

Extending the Storage Life of 'Fuyu' Persimmon by Modified-atmosphere Packaging

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Abstract. The commercial storage life of the nonastringent Japanese 'Fuyu' persimmon (*Diospyros kaki* L.), grown in Israel, was extended from 6 to 18 weeks at 0C by modified-atmosphere packaging (MAP) in a low-density polyethylene (LDPE) film. MAP retarded fruit softening and inhibited development of peel and flesh disorders, which limited the storage life of the naked fruit. The fruit maintained its external and internal quality within the MAP during a subsequent week at 20C in the 0.08-mm LDPE film. Fruit quality deteriorated more rapidly in a 0.06-mm package. The difference between fruit quality in the two packs is attributed to specific physiological effects of the different atmospheric equilibria established due to film thickness.

The rationale for the application of modified-atmosphere packaging (MAP) to extend the postharvest life of fresh produce is that by reducing O_2 and increasing CO_2 levels, respiration is inhibited and senescence is subsequently postponed (Kader et al., 1989). However, although this is undoubtedly a major effect of MAP, there are additional direct or indirect effects attributable to altered environments. These effects are not predictable and make it difficult to model the optimal commodity package on the basis of known respiratory behavior. MAP for extended storage of the nonastringent Japanese 'Fuyu' persimmon might be considered an example.

Kawada (1982) showed that 'Fuyu' fruit grown in Japan could be stored for 5 to 6 months at 0C if individually packed and sealed in 0.06-mm polyethylene bags. The limiting factor was fruit softening. The same cultivar, grown in New Zealand, could be stored satisfactorily for only 4 weeks under the same conditions (MacRae, 1987). The limiting factor in this case was chilling injury, expressed as gel formation and loss of juiciness, not necessarily accompanied by fruit softening. The disorder was alleviated by MAP. Fruit of the same cultivar recently introduced from Japan and now grown in Israel has shown limited storage life in air at 0C, due primarily to peel browning, which was not regarded as a symptom of chilling injury (MacRae, 1987), and to internal flesh browning. The purpose of this study was to examine the effect of MAP on peel and flesh browning of stored 'Fuyu' persimmons, con-

sidering that these disorders might be the result of oxidation.

'Fuyu' persimmon fruits of uniform size (60 to 65 mm in diameter) were harvested at full orange color (grade 5 on the Japanese color chart) (Yamazaki et al., 1981), with firmness = 110.8 ± 9.7 N and soluble solids concentration = 20%. The fruits were packed in groups of six in 25×30 -cm low-density polyethylene (LDPE) bags 0.06 or 0.08 mm thick and sealed. Half of the bags were flushed with N_2 to replace the air before sealing and half were not flushed. The packed and naked (control) fruit were stored at 0C for 6, 10, 14, or 18 weeks. At the termination of each storage period, 12 bags per treatment and 72 unpacked fruits were transferred to 20C: one-third was examined on the same day, one-third after 3 days, and the remainder after 7 days. Before the bags were opened to examine the fruit, 30 ml of the air within each bag was sampled with gas-tight syringes to determine the levels of CO_2 , O_2 , N_2 , and ethanol (Pesis et al., 1986). Fruit examination consisted of external and internal visual description, penetrometer determination of fruit firmness with a mounted

Hunter-Spring pressure tester using the 11-mm-diameter plunger to a depth of 7.5 mm, and flavor evaluation by a panel of 12 to 15 untrained persons.

The factors that most affected the composition of the atmosphere within the bags were the thickness of the LDPE film and the storage temperature. There were no appreciable differences between the states of equilibrium established in bags sealed initially under air or N_2 . Average values were calculated for eight replicate flushed or non-flushed bags stored after packaging. There was little change in the respective O_2 and CO_2 levels throughout the storage period once equilibrium levels had been obtained in bags of both thicknesses at either temperature (Fig. 1). At 0C the average O_2 levels at equilibrium were 13.8% and 5.8% in bags of 0.06 and 0.08 mm thickness, respectively. These

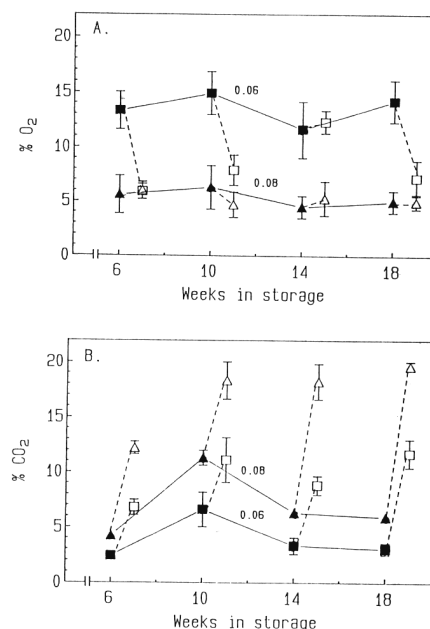


Fig. 1. Equilibrium levels of O_2 (A) and CO_2 (B) established within low-density polyethylene bags, 0.06 or 0.08 mm thick, six 'Fuyu' persimmons per bag, during storage at 0C (—) and after transfer to 20C (---). Bars represent $\pm$ SD.

