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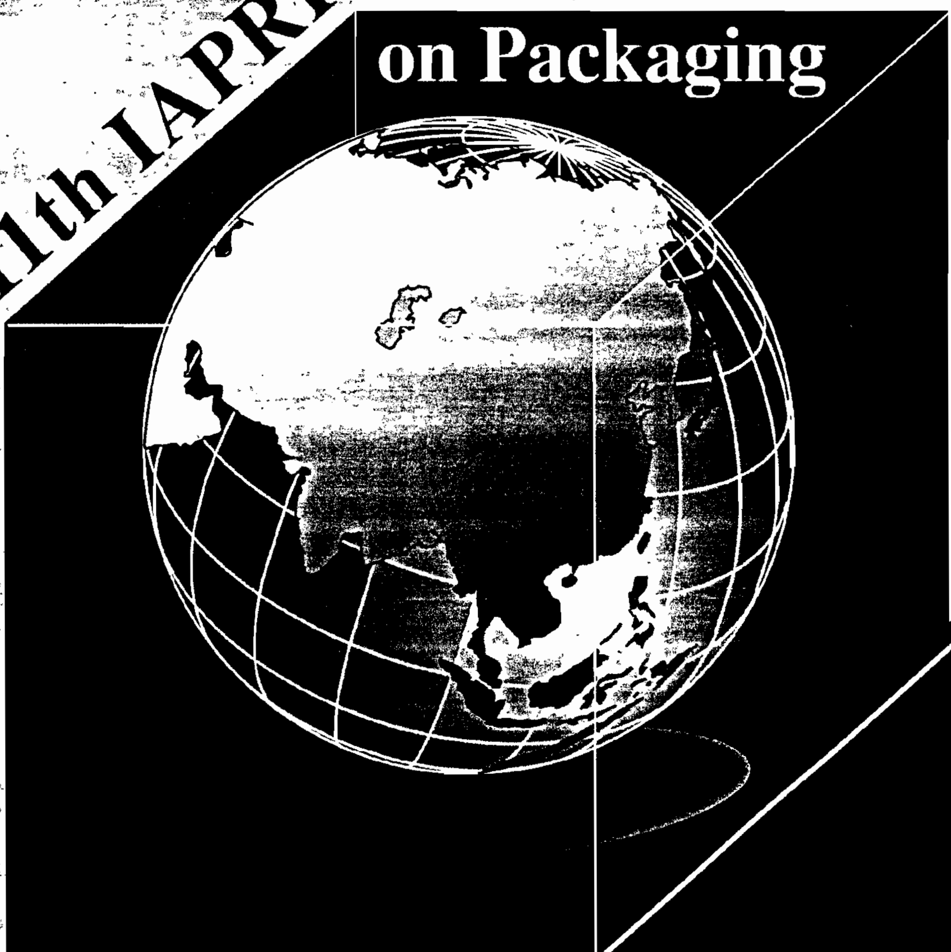

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Condition Of Film Wrapped "Fairchild" Fruits Held In Shelf-Life Conditions

CONDITION OF FILM WRAPPED "FAIRCHILD" FRUITS HELD IN SHELF-LIFE CONDITIONS

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Abstract
“Fairchild” mandarins were washed with water or treated with imazalil (250) ppm, then were left un-wrapped or sealed in polystyrene trays using two polyolefinic films (MR 19 µm or MY 20 µm) with different permeability characteristics. Soon after fruits were stored at room temperature (19-20°C) and 70-75% relative humidity for 8 weeks. Inspections were carried out after 4 weeks or 8 weeks. Both the films were very effective in reducing weight losses, shrinking of the peel and in maintaining freshness of the fruits. Wrapped fruit had the highest losses of acidity, total soluble solid and vitamin C, especially those sealed with MY film, the less permeable to gases. In addition, decay was very high in both packed fruits non treated with imazalil. Respiration rate of non treated fruit decreased by the time in storage, and the same trend was revealed for the in-package CO_2, in the trays free of rotten fruits, with an average of about 4% and 12% for MR and MY film, respectively.
The best results were obtained in the thesis where fruits wrapped with MR film were previously treated with imazalil.

