, external and internal decay incidence, and ethanol and acetaldehyde concentrations. Overall visual quality was rated on a scale of 9 = excellent, 7 = very good, 5 = good (limit of marketability), 3 = fair (limit of usability), and 1 = very poor. Flesh firmness was measured as deformation of the fruit after 45 sec under a constant 400-g load, using a deformation tester made in our laboratory. The number of fruit exhibiting external and/or internal decay was noted. The juice of five figs was extracted with a handpress juicer. Ethanol and acetaldehyde contents were measured on a 5-ml juice sample (per replicate) using a HP5890A gas chromatograph (Hewlett Packard, Palo Alto, Calif.) equipped with a flame ionization detector (at 250C) and a glass column (2 mm × 1.8 m) containing 5% Carbowax on 60/80 Carbopack as stationary phase (at 85C).

*Respiration and $C_2H_4$ production.* Respiration rates decreased with the decrease in storage temperature (Fig. 1). No climacteric rise in respiration was detectable because fruit were already in a postclimacteric stage at the time of harvest. High $CO_2$ levels greatly reduced $C_2H_4$ production (Fig. 2). The difference in $C_2H_4$ production rates between figs kept in 15% and 20% $CO_2$-enriched atmospheres was small at 5C and almost undetectable at 0C. Elevated $CO_2$ levels are known to inhibit $C_2H_4$ action and they could affect autocatalytic $C_2H_4$ biosynthesis together with all the ripening processes that $C_2H_4$ stimulates.

*Visual overall appearance and decay incidence.* Figs kept in 15% or 20% $CO_2$-enriched atmospheres generally showed a better overall appearance than the control fruit for the duration of the experiment at 5C and after 2 weeks at 2.2C (Fig. 3). The effect of $CO_2$-enriched treatments was greatest at 5C, where fruit kept in air deteriorated to the limit of marketability score after only 2 weeks, while the figs kept in 15% or 20% $CO_2$ were scored higher than 5 up to the end of the 4th week. After 24 h at 20C following each storage duration, fruit quality decreased but treatment differences followed the same pattern, and fruit from high-$CO_2$ treatments remained above the limit of marketability (data not shown).

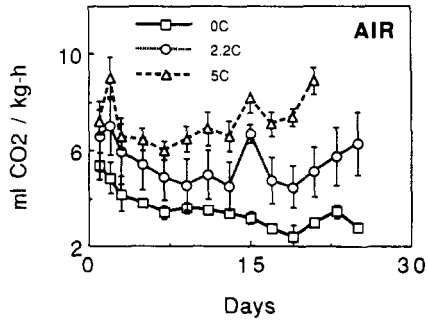


Fig. 1. Effect of temperature on rate of $CO_2$ production of 'Mission' figs (vertical bars = SD).

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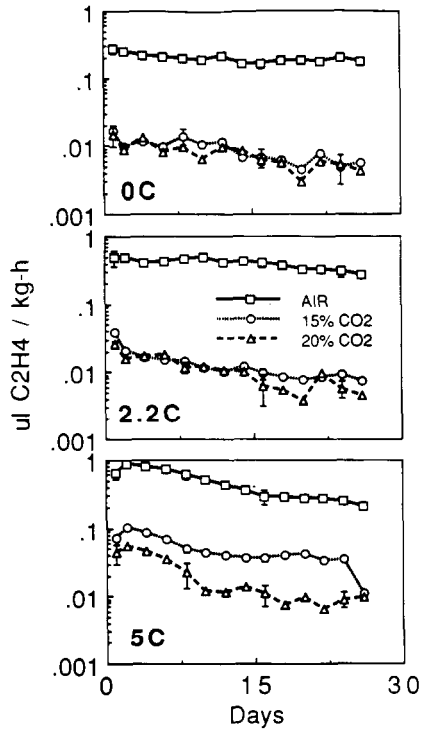


Fig. 2. Effect of temperature and $CO_2$ concentration on $C_2H_2$ production rate of 'Mission' figs (vertical bars = SD).

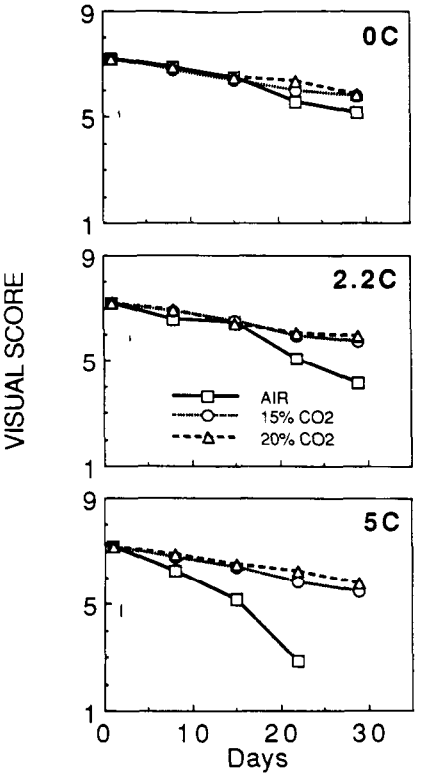


Fig. 3. Effect of temperature and $CO_2$ concentration on appearance of 'Mission' figs (vertical bars indicate LSD at 1% for treatments at each temperature).

