PAPER

INFLUENCE OF FILM WRAPPING ON QUALITY MAINTENANCE OF "SALUSTIANA" ORANGES UNDER SHELF-LIFE CONDITIONS

INFLUENZA DEL CONFEZIONAMENTO CON FILM PLASTICI SULLA CONSERVABILITÀ DI ARANCE "SALUSTIANA" IN CONDIZIONI DI SHELF-LIFE

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ABSTRACT

"Salustiana" oranges were dipped in a 500 mg/L imazalil emulsion and wrapped in polystyrene trays using three different plastic films: Omni, MR and MY, with high, medium and low permeability to gases and water vapour, respectively. Fruits were then stored at ambient temperature (18°-20°C) and relative humidity (60-65%) for 6 weeks. MY film created in-package anaerobic conditions (about 10% CO_2 and 8% O_2), increased the rate of deterioration of internal quality parameters and pro-

RIASSUNTO

Frutti di arance "Salustiana", trattati con una emulsione contenente 500 mg/L di imazalil, e confezionati con tre film plastici (Omni, MR ed MY) aventi caratteristiche di permeabilità ai gas ed al vapore acqueo decrescenti, sono stati conservati in condizioni di mercato a 18°-20°C e 60-65% di umidità relativa per 6 settimane. A cadenza bisettimanale sono stati rilevati i principali parametri morfologici e qualitativi, oltre alla composizione dell'atmosfera interna alle confezioni. Il film MY ha creato

- Key words: decay, oranges, plastic film, quality, storage, transpiration -

moted pathogen development, even in fruits treated with imazalil (28% decayed fruits after 6 weeks). Omni film did not alter the nutritional composition, but had little influence in reducing the transpiration rate as fruits at the end of storage lost about 14% weight, compared to 18% for non-wrapped fruits and 2% for those wrapped with the other two films. Very positive results were obtained with the imazalil-MR film combination, which let the fruits maintain their initial chemical and aesthetical characteristics during the entire storage time and limited loss due to decay to about 1%.

condizioni asfittiche (circa 10% di CO_2 e 8% di O_2), che hanno alterato il gusto dei frutti sin dalla quarta settimana e accelerato la degradazione degli acidi organici, degli zuccheri e della vitamina C. Inoltre, è stata rilevata un'alta incidenza dei marciumi anche nelle confezioni trattate con imazalil (circa il 28%). Il film Omni, pur preservando le caratteristiche chimiche non ha ridotto dovutamente la traspirazione, facendo registrare a fine conservazione perdite di peso intorno al 14%, contro il 18% circa dei frutti non confezionati ed il 2% degli altri due film. Risultati positivi, invece, sono stati ottenuti dalla combinazione film MR-imazalil, che ha consentito di mantenere quasi inalterate le caratteristiche chimiche ed estetiche per tutta la durata della prova con un'incidenza media dei marciumi di circa l'1%.

INTRODUCTION

Citrus fruits reach the final stage of maturity while on the tree. Ripening goes on slowly and progressively and, depending on the cultivar, can even take several months to reach the final stage (ERICKSON, 1968). Being non-climacteric, citrus fruits cannot continue to ripen once harvested, and hence they differ greatly from climacteric fruits, which reach the final stage of maturity in a few days regardless if the fruit is still attached to the tree or not.

The morphological characteristics of the rind make citrus fruit different from many other kinds of fruit. The rind is made up of two tissues, the outer part called flavedo and the spongy-white inner part called albedo, which protects the inner edible part of the fruit. The rind prevents dehydration of the inner segments and allows the flesh to stay in a natural modified atmosphere (important in reducing metabolic activity) which can be beneficial when the fruit is kept at room temperature. This is particularly true for oranges, lemons and grapefruits, which have a thick rind, usually tightly connected to the segments.