INTRODUCTION
Mandarins usually have short postharvest life, they age very rapidly, losing acidity and sweetness. Weight loss, together with reduction of nutritional value represent the major cause of quality alteration. The best conditions to store mandarins are temperature of about 2°C-5°C and relative humidity higher than 95%. In these conditions they, accordingly to the cultivar, can be stored for a couple of months in good conditions (Hardenburg *et al.*, 1986). Since loss of quality may happen during transportation and marketing, proper handling is necessary to reduce decay spoilage and loss of weight. Satsuma mandarins, which are very perishable fruit were maintained in shelf-life condition for 4 weeks applying plastic films (D'Aquino *et al*, 1996). So, the application of plastic films can be beneficial in preserving quality attributes in shelf-life conditions of citrus fruits.
Postharvest life of citrus fruit, anyway, is strongly influenced by the nature of the peel. In satsumas, mediterranean mandarins or clementines, the peel is thin and separated from the segments, the edible portion of the esperidium. Usually, citrus fruits with these characteristics present a shorter postharvest life than those which, like oranges, lemons and grapefruits, have a thick and compact layer of albedo stongly linked to the segments.
Fairchild mandarin, which is an early ripening cultivar, has a relatively long on-tree life (from the beginning of December to all February) and present a peel similar to oranges.

The objective of this experiment was to study the potential postharvest life of this mandarine in shelf-life condition and the effect of two plastic films with different permeability characteristics to gases and water vapor in combination with a very low dose (250 ppm) of imazalil as fungicide to preserve from microbiological spoilage.

MATERIALS AND METHODS

Fruits and Treatments

"Fairchidl" mandarins were harvested the 15th of January from the experimental station of the CNR situated in Oristano. A total of 1080 fruits free of visual defect were chosen, weighed individually, and splitted into two lots of 540 fruits, of which the first one was dipped in a 250 mg/l of an imazalil emulsion, while the remaining one was left untreated. Then all the fruits, after being allocated in polystyrene trays (6 fruits per tray), were divided into three lots, each one containing half of the fruits untreated and the other half treated with imazalil. The first lot was left unwrapped, while the other two were wrapped using two different plastic films supplied by Cryovac. The first one indicated as MR, had a tickness of 19 µm, and was a heat shrinkable polyolefinic film (water transmission rate = 18 g/24 h m^2 at 38°C and 100% delta RH; CO_2 permeance = 19500 cm^3/24 h m^2 bar; O_2 = permeance 7500 cm^3/24 h m^2 bar), while the second indicated as MY, was also a polyolefinic film and had a tickness of 20 µm (water transmission rate = 8 g/24 h m^2 at 38°C and 100% delta RH; CO_2 permeance = 6400 cm^3/24 h m^2 bar; O_2 = permeance 2500 cm^3/24 h m^2 bar).

Both films were applied using a Minipack-R.A.S. wrapping machine.

Fruits were then stored at 19-20°C and 70-75% relative humidity (RH) for 8 weeks, and inspected at 4-week intervals.

Assesments and Measurements

In-package atmosphere was determined after 2 days from applying the films and at each inspection time. Ten packages free of rotten fruits for each treatment were used. Periodical measurements of the atmosphere of packages containing rotten fruits were also accomplished.

For CO_2 and O_2 determination a 20-ml sample of air was withdrawn from each package and injected in an analyser equipped with an infrared detector for CO_2 and a paramagnetic detector for O_2 (Servomex 1450B3, O_2/CO_2 analyser). From the same packages were also taken 2 ml samples for C_2H_4 determination. C_2H_4 was measured using a gas-cromatograph (Varian 3300) as previously reported by Agabbio *et al.* (1999).

Respiration rate was carried out closing 10 single fruits from each treatment in 0.5-L glass jars for 2 hours. From the jars were first withdrawn the samples (2 ml) for C_2H_4 measurements

and then those for CO_2. Fruits from packaging were closed into the jars immediately after removing the films. Respiration rate and ethylene production rate of the same fruits were also determined the day after.

Two ml samples of endogenous atmosphere were collected from 20 individual fruits from each treatment by inserting the needle of a syringe from the stilar end of the fruit inside the calyx cavity. Ten of the samples were used for internal CO_2 and O_2 concentration, while the remaining 10 samples served for C_2H_4 determination. Endogenous atmosphere was also determined the day after removing the film.

