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## EFFECT OF LOW-OXYGEN ATMOSPHERE ON STORAGE BEHAVIOUR OF KIWIFRUIT

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### Abstract

Storage behaviour of "Hayward" kiwifruit was evaluated during and after storage for 88, 133, 200 and 250 days in 0.5% O<sub>2</sub>, 1% O<sub>2</sub>, 1% O<sub>2</sub> + 1% CO<sub>2</sub> and air at 0° C. Flesh firmness, soluble solids content, weight losses, flesh colour, acetaldehyde content, ethanol content and flavour index were measured. Flesh firmness of kiwifruit decreased during storage. Fruits stored in 1% O<sub>2</sub> + 1% CO<sub>2</sub> retained a satisfactory level of firmness (1.5kg), were firmer than the other treatments and showed the lowest weight losses. Soluble solids content was increased in all treatments. Flesh colour changes of fruits stored in 1% O<sub>2</sub> + 1% CO<sub>2</sub> were less pronounced than other treatments. Upon removal all fruit treated with low oxygen showed considerable amounts of acetaldehyde and ethanol content, whereas the control fruit showed small amounts of acetaldehyde and ethanol content. Acetaldehyde and ethanol content of fruits stored in 0.5 O<sub>2</sub> was higher than other treatments. After a 7-day shelf life of fruits (at 20° C) ethanol content decreased but not entirely. The flavour index of fruits stored in O<sub>2</sub> was lower than that of fruits stored in other atmosphere compositions.

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### 1. INTRODUCTION

Kiwifruit (*Actinidia chinensis* Planch) cultivar "Hayward" has been grown as an important crop in Greece, as well as in other countries. The increase of production in the last ten years created problems in the handling and distribution of fruits.

Under optimum conditions, particularly in the absence of ethylene, kiwifruit can be stored for 4-6 months at 0° C, during which time the firmness of the fruit declines rapidly from 80 to 30 N in 4 - 6 weeks, and then much more slowly to about 10N (Arpaia *et al.*, 1987). Ethylene as well as propylene influences the rate of softening in air storage (Arpaia, 1980; Arpaia *et al.*, 1986; Mitchell *et al.*, 1981; Reid and Harris, 1988; Sfakiotakis *et al.*, 1989).

CA storage (2 %O<sub>2</sub> + 5% CO<sub>2</sub>) retards softening of kiwifruit at 0°C (Arpaia, 1980; Arpaia *et al.*, 1984; 1986, 1987) as long as the ethylene is excluded (McDonald

and Harman, 1982; Arpaia *et al.*, 1985). Commercial application of CA storage in Greece or Italy showed that the fruit does not ripen evenly and the eating quality is inferior in comparison with the air-stored fruit.

The objective of this study was to examine the effects of ultra low oxygen (UL) (0.5% O<sub>2</sub>, 1% O<sub>2</sub>, 1% O<sub>2</sub>, 1% O<sub>2</sub> + 1% CO<sub>2</sub>) in the storage performance of kiwifruit. Since it has been shown that ULO in several fruit causes injuries by creating anaerobic conditions through acetaldehyde and ethanol production, we included in our study measurements of acetaldehyde and ethanol after storage.

## 2. MATERIAL AND METHODS

### *Harvest and preparation of fruit*

Fruit from mature kiwifruit "Hayward" vines were harvested, from established vineyards in Pieria, North Greece, when their soluble solids content was 10.3% and transported to the Postharvest Pomology Research Facility at the University Farm in Thessaloniki. The fruit were sorted for defects. Thirty six lots of 15 fruits (9 for each treatment) were weighted and dipped for 10 sec. in suspension of benomyl (600 ppm) for decay control. Nine lots of 15 fruits were put into each of 6 airtight 200 L metal chambers in a cold room at 0° C. Each chamber was equipped with an inlet and outlet port-hole connected to compressed cylinders with N<sub>2</sub>, O<sub>2</sub> + CO<sub>2</sub>. Ethysorb (1.5 kg) was placed in a tray to scrub ethylene from each chamber. After sealing the chambers, the desired treatments of CO<sub>2</sub> and O<sub>2</sub> (0.5% O<sub>2</sub>, + 99.5% N<sub>2</sub>, 1.0% O<sub>2</sub> and 99% N<sub>2</sub>, 1.0% O<sub>2</sub> + 1.0% CO<sub>2</sub> + 98%N<sub>2</sub> and control (21% O<sub>2</sub>) were attained within a few hours by mixing gases from cylinders. The concentrations O<sub>2</sub> and CO<sub>2</sub> were monitored by an infrared and paramagnetic gas analyser, connected through an interface to an Apple Macintosh IIcx Computer. The computer activating valves automatically adjusted the gas concentration to the desired values.