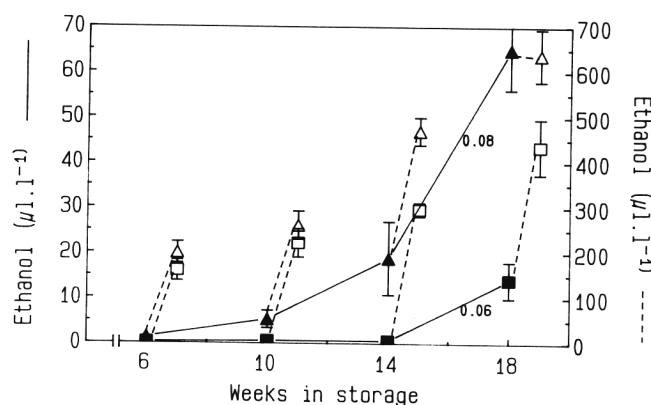


Fig. 2. Accumulation of ethanol in low-density polyethylene bags, 0.06 or 0.08 mm thick, six 'Fuyu' persimmons per bag, during storage at 0C (—) and after transfer to 20C (---). Bars represent $\pm$ SD.

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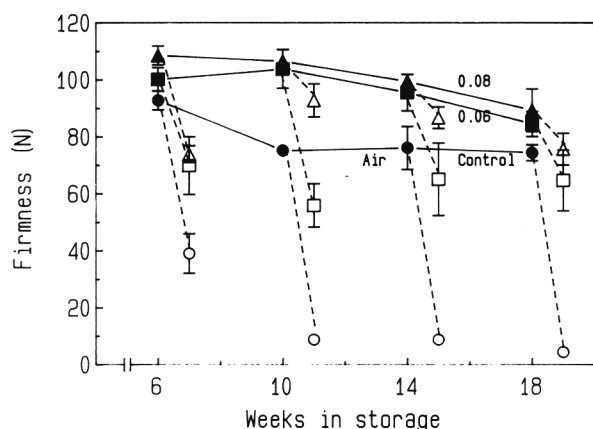


Fig. 3. Firmness of 'Fuyu' persimmons stored naked in air or in 0.06- or 0.08-mm-thick, low-density polyethylene bags upon removal from 0C (—) and after transfer to 20C (---). Bars represent $\pm$ SD.

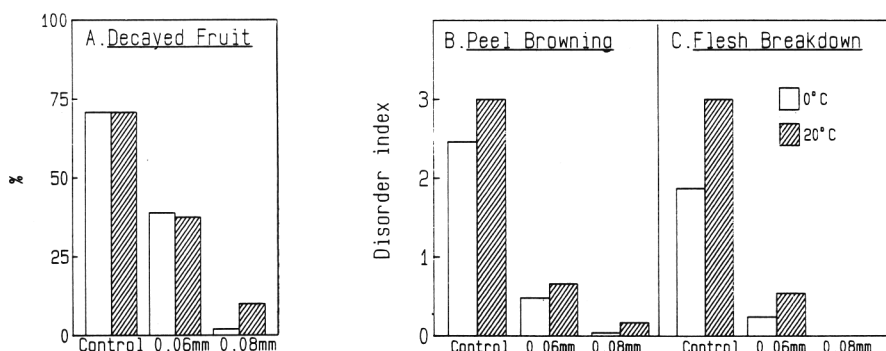


Fig. 4. Effect of MAP in 0.06- or 0.08-mm-thick, low-density polyethylene bags on the extent of peel and flesh disorders in 'Fuyu' persimmons after 18 weeks of storage at 0C followed by 1 week at 20C.

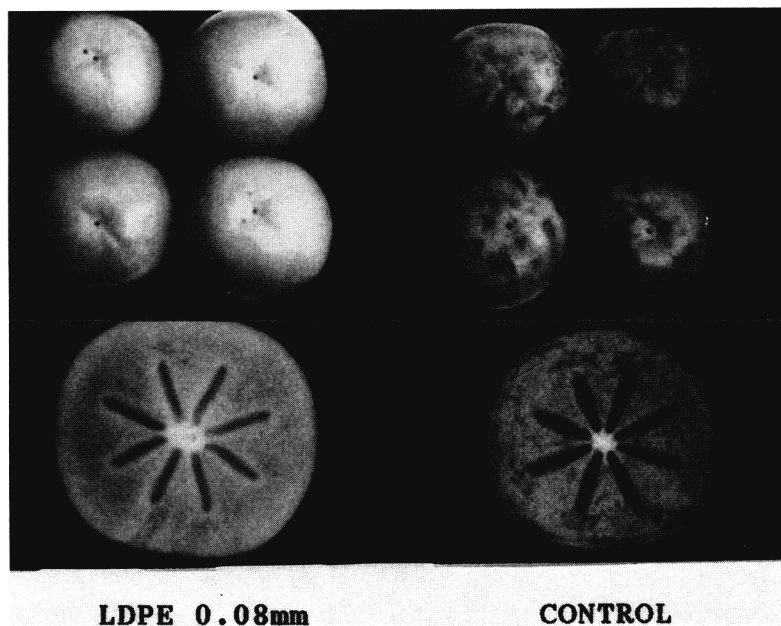


Fig. 5. Effect of MAP in 0.08-mm-thick low-density polyethylene bags on peel and flesh disorders of 'Fuyu' persimmons after 18 weeks of storage at 0C and 1 week at 20C.