Quality maintenance of citrus fruit is mainly affected by water vapour loss, which can result in peel shrinkage, reduction of turgidity and increase in resistance to gas diffusion (BEN-YEHOSHUA, 1969; MCDONALD *et al.*, 1993), with negative consequences on flavour and taste. According to AIT-OUBAHOU *et al.* (1996), better than cooling to optimal temperature, wrapping citrus fruit with plastic film can double the shelf-life and delay physiological quality deterioration, even at room temperature.

The objective of this work was to study the effect of different types of plastic films, from the physiological and qualitative points of view, on oranges held continuously in shelf-life (S-L) conditions rather than refrigeration.

MATERIALS AND METHODS

Fruit was obtained from the experimental station of Oristano (west-central Sardinia) from trees grafted onto 15-year-old sour orange trees. All of the chosen fruit, free of visual defects, was divided into two groups; the first group was dipped in water at room temperature, while the second was dipped in an emulsion of imazalil at a concentration of 500 mg/L. Fruit was allowed to dry overnight. The next day, the fruit was placed in polystyrene trays (six fruits per tray) and the trays were divided into four lots. Each lot was subjected to one of the following treatments: no treatment; wrapped manually with a 12.5 μm extensible PVC film (Omni-Huntsman, Deggendorf, Germany); wrapped with a 25 μm polyolefin film (MY-Cryovac, Milan, Italy), or a 19 μm heat shrinkable polyolefin film (MR-Cryovac, Milan, Italy), using a "Minipack-R.A.S." wrapping machine. Film characteristics are reported in Table 1.

Fruit was then stored in non-controlled room conditions (S-L), with the temperature ranging from 18° to 20°C and relative humidity (RH) ranging from 60 to 65%, for six weeks with inspection every two weeks.

Respiration and ethylene production

Respiration and ethylene production rate were determined on 10 fruits of the control group. The respiration rate was determined on the wrapped fruit (n=10) 4 h after removing the film. In both case, fruits were individually put into 1-litre jars, and after 2 or 4 h, samples were withdrawn for respiration and ethylene determination, respectively. Carbon dioxide was determined using a CO_2/O_2 analyser (Servomex 1450B3, Crowborough, England) fitted with a coupled infrared/paramagnetic detector. Ethylene was determined by gas chromatography using a Varian 3300 gas chromatograph (Walnut Creek, California) equipped with a flame ionisation detector (FID) and a 1.82 m x 3.18 mm packed column (Unibeds®S, Alltech Italia, Milan, Italy) as reported by AGABBIO *et al.* (1999). Respiration activity and ethylene production rate are expressed as mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ or μL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$, respectively.

In-package atmosphere

For each treatment 10 packages were chosen for in-package atmosphere analysis. Samples from the same packages were taken 2 days after wrapping with film or at each inspection time. Carbon dioxide, oxygen and ethylene were determined as reported by D'AQUINO *et al.* (1997).

Colour

Colour of the peel was measured with a Minolta CR-300 colorimeter (Minolta, Osaka, Japan) using the Commission

Table 1 - Characteristics of the films.

	Permeability		
	MR Film	MY Film	Omni Film
Thickness	19 μm	25 μm	12.5 μm
Water vapour	18 g/24h·m² (38°C and 100% delta RH)	6.5 g/24h·m² (38°C and 100% delta RH)	515 g/24h·m² (38°C and 100% delta RH)
O_2	7,500 cm³/24h·m²·bar at 23°C	2,000 cm³/24h·m²·bar at 23°C	22,000 cm³/24h·m²·bar at 23°C
CO_2	19,500 cm³/24h·m²·bar at 23°C	5,100 cm³/24h·m²·bar at 23°C	160,000 m³/24h·m²·bar at 23°C

Internationale de l'Eclairage (CIE) (L*, a*, b*) colour scale. At harvest, for each treatment and inspection time, 18 fruits were used. Fruits were chosen before wrapping with film, and the readings were taken at the beginning of the trial and at each inspection time on two circled areas on the opposite cheeks of the fruit.