At harvest and upon each fruit removal from CA storage, flesh firmness, soluble solids content, weight losses, flesh colour, acetaldehyde and ethanol content were measured. Fruits removed from the storage were kept at 20° C for seven days. After this shelf life period, a test panel was done by twelve people in order to determine taste and aroma score.

Measurements of flesh firmness were made with a Chatillon penetrometer (7.9 mm tip) on opposite paired sides, removing the skin of the fruit.

Juice extracted from two flesh sections of each fifteen fruits was used for soluble solids (Brix) measurements. Soluble solids content was determined using an Atago Model PR-1 (Atago Co, Ltd. Tokyo) digital electronic refractometer.

Flesh colour was measured with a Minolta Chromameter CR 200 using samples of fifteen fruits after harvest and upon the removal from storage. Two measurements were taken on opposite paired sides, removing the skin of the fruit.

The determination of acetaldehyde and ethanol content were made by gas chromatographic analysis of head-space according to Davis and Chase (1969). Fruit juice was extracted by a hand-press juicer and frozen until use. Thawed juice (95 ml) was placed in a test tube which was sealed with a plastic septum and incubated after in water bath at 60° C for 60 min. A 1 ml-head-space sample was withdrawn with a syringe and injected in a Varian 3000 gas chromatograph with FID at 250° C, glass column (2.8 mm x 1.8 m) containing 5% Carbowax 20M on 60/80 Carboback. The flow rate of carrier gas (N<sub>2</sub>) was 20 ml/min and oven temperature was 85° C.

A twelve-member panel was involved in the evaluation of taste and aroma score which was made after seven days of shelf life of fruits kept at 20° C. A scale 0-5, where: 5 = excellent; 4 = good; 3 = fair; 2 = moderate; 1 = tasteless and 0 = without / or bad aroma (generally unacceptable), were used for the test panel.

### 3. RESULTS

Flesh firmness of kiwi fruits was decreased with storage duration. Fruits in 1% O<sub>2</sub> + 1% CO<sub>2</sub> were firmer (1.5 kg) than fruits stored in 0,5% O<sub>2</sub>, 1% O<sub>2</sub> and control (0.3 - 0.2 kg) after nine months of storage (Fig. 1A).

Soluble solids content was increased in all treatments. The increase of soluble solids was more pronounced during first 3 months and after that period it was almost stable (Fig. 1B).

Weight losses were increased with storage duration in all treatments. Fruits stored on 1% O<sub>2</sub> + 1% CO<sub>2</sub> showed significantly lower weight losses than other treatments. Weight losses of fruit stored in air at 0° C as control were the highest (Fig 2A).

Flesh colour changed during low oxygen storage of kiwifruit and there was an increase of a\*-value and a decrease of b\* -value as storage duration increased. Colour changes of fruits stored in 1% O<sub>2</sub> + 1% CO<sub>2</sub> were less pronounced than other treatments (Fig. 2B).

Acetaldehyde content of kiwifruits stored in 0.5% O<sub>2</sub> was higher than fruits stored in 1% O<sub>2</sub>, 1% O<sub>2</sub> + 1% CO<sub>2</sub> and control. Acetaldehyde content of fruits during the first period of storage was increased with storage duration but upon the final removal it was the same or lower than previous removals (Fig. 3A).

During shelf life (7 days at 20° C) acetaldehyde content was decreased in all treatments but in many cases it remained the same high or slightly lower than the content upon the removal of the fruits from storage (Fig. 3B).

Ethanol content of fruits stored in 0.5% O<sub>2</sub> was higher than ethanol content of fruits stored in other atmospheres. Ethanol increased with storage duration (Fig. 4A). After shelf life of fruits (7 days at 20° C) ethanol content significantly decreased but it did not remove entirely (Fig. 4B).

Flavor index of kiwi fruits stored in 1% O<sub>2</sub> was higher than flavour index of fruits stored in 0.5% O<sub>2</sub>, 1% O<sub>2</sub> + 1% CO<sub>2</sub> and control (21% O<sub>2</sub>) (Fig. 5). Fruits stored in 1% O<sub>2</sub> + 1% CO<sub>2</sub> did not ripe well after removal from storage. Good ripening was achieved when ethylene was applied after removal of fruits from storage. The lowest flavour score was that of fruits stored in 0.5% O<sub>2</sub>.