Electrolyte leakage was determined as previously reported by McCollum and McDonald (1991) with some modifications. Five fruits were selected at random from 5 different packages for each treatment, and from each fruits 10 disks of 13-mm were obtained from the equatorial area. The disks were then transferred in vials containing 25 ml of 0.4 M mannitol at 20°C. Electrical conductivity of the bathing solution was measured after 2 hours. The tissue was then autoclaved for 20 min, held overnight, and total conductivity was measured. Electrolyte leakage was calculated as (initial/total) x 100.
Chemical analysis [pH; titratable acidity, as % citric acid; total soluble solids (TSS) as °Brix; vitamin C as mg/100 ml of juice) were carried out as previously reported by D'Aquino *et al.* (1998a).
Firmness of the fruits was determined either as mm of deformation by putting a weight of 1 kg upon the equatorial area of the fruits for 5 sec., or as resistance to the penetration of a needle of 2 mm of diameter applied to an Effegì penetrometer, by taking two readings from two opposite points of the equatorial area. For both determination 10 fruits were used from each treatment.
Fruits were inspected for the presence of decay, were re-weighed for the determination of the weight loss, and then evaluated for overall appearance on a scale ranging from 1 to 9, where 9 was very fresh, 5 the limit of marketability, and 1 very old (fruits severely shrivelled).
Finally, 20 fruits for each treatment were peeled, divided into segments, placed in dishes and evaluated for sensory quality by 7 technicians. They expressed their preference on the basis of a scale ranging from 1 to 9.
All data were subjected to analysis of variance, and the separation of the means was done by the Duncan Multiple Range Test.

RESULTS

The factor "fungicidial treatment" had only slight influence on in-package atmosphere, endogenous atmosphere, respiration activity, electrolyte leakage and chemical parameters. Thus, data presented refer to the factor "wrapping", and the means are the average of the pooled data coming either from fruit treated with imazalil or not-treated.
In-package atmosphere changed slightly during storage (Fig. 1A). From the 2nd day after applying the films, CO_2 decreased, while O_2 increased. This was true only for packages free of rotten fruits. In those where decay occurred CO_2 increased sharply reaching soon values higher than 20%. Conversely, the level of O_2 was near to zero (data not shown). The differences between the two films were very marked. Similar results were previously obtained by the same authors (D'Aquino *et al.*, 1998a and 1998b). In MR film CO_2 never exceed 6%, while in MY film the percentage of CO_2 was always higher than 12%. Complementary was the content of O_2, which was always higher than 14% in packages made with MR film, while in MY film packages it ranged between 3.6% after 2 days and 6.3 % at the end of the trial (Fig. 1B). Regarding C_2H_4 concentration (Fig. 1C), it was very low until the 1st inspection time and increased moderately, but never reaching 1 ppm, after 8 weeks of storage. However, data were not consistent due to the large variability revealed among the packages.
Endogenous atmosphere in packed fruit was strongly influenced by the films. In fact, as shown in Fig. 2A and 2B, after the removal of the films, the detected values either for CO_2 or for O_2 were similar to those at harvest. Differently was the behaviour of