Firmness, peel thickness, and weight loss

Firmness was measured by determining resistance to the penetration of a probe or as deformation. In the first case a 2 mm-diameter probe connected to an Effegì penetrometer (TR Turoni & C., Forlì, Italy) was used and results are expressed as g. Deformation was measured as the mm of reduction in the transversal axis after putting a weight of 1 kg for a period of 10 s on the equatorial area of the fruit using the device described by D'AQUINO *et al.* (1998a). For both measurements 10 fruits per treatment were used; the same fruit was then cut transversally to record peel thickness using a ruler.

Visual quality evaluation

Six trays of fruit per treatment were used to evaluate the amount of rotten fruit, and the number which had lost their buttons. Identification of disease was carried out by comparing the fruit with the illustrations and descriptions reported by SNOWDON (1990). The same fruit was used for evaluating overall appearance. A subjective scale ranging from 1 to 9 was used, where: 9 indicated the fruit as fresh as at harvest; 5 the limit of marketability and 1 a very aged fruit.

Chemical analysis

Thirty oranges, divided into three replications, were used for the chemical analysis. The fruit was juiced using a hand juicer, and the juice was then centrifuged before analysis. Chemical parameters (pH, titratable acidity -TA-, as % of citric acid, total soluble solid -TSS- as °Brix, and Vitamin C) were determined as described by AGABBIO *et al.* (1999).

Sensory evaluation

Ten fruits chosen at random from each treatment were peeled, divided into segments and placed in a dish for sensory evaluation. The ten panelists (technicians and students from the laboratory) had no knowledge of the treatments. After tasting different segments from each dish, they gave a score for acceptability, ranging from 1 to 9, with 9 representing the highest appreciation; 5 a still edible fruit and 1 the worst appreciation.

Statistical analysis

The experiment was a completely randomised 4x2x4 factorial block design, with factor A being the storage time (harvest, 2, 4 or 6 weeks), B the fungicidial treatment (no fungicide, imazalil) and C the packaging (no wrapping, Omni film, MR film, or MY film). All data were subjected to analysis of variance and mean separation was accomplished by the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Respiration and ethylene production rate

Respiration rate at harvest was about 9 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$. With storage, respiration activity decreased in the non-wrapped fruits as well as in those wrapped with Omni film, even if to a lesser extent. Little change occurred in fruits wrapped with the other two films (Fig. 1). A decrease in respiration rate, commonly considered as typical physi-

ological behaviour associated with the loss of respirable substrate (TING and ATTAWAY, 1974), has been observed by others at ambient temperature in other citrus fruits (ARTES *et al.*, 1994; SINCLAIR, 1984). These results show a higher respiration activity in wrapped fruits with respect to non-wrapped ones, contradicting the principle that the decrease in respiration activity is a consequence of a reduced availability of organic substrate. In fact, the greatest loss in organic acids occurred in fruits wrapped with MR and MY films (the less permeable to gases and water vapour) (Table 2). The internal atmosphere was not measured, but, from data reported in other experiments (D'AQUINO *et al.*, 1999; EAKS, 1991), it is most likely that the changes in respiration activity of non-wrapped fruits were mainly due to the reduction in permeability to gases of the peel caused by excessive drying. This might have had the physiological effect of altering the composition of the internal atmosphere (enhanced concentration of carbon dioxide and consequent reduction of oxygen) and reducing respiration activity, by slowing down the rate of degradation of sugars and acids. On the other hand, the composition of the inner atmosphere of the tissue could have activated anaerobic metabolism, which to produce the same amount of ATP requires more substrate than aerobic metabolism (KADER, 1987). Finally, the negligible water loss of the fruits wrapped in MR and MY film, with no alteration in the permeability of the peel, could account for the slight reduction in respiration activity with respect to that at harvest.

The production of ethylene, was very low (0.08 $\mu L \cdot kg^{-1} \cdot h^{-1}$ at harvest), as usually happens for non-climacteric fruits. In any case data were very inconsistent and there was very high variability among fruits of the same treatment (data not shown). Since ethylene production in healthy citrus fruits is very low, it is possible that those fruits which produced some ethylene were injured or had incipient decay, which was not visible at the time of measuring.