#### 4. DISCUSSION

The extent to which controlled atmosphere is beneficial or quality maintenance of kiwi fruits depends upon the maturity stage, initial quality, concentrations of oxygen, carbon dioxide and ethylene during storage, temperature and duration of the exposure to those conditions. Although kiwi fruits at harvest stage produce negligible amount of ethylene they are sensitive to exogenous ethylene. During storage, ethylene has to be maintained below 0.05 ppm (Arpaia *et al.*, 1986).

Controlled atmospheres (0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub>) storage of kiwi fruits at 0° C retarded flesh softening compared to storage in the air.

Elevated levels of CO<sub>2</sub> counteracted ethylene production and ripening. Also, the sensitivity of the fruit to ethylene was greatly reduced under low O<sub>2</sub>, elevated CO<sub>2</sub> and low temperature conditions during storage.

Controlled atmospheres, particularly those containing high CO<sub>2</sub>, inhibit breakdown of pectic substances so that a firmer texture is retained for a longer period of storage (Wills *et al.*, 1981).

Soluble solids content was increased during storage due to starch to sugar conversion. The need of gas-tight environment for CA storage and high relative humidity around fruits resulted in reduced water losses and their consequences. Controlled atmosphere 1% O<sub>2</sub> + 1% CO<sub>2</sub> was more effective on weight loss reduction than other treatments.

The improved retention of green colour of the flesh of the fruit stored under low O<sub>2</sub> and elevated CO<sub>2</sub> concentration (1% O<sub>2</sub> + 1% CO<sub>2</sub>) is mainly due to a lower rate of chlorophyll destruction. High cellular pH caused by elevated CO<sub>2</sub> may reduce the breakdown of chlorophyll to pheophytin. Low sensitivity of fruit tissue to ethylene in the presence of low O<sub>2</sub> and high 1% CO<sub>2</sub> is partly responsible for reduced chlorophyll breakdown (Zagory and Kader, 1989).

Ethanol and acetaldehyde accumulation was high in anoxic conditions during storage but there was not off-flavour development on the commodity. Low levels of O<sub>2</sub> atmospheres like 0.5% O<sub>2</sub> and 1% O<sub>2</sub> cause low production of volatile compounds responsible for aroma development (Streif and Bangerth, 1988).

The taste of the fruit is determined by the types and amounts of carbohydrates, organic acids, aminoacids, lipids and phenolics. CA combinations to the degree that they modify changes of these constituents can affect the taste of stored fruits. Usually, extremely low O<sub>2</sub> or high CO<sub>2</sub> levels result in off-flavour development and reduce quality due to anaerobic respiration.

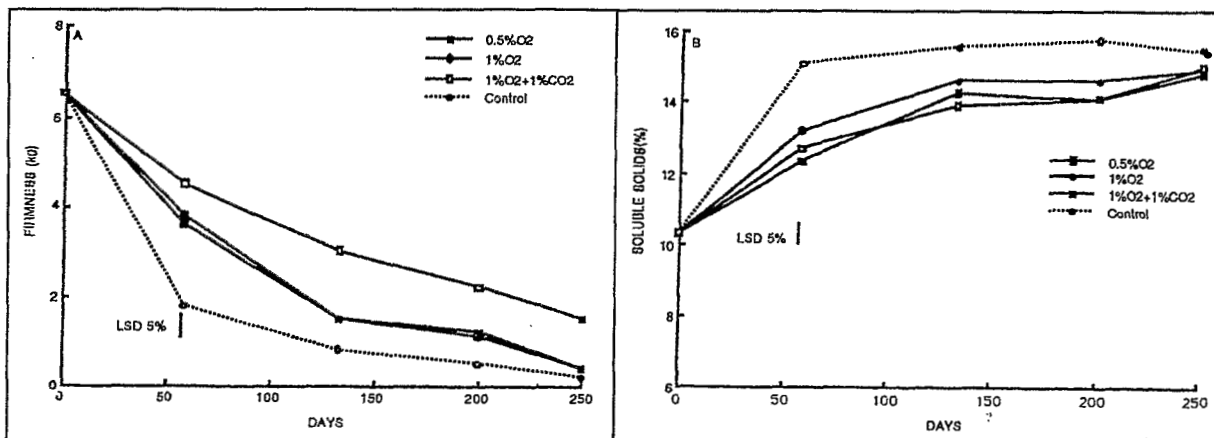
More research is needed to clarify the mechanisms of the influence of low O<sub>2</sub> and high CO<sub>2</sub> on respiratory metabolism, ethylene biosynthesis and action and compositional changes related to quality attributes of fresh fruits.