unwrapped fruits, for which from harvest until the 8 week of storage there was a progressive increase of endogenous CO_2 and concomitant reduction of O_2 (Fig.2A and 2B). Data related to endogenous C_2H_4 were not consistent and only at the 2nd inspection time in different fruits detectable amount of ethylene were revealed, in any case only some fruits had peaks around 1 ppm, while the others, which represented the majority, showed concentration of 0.01 ppm or not detectable (data not shown).
Regarding respiration activity (Fig. 2C), the CO_2 produced by un-wrapped fruit decreased progressively during the storage period, while in fruits sealed with the plastic films, after the great production detected immediately after the removal of the packages, CO_2 dropped at the same rates of the harvesting time, which were significantly higher than the values measured in un-wrapped fruits. The desiccation of the peel during storage reduced progressively its permeability to gases and consequently inside the fruits there was a continue increase of CO_2 and a concomitant reduction of O_2, which, in turn, reduced the respiration activity of the fruit. On the other hand in wrapped fruits the films avoided changes in permeability to gases, letting the fruits restore the physiological behaviour of the harvesting period when a steady-state was reached following the removal of the films.
Results related to electrolyte leakage (Tab. 1) were not consistent. There was too much variability among the fruits within each treatment. An overall increase was observed at the 8th week of storage. Electrolyte leakage was not a good parameter to measure the influence of the studied factors.
In table 1 are reported the results of chemical parameters. During storage a general decrease of TSS, acidity, vitamin C and a concomitant increase in pH was observed. Very strong was the influence of the two films. The general trend, in fact, was marked in fruits wrapped with MR film, and dramatic in those wrapped with MY film, especially regarding titratable acidity and vitamin C. Studies with citrus fruit indicate contrasting results on the effects of modified or controlled atmospheres on nutritional value. Some authors found no or little influence (Ben-Yehoshua *et al.*, 1979; Eaks, 1991; Purvis, 1983) on chemical parameters applying different kinds of plastic films, others report of negative effects (Ito *et al.*, 1974, Purvis, 1983).
Concerning weight loss, both the films created a very efficient barrier against water vapour, in particular, weight losses were maintained at less than 2% and at about 2.5% in MY and MR film-wrapped treatments, respectively, against 20% of un-wrapped fruits, at 8 weeks of storage (Tab. 2).
Un-wrapped fruits increased their resistance (Tab. 2) to puncture by the time in storage, while in wrapped fruits there was a progressive decrease. Regarding the turgidity of the fruits, measured as deformation, in both film wrapped fruits was observed a slight increase during storage, while in un-wrapped fruit at an initial rapid rise, which reached more than 4 mm after 4 weeks of storage, followed an apparent weak recovery of the turgidity (Tab. 2).
Microbiological spoilage was strongly influenced by fungicide treatment and film wrapping (tab. 2). Un-wrapped not treated fruits reported an average loss of 10% against 2.6% of un-wrapped imazalil-treated fruit. Film wrapping favoured decay development, especially MY film. Non treated fruit wrapped in MY film reported a percentage of rotten fruits of 45% at the 1st inspection time and of almost 70% at the 2nd inspection, against 24% and 35% for MR film. The combination film-imazalil significantly reduced the incidence of decay, but gave good results only with MR film (3.5% and 6.3% after 4 and 8 week of storage, respectively); in association with MY film its effectiveness lasted until the 1st inspection, when the rotten fruits were about

9%, reaching some 52% at 8 week's storage. These results are similar to those found in other experiments in which the application of films promoted decay development (Kawada and Albrigo,1979; Hale *et al.* 1982, Piga *et al.*, 1996), while the use of imazalil was very effective in controlling microbiological attack of *Penicillum spp.*(D'Aquino *et al.*, 1997; Miller *et al.*, 1988).

DISCUSSION AND CONCLUSION

Film wrapping is becoming increasingly more important and widely used for its beneficial effect in preventing microbiological and physiological spoilage of produce and retaining its quality. In spite its advantage if not properly chosen film wrapping can have detrimental effect on fruits physiology and quality (Pala and Damarli, 1998). The feasibility and efficacy of wrapping depend upon several factor, as temperature, kind of fruit, metabolic activity of the tissue, films surface-weight of fruit ratio, sealing device, which, if not well-defined, can lead to inconsistent and irreproducible results. D'aquino *et al.* (1998b) in a different trial using the same films of this experiment, detected in-package atmosphere compositions very similar for both the films, because the films seals were not airtight.

In-package CO_2 and O_2 strongly influence maintenance of chemical characteristics and physiological behaviour of fruits. In particular, citrus fruits, differently than other species which receive beneficial effects from elevated concentrations of CO_2 and reduced levels of O_2, seem not to get any advantage. Anaerobic metabolism usually occur in the inner tissue of citrus when the permeability of the peel is reduced due to transpiration. So, often, the monitored data give only an average of what really happens in the different areas of the fruit. In respiration of un-wrapped fruit, for example, CO_2 is mainly produced by the outer tissues by aerobic metabolism and the portion coming from the inner tissues in part is produced by anaerobic metabolism. In wrapped fruits the lower O_2 concentration available to the outer tissue can reduce their respiration activity, but the inner tissue can increase their CO_2 production due to anaerobic metabolism. At harvest, endogenous CO_2 range from 0.5% to 1%, but during storage as the rind lose water, gas permeability of the rind decreases and consequently internal CO_2 concentration grow up reaching even 4-5% according to the cultivar. The experiments carried out in our laboratory with different species of citrus fruits, show that internal concentrations of 2% or 3% of CO_2 can be beneficial at room temperature, because induce a reduction of respiratory activity of internal tissue and contain the anaerobic metabolism at a low level. So we should use a plastic film which would give a positive contribution in reducing weight loss, but in the same time should have a good permeability to gases to ensure internal concentrations of CO_2 and O_2 lower than 3% and higher than 13-15%, respectively. In this trial un-wrapped fruits after 4 weeks' storage had an internal CO_2 of 2.3% against 4.2% of MR wrapped fruits, but after 8 weeks the measured values were 3.5% and 4.1%, respectively. Fruit wrapped in MR film maintained nutritional characteristics of Fairchild mandarin better than MY film, but respect to un-wrapped fruits the rate of degradation was higher.