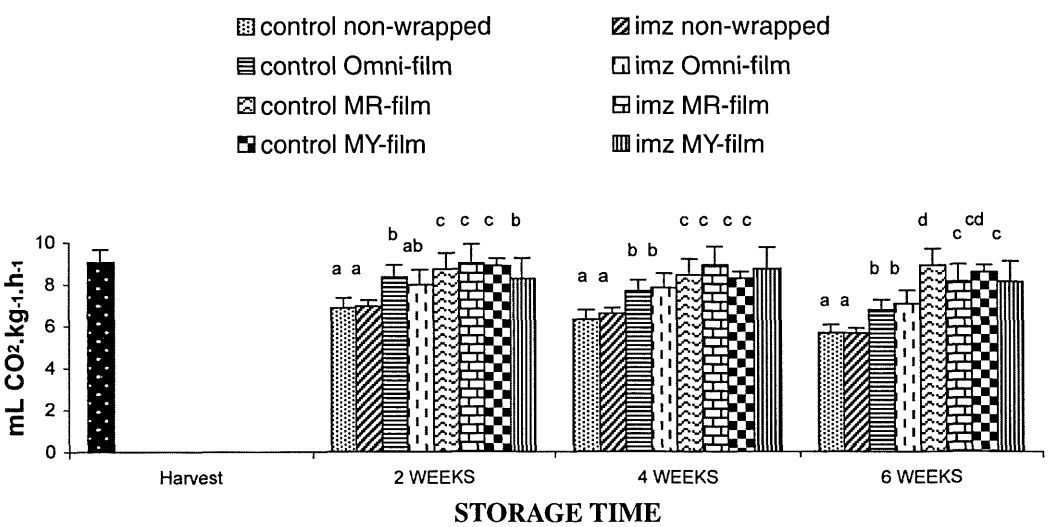

Fig. 1 - Influence of imazalil and film wrapping on respiration of "Salustiana" oranges after 2, 4 or 6 weeks at 18°-20°C and 60-65% RH. Measurement of wrapped fruits was made 4 h after removing the films. Vertical bars indicate standard error (n=10). For each storage time, values with different letters differ significantly at P≤0.05 by the LSD test.

In-package atmosphere

The composition of the atmosphere inside the packages free of decayed fruits was greatly influenced by the different kinds of film. After 2 days, carbon dioxide ranged from around 2% in the packages wrapped with Omni film and 4% in those wrapped with MR film to 10% in MY (Fig. 2), while the concentration of O_2 was complementary to CO_2, with values of about 18, 15 and 10% in packages wrapped with Omni, MR and MY, respectively. With storage there was a slight decrease in CO_2 for all the films, and a concomitant increase in O_2. These data confirm what had previously been observed (D'AQUINO *et al.*, 1998b) for other citrus fruits. Fungicidal treatment had no significant direct effect on in-package atmosphere composition. In fact, no statistical difference in gas composition

Table 2 - Chemical parameters of "Salustiana" orange juice after 2, 4 or 6 weeks of storage at 18°C and 60-65% RH.

Storage time	pH	T.A (% Citric acid)	TSS (° Brix)	Vitamin C (mg/100 g)
HARVEST	3.70	0.82	99.93	67.14
2 WEEKS				
Non-wrapped	3.72a[1]	0.79b	10.2a	63.1b
Omni Film	3.80b	0.76b	10.2a	63.9b
MR Film	3.83b	0.71a	10.6a	62.6b
MY Film	3.89c	0.72a	10.4a	58.9a
4 WEEKS				
Non-wrapped	3.77a	0.72ab	10.3a	62.0c
Omni Film	3.85b	0.75b	10.1a	56.1b
MR Film	3.83b	0.71ab	10.3a	55.4ab
MY Film	3.94c	0.67a	10.0a	54.3a
6 WEEKS				
Non-wrapped	3.90a	0.65b	10.4b	60.6c
Omni Film	4.37b	0.64b	10.5b	57.0b
MR Film	4.40bc	0.62ab	10.1b	56.3b
MY Film	4.46c	0.59a	9.6a	52.6a