## ACKNOWLEDGEMENTS

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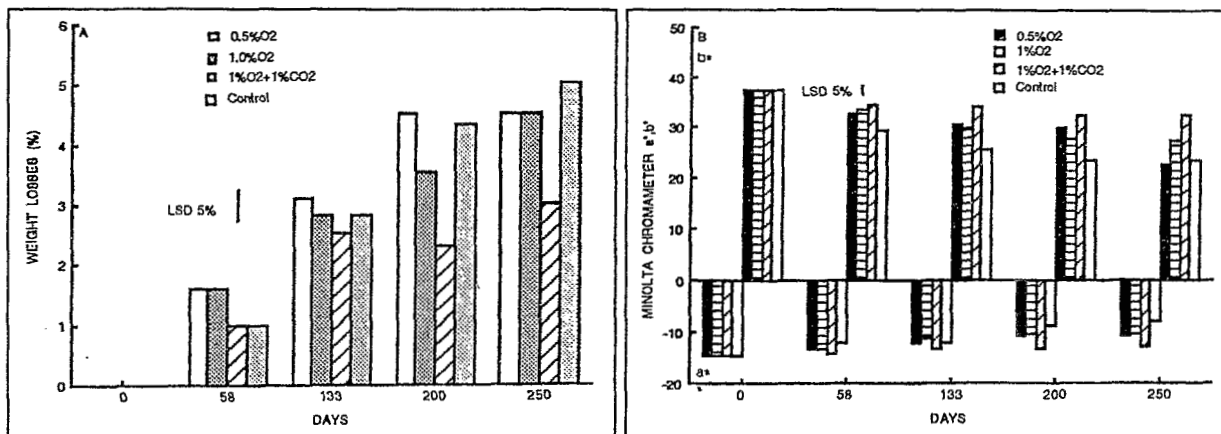
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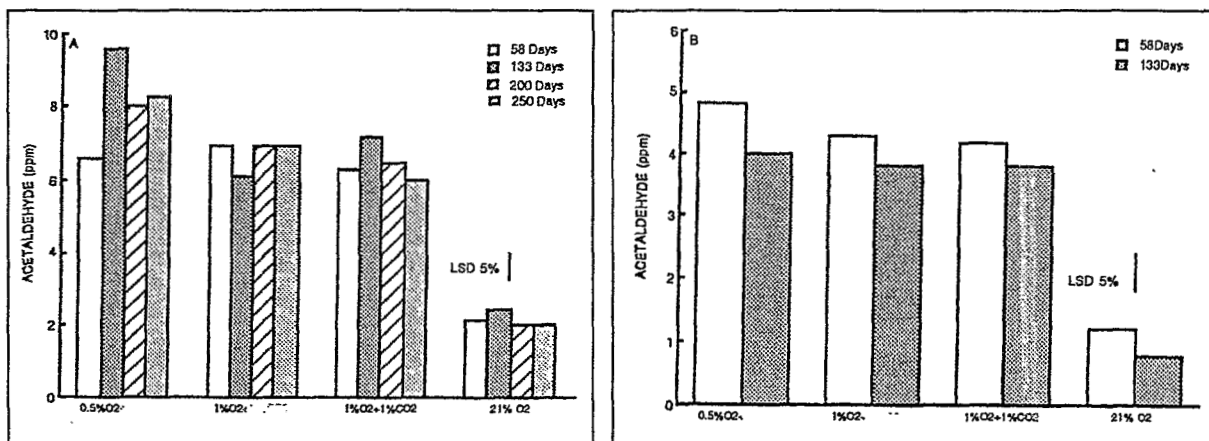


**Fig 1a.** Kiwifruit softening during storage at 0°C in air (control), 0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub>

**Fig 1b.** Soluble solids content changes during storage at 0°C in air (control), 0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub>. LSD values shown were calculated on a 2-way analysis of variance.