The combination of MR film with imazalil, in any case, gave good results, reducing the loss for decay at 3% after 8 weeks of storage at ambient conditions, maintaining the overall appearance very similar as at the harvest time and containing the weight losses to about 2.4%.

Regarding sensory attribute, in any case fruits wrapped in MR film were better appreciated by the panellist than unwrapped fruits due to the more consistent texture of the segment, which in un-wrapped fruits were flaccid. MY film gave the worst results and fruits, due to anaerobic conditions, were not edible since the first inspection time. Fairchild mandarins showed to have a postharvest life different than the other easy pealing mandarins and very similar to oranges, grapefruits and lemons, confirming that, as we have just observed in previous studies carried out in our laboratory, the structure of the peel plays a very important role in the postharvest life of citrus fruits.

Imazalil was very effective even at the very low concentration of 250 mg/l, and this reducing the risk of toxic residues represents a very important feature for the safety of consumer.

Although the results so far obtained are encouraging more studies to test new films, which lower the rate of nutritional value degradation at the same level of un-wrapped fruits, and more friendly products to control microbiological spoilage, in order to commercialise fruits totally free of toxic residues, remain the major objectives of our research.

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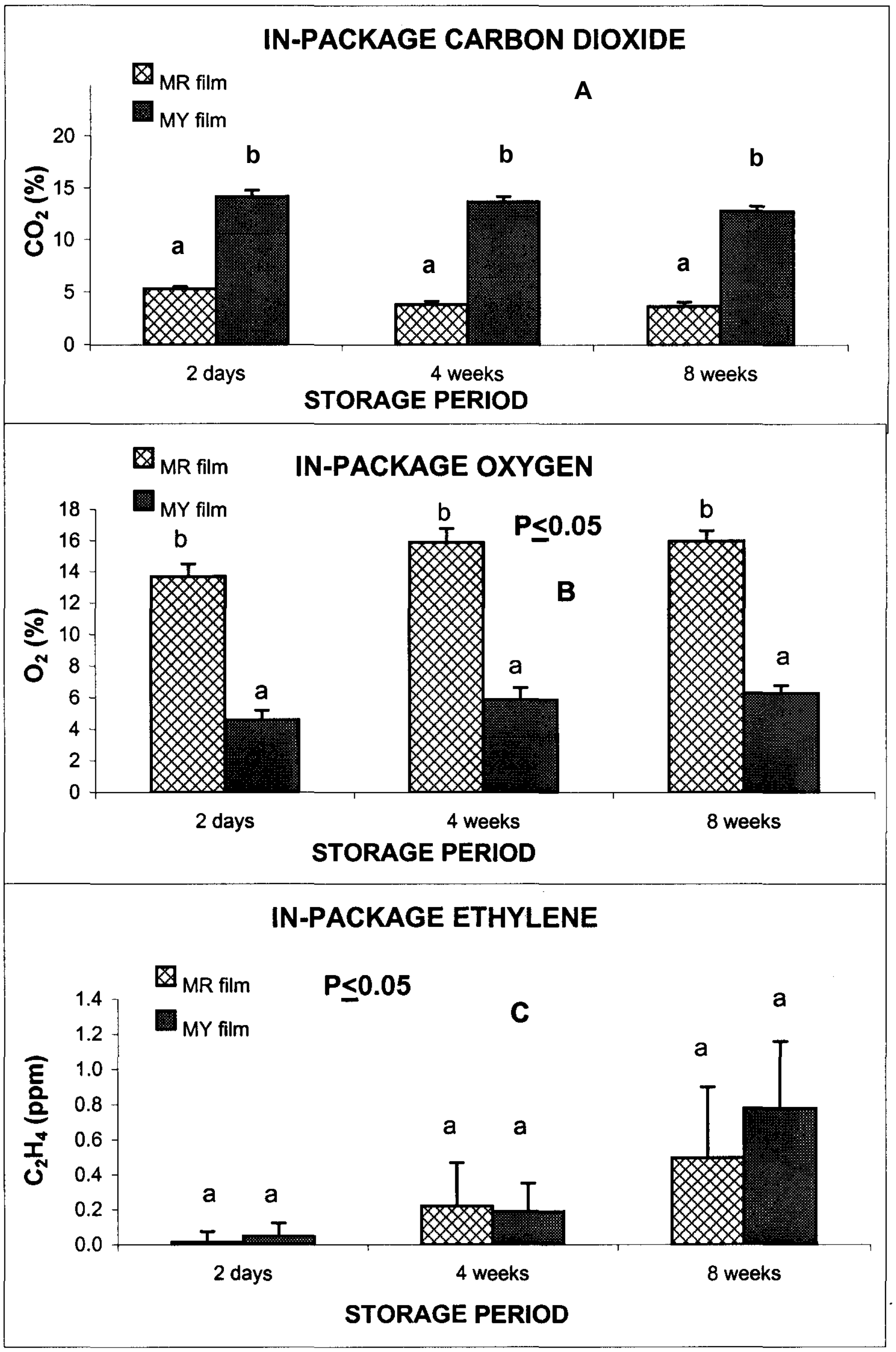