equilibrium levels changed to 9.5% and 5.2% upon transfer to 20C. Parallel values for CO_2 averaged 3.8% and 7.0% at 0C and 9.5% and 16.4% at 20C, respectively.

These levels represent the equilibria established between the rates of respiration of

the fruits at each temperature and the permeability rates of the LDPE films to each gas. As the respiration rate of the fruit was affected more by temperature than by the permeability of the film to either gas, transfer from 0 to 20C resulted in a dramatic

change in equilibrium levels (Fig. 1). This change was expressed as a significant increase in CO_2 concentration, which was not necessarily accompanied by a decline in O_2 concentration. In the 0.06-mm LDPE bags, the O_2 level did decline parallel with the rise in CO_2 , but in the 0.08-mm bags, there was no further decline in O_2 level at 20C. This result may indicate that the steepness of the O_2 gradient between the internal and external atmospheres affected the flux of O_2 into the bags so that a steady level of $\approx 5\%$ O_2 was maintained.

The impermeability of the LDPE films to ethanol resulted in continuous accumulation of the latter in bags of both thicknesses (Fig. 2). The significantly greater accumulation in the 0.08-mm bags was probably due to the lower O_2 levels, which enhanced anaerobic respiration, especially at 20C.

The modified atmospheres produced in the bags improved the keeping quality of the fruit in storage and during subsequent shelf life by retarding the rate of softening (Fig. 3) and the extent of peel disorders and flesh breakdown (Figs. 4 and 5), compared with air-stored fruit. In MAP at 0C, the fruit hardly softened in bags of both thicknesses, but upon transfer to 20C, the rate of softening was greater in the 0.06-mm than in the 0.08-mm bags (Fig. 3). The correlations between fruit firmness and the levels of O_2 and CO_2 were similar (O_2 , $R^2 = 0.143$, $P < 0.001$; CO_2 , $R^2 = 0.194$, $P < 0.001$), and the effect of MAP could not be attributed to either of them specifically. The unpacked control fruit maintained a modicum of firmness during shelf life at 20C after prior storage for only 6 weeks at 0C and thereafter became completely soft.

Upon removal from storage after 4 weeks, the peel of air-stored fruit began to show brown staining, and the fruit decayed during holding at 20C due to the development of *Alternaria alternata*. However, MA-packed fruit showed much less decay and peel browning, especially in the 0.08-mm bags, even after 18 weeks of storage (Figs. 4 A and B, 5). The correlation between the degree of peel disorders and the composition of the atmosphere in the bags was highly significant: for O_2 , $R^2 = 0.41$, $P < 0.0001$; for CO_2 , $R^2 = 0.25$, $P < 0.0001$; and for ethanol $R^2 = 0.185$, $P < 0.001$.

Internal discoloration and breakdown of the fruit flesh became apparent in the naked control fruit after 6 weeks of storage at 0C, when the fruit was still firm. After 10 weeks of storage, flesh breakdown also occurred during the week at 20C. MA storage in 0.06-mm bags delayed the onset of internal flesh disorders. In 0.08-mm bags, these disorders were absent during 18 weeks at 0C plus 1 week at 20C (Figs. 4C and 5).

In spite of the relatively high levels of ethanol produced inside the MA bags after 7 days at 20C, following various periods of storage at 0C, no off-flavors were detected by the taste panels at any time during the course of the trial. At those times when the control fruit was still edible, the taste panel showed no preference for these fruits com-

pared with the MA-packed fruits or vice versa.

In conclusion, MAP of the nonastringent 'Fuyu' persimmon extended the storage life of the fruit at 0C and added subsequent shelf life at 20C by delaying the rate of softening and inhibiting the onset of storage disorders. The delayed softening was probably the outcome of retarded senescence due to the inhibition of respiration at low O₂ and elevated CO₂ levels. The ameliorative effect on physiological peel and flesh disorders could be attributed to the direct effects of the altered atmospheric composition: 1) reduced O₂ levels may have inhibited phenol oxidation that leads to the formation of brown pigments (Ben-Arie and Or, 1986) and 2) elevated CO₂ levels likely were responsible for retarding decay development due to *Alternaria alternata* (Wells and Uota, 1970). We do not

know whether the levels of ethanol produced in the MAP have any direct effect on the disorders observed.

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