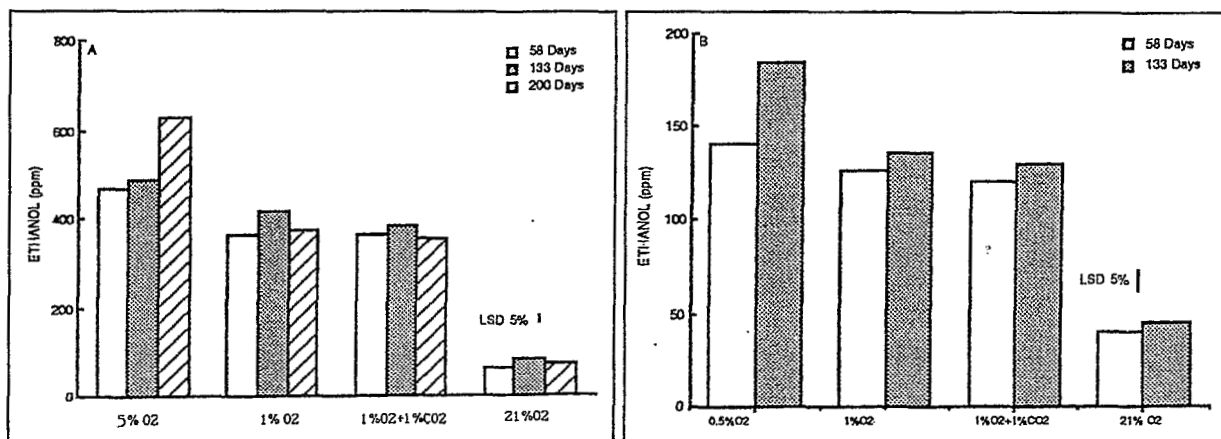
**Fig 2.** Weight losses (A) and color changes (Chromameter a\* and b\* values) (B) of kiwifruit during storage at 0 °C in air (control), 0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub>. LSD values shown were calculated on a 2-way analysis of variance.



**Fig. 3a.** Effects of ULO storage (0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub> and air) on acetaldehyde content of kiwifruit stored for 58, 133, 200 and 250 days.

**Fig. 3b.** Effects of ULO storage (0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub> and air) on acetaldehyde content of kiwifru stored for 58 and 133 days followed by holding in air at 20o C for 7 days.

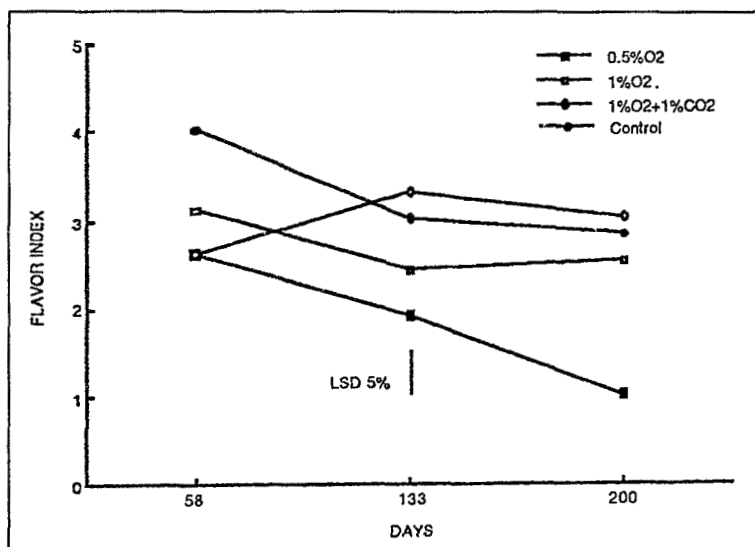
LSD values shown were calculated on a 2-way analysis of variance



**Fig. 4a.** Effects of ULO storage (0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub>+ 1% CO<sub>2</sub> and air) on ethanol content of kiwifruit stored for 58, 133, 200 and 250 days.

**Fig. 4b.** Effects of ULO storage (0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub> and air) on ethanol content of kiwifru stored for 58 and 133 days followed by holding in air at 20 °C for 7 days.

LSD values shown were calculated on a 2-way analysis of variance



**Fig. 5.** Effects of ULO storage (0.5% O<sub>2</sub>, 1% O<sub>2</sub> and 1% O<sub>2</sub> + 1% CO<sub>2</sub> and air) on flavour score of kiwifru stored for 58, 133 and 200 days.

LSD values shown were calculated on a 2-way analysis of variance