ANOVA

Source	df	Mean squares	gl	Mean squares	gl	Mean squares	gl	Mean squares
Period (P)	3	1.50***	3	0.15***	3	0.69***	3	300***
Fungicide (T)	1	0.00ns	1	0.0001ns	1	0.0007ns	1	6.6ns
Film (F)	3	0.22***	3	0.011***	3	0.32***	3	59.86***
PxT	3	0.001ns	3	0.0003ns	3	0.00044ns	3	1.71ns
PxF	9	0.10***	9	0.001*	9	0.38***	9	14.0**
TxF	3	0.002ns	3	0.004**	3	0.0018ns	3	5.27ns
Error	72	0.001	72	0.0008	72	0.05	72	5.06

[1] Means in columns for each storage period followed by different letters are significantly different at the 5% level by the LSD test.
ns, *,**,*** = non significant or significant at P≤0.05, 0.01 or 0.001, respectively.

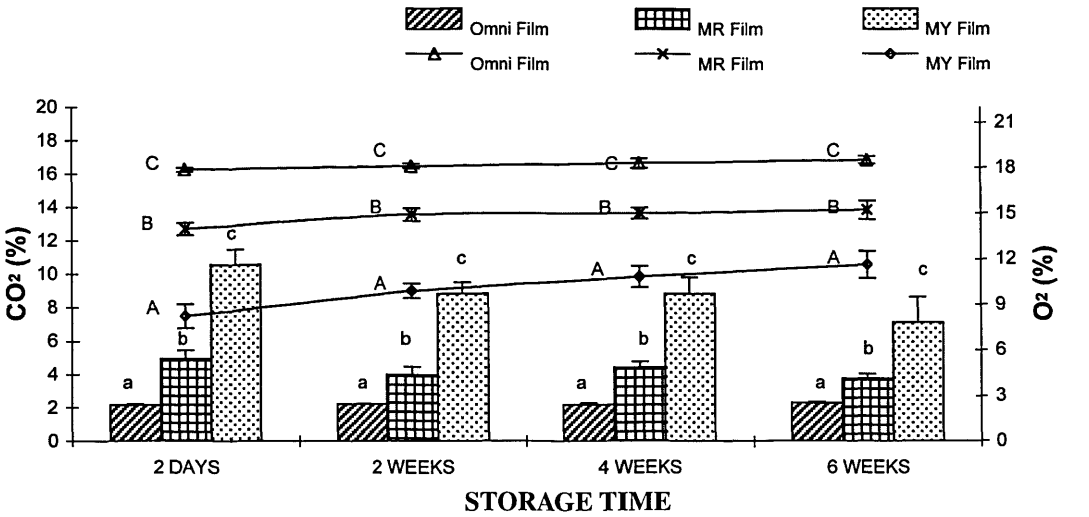

Fig. 2 - In-package atmosphere evolution as affected by the different plastic films measured only in packages free of rotten fruits. Histograms represent CO_2 and lines represent O_2. Vertical bars indicate standard error (n=10). For each storage time, values with different letters differ significantly at P≤0.05 by the LSD test.

was observed during storage until packages were free of decay; on the other hand a sharp increase in CO_2 and a concomitant decrease in O_2 (data not shown) occurred when some decay developed. Data shown in Figs. 2 and 3 refer only to packages free of rotten fruits.