Figure 1- In-package CO_2 (A), O_2 (B), and C_2H_4 (C) during storage. In-package CO_2, O_2 and C_2H_4 are significantly different at the 5% level for the storage period. Vertical bars indicate the standard error (n=20).

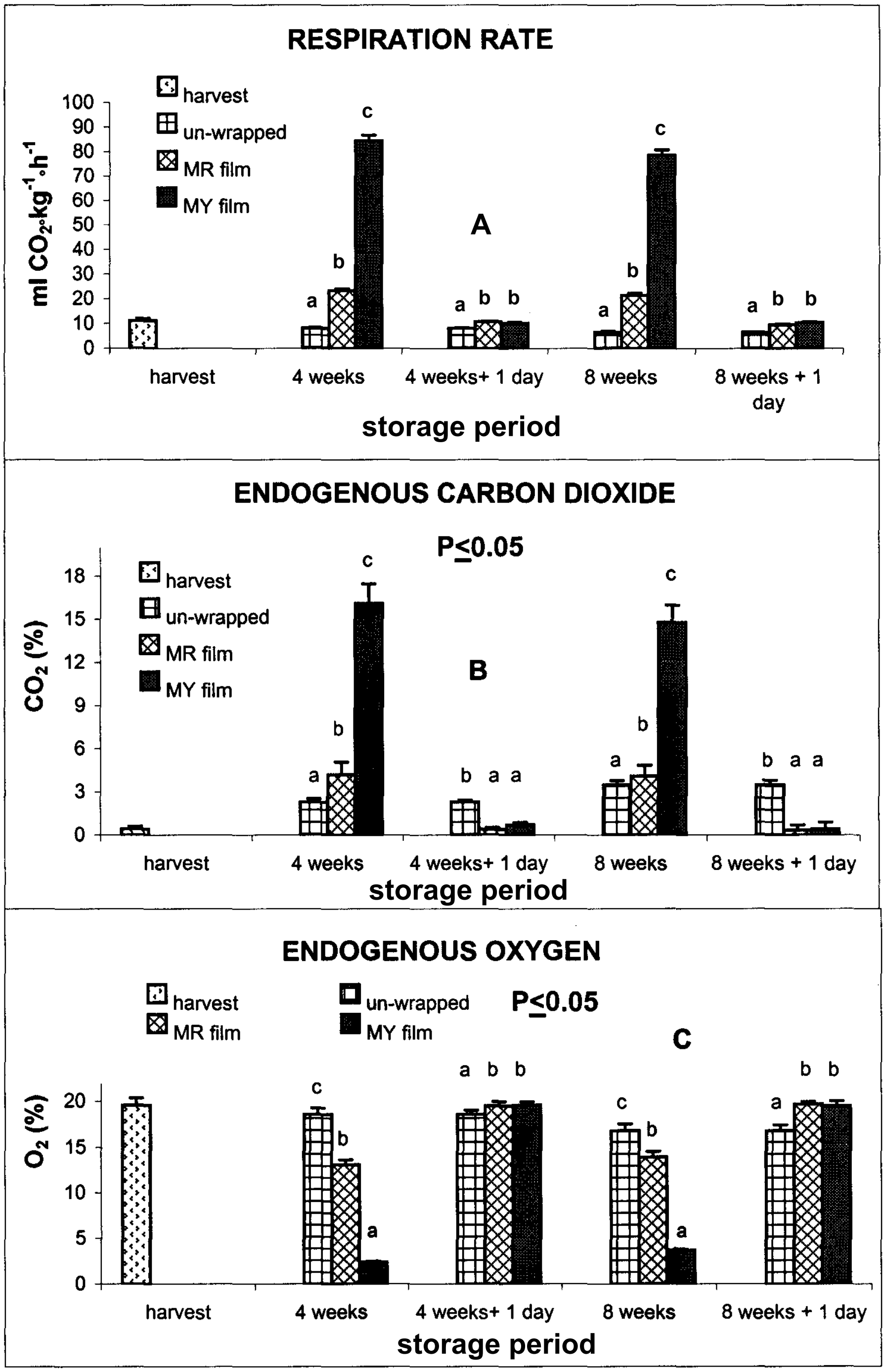

Figure 2- Respiration activity (A), endogenous CO_2 (B) and endogenous O_2 (C) at each inspection time and the day following the removal of the films. Vertical bars indicate the standard error (n=20).

Table 1- Changes of chemical characteristics and electrolyte leakage during storage of "Fairchild" mandarins held at 19-20°C and 70-75% relative humidity.

STORAGE PERIOD	pH	SST (°Brix)	TITRATABLE ACIDITY (% Citric Acid)	VITAMIN C (mg/100 ml)	ELECTROLYTE LEAKAGE (% of total electrolyte leakage)
HARVEST	3.54	12.4	0.88	45.4	42.3
4 WEEKS					
Un-wrapped[1]	3.93*a	12.8c	0.81c	42.7c	45.8a
MR-film	4.15b	12.2b	0.76b	39.7b	44.2a
MY-film	4.40c	11.6a	0.51a	32.1a	46.3a
8 WEEKS					
Un-wrapped	4.12a	12.7c	0.69c	41.4c	57.9a
MR-film	4.35b	11.8b	0.51b	35.6b	59.8a
MY-film	4.82c	10.2a	0.37a	28.4a	64.3a

***For each storage period means followed by different letters are significantly different at $P \leq 0.05$.**

[1]The values reported for each treatment are the average of fruits treated plus fruits non treated with imazalalil,since no statistical differences due to fungicidial treatment were revealed.