The $CO_2$-enriched atmospheres were also strongly fungistatic. No external or internal decay was observed on any of the figs kept for up to 4 weeks at 0C in air + 15% or 20% $CO_2$, while those stored in air exhibited 40% external decay after 3 or 4 weeks. At 2.2C, external and internal decay were noted on figs kept in air after 2 and 3 weeks, respectively, and affected fruit reached incidences of 80% (external) and 20% (internal) after 4 weeks. Figs held in a $CO_2$-enriched atmosphere showed no decay, except those from the 4-week, 15% $CO_2$ treatment, where the incidence of external decay was 7%. At 5C, fruit kept in air showed both internal and external decay after 1 week in storage; external decay affected 70% of the fruit after 3 weeks, and all fruit had both internal and external decay at the end of the experiment. Figs stored in $CO_2$-enriched atmospheres showed no decay for up to 3 weeks, and ≈ 7% had internal decay at the end of the 4th week. Fruit firmness was not significantly different among treatments at 0 and 2.2C, but was 20% to 30% lower in air-kept figs than in $CO_2$-treated figs at 5C (data not shown).

*Ethanol and acetaldehyde production.* Fruit stored in air enriched with 15% or 20% $CO_2$ produced more ethanol than the fruit kept in air (Fig. 4). The increase in ethanol content due to high-$CO_2$ treatments was below 50% during the first week at 5C and 2 to 3 weeks at 0 and 2.2C, but exceeded 50% during the 4th week at 0 and 2.2C and after 2 weeks or longer at 5C. Ke et al. (1991) reported that the threshold ethanol concentration at which off-flavors are detected in fruit increases with the increase in their soluble solids concentrations. Since fresh figs have a relatively high soluble solids concentration (15% to 20%), even the high ethanol levels found after 4 weeks of storage might not have caused detectable off-flavors.

A sharp increase in acetaldehyde concentration occurred in figs kept in air + 15% or 20% $CO_2$ by 1 week of storage. Subsequently, the acetaldehyde content either decreased sharply at 5C or remained generally high at 0C (Fig. 5). After 4 weeks at 5C, the acetaldehyde content returned to near its initial level. After 4 weeks at 0C, the acetaldehyde level was still more than double its initial value. At 2.2C, the pattern was about midway between those observed at 0 and 5C. These trends may be due to increased acetaldehyde metabolism with increasing temperature.

*Conclusion.* The postharvest life of fresh 'Mission' figs potentially can be extended by holding them at 0 to 5C in atmospheres enriched with 15% to 20% $CO_2$. Under such atmospheres, the postharvest life (based on all quality attributes) of fresh figs can be extended to 2 or 3 weeks (with the longer duration at 0C). While it is possible to maintain visual quality and firmness of fresh figs for 4 weeks, the potential for off-flavor development (resulting from ethanol accumulation) may negate the other benefits of $CO_2$-enriched atmospheres.

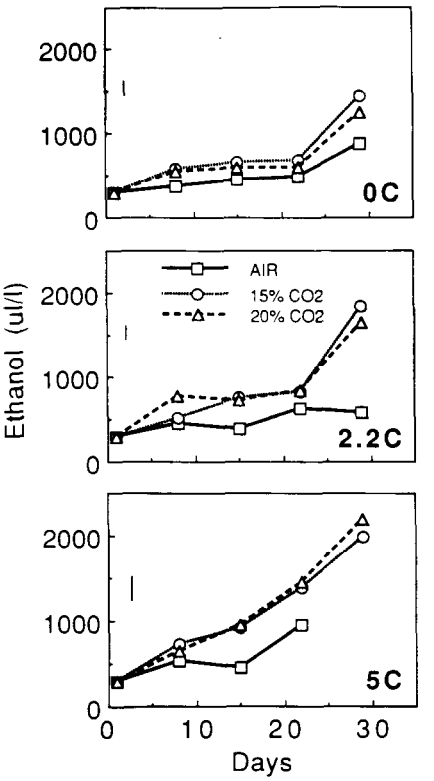


Fig. 4. Effect of temperature and $CO_2$ concentration on ethanol concentration in 'Mission' figs (vertical bars indicate LSD at 1% for treatments at each temperature).

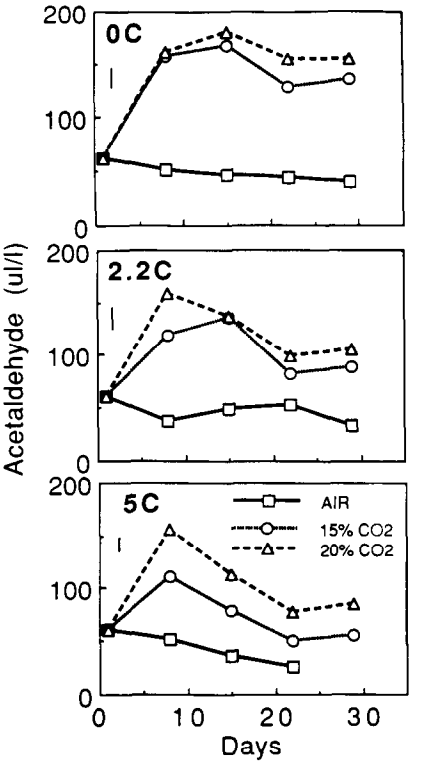


Fig. 5. Effect of temperature and $CO_2$ concentration on acetaldehyde concentration in 'Mission' figs (vertical bars indicate LSD at 1% for treatments at each temperature).

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