Regarding in-package ethylene, a progressive increase was observed during storage, with very low concentrations after 2 days of wrapping and values ranging from 0.05 to 0.7 $\mu L \cdot L^{-1}$ at the end of the trial (Fig. 3). With the exception of the first recording at 2 days, when there was a significant difference between Omni and MY packages, there was no

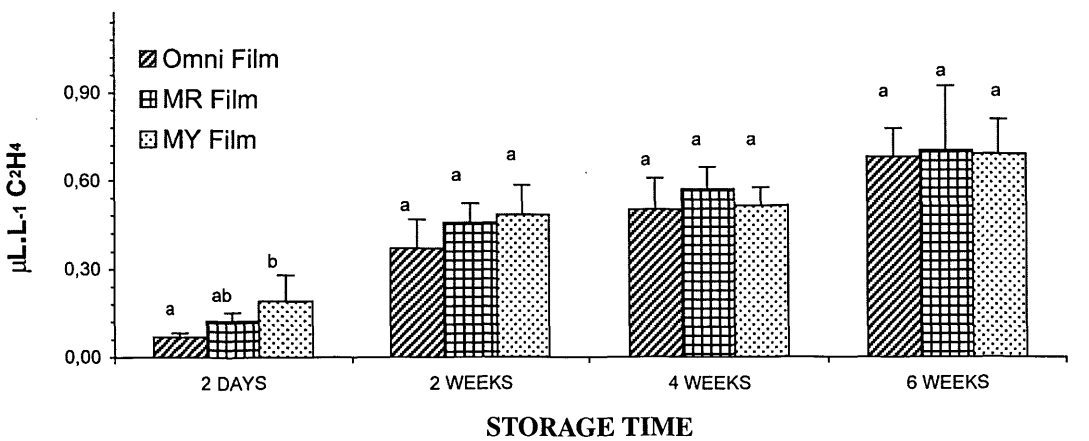

Fig. 3 - In-package ethylene evolution as affected by the different plastic films measured only in packages free of rotten fruits. Vertical bars indicate SE (n=10). For each storage time, values with different letters differ significantly at P≤0.05 by the LSD test.

statistical difference with the three films (Fig. 3).

Decay

The amount of decay increased progressively with storage, especially in fruits not treated with fungicide (Table 3). As observed by others (D'AQUINO *et al.*, 1997; MILLER *et al.*, 1988), imazalil is very effective in controlling microbiological deterioration, particularly green mould rot caused by *Penicillium digitatum*, which was the major cause of decay. Decay development was favoured by the application of film. Its incidence was greatly linked to film permeability, with Omni being the lowest, MR intermediate, and MY the highest. Imazalil reduced the loss due to decay in Omni and MR packages, while in MY, although its efficacy was also statistically significant, the incidence of rotten fruits was too high for it to be used commercially. In fact, at the 4th week of storage most packages contained decayed fruits. The different permeability of the films also influenced how the green mould rot developed. While in fruits wrapped with Omni film the fungus had a normal development, in those packaged with MR and MY films, the low levels of oxygen partially inhibited the production of spores and rotten fruits were covered with a white mycelium.

In non-wrapped fruits most of the microbiological deterioration occurred by the 4th week of storage and from then on a very slight increase, although significant, was observed. It appears that after some weeks from harvest, the ability of the pathogens to invade the tissue was reduced. The rapid dehydration of the peel might create unfavourable conditions for development of micro-organisms. Regarding the nature of pathogens, most of the infections were caused by *Penicillium digitatum*, while only a low percentage of fruit was affected by *Botritis cinerea* and *Alternaria* spp. (data not shown).

Weight loss, aesthetical aspect and colour changes

Weight loss increased progressively reaching 18% in non-wrapped fruits at the end of the trial (Table 4). In fruits wrapped with MR and MY films, transpiration was reduced to a very low level, and after the 6 weeks of storage it was about 2.3 and 1.8%, respectively. Omni film, on the contrary, showed only a slight influence and at the end of the trial a 14% reduction of the initial weight was recorded. Imazalil had no significant effect on transpiration.

Weight loss was highly correlated to the aesthetical deterioration of the fruit. Non-wrapped fruits, starting with the first inspection time, showed signs of ageing (Table 3) and at the 2nd inspection most of them were not able to be marketed. On the other hand, fruit that was wrapped in MR and MY films, even at the end of the trial, showed no signs of senescence and the only aesthetical alteration was due to the loss of the button. Fruit wrapped with