Table 2 – Changes in weight loss, firmness, deformation, decay, overall appearance and acceptability of "Fairchild" tangerine fruits stored at 19-20°C and 70-75% RH as influenced by fungicide treatment and storage period.

STORAGE PERIOD	WEIGHT LOSS (%)	FIRMNESS ($g/3.14mm^2$)	DEFORMATION (mm)	ROTTEN FRUIT (%)	OVERALL APPEARANCE (index number)	ACCEPTABILITY (index number)
HARVEST	-	922	2.1	-	9	9
4 WEEKS						
Un-wrapped	15.9*c	884 b	4.5 b	8.5 c	4.2 a	7.5 b
Un-wrapped Imazalil	15.6 c	864 b	4.1 b	2.1 a	4.8 a	7.6 b
MR-film	1.73 b	786 a	2.5 a	24.2 d	7.8 b	8.1 c
MR-film Imazalil	1.77 b	791 a	2.7 a	3.5 b	9 d	8.0 c
MY-film	1.11 a	809 a	2.2 a	44.8 e	7.4 b	4.3 a
MY-film Imazalil	1.06 a	790 a	2.5 a	8.9 c	8.7 c	4.7 a
8 WEEKS						
Un-wrapped	21.1 c	1064 b	3.8 b	11.4 c	2.3 a	6.4 b
Un-wrapped Imazalil	19.2 c	1001 b	3.9 b	3.2 a	2.8 a	6.3 b
MR-film	2.38 b	747 a	2.1 a	35.7 d	8.7 c	7.2 c
MR-film Imazalil	2.55 b	782 a	2.5 a	6.3 b	6.8 b	7.5 c
MY-film	1.68 a	803 a	2.6 a	68.9 f	6.1 b	1 a
MY-film Imazalil	1.72 a	771 a	2.4 a	51.6 e	6.6 b	1 a

***For each storage period means followed by different letters are significantly different at $P \leq 0.05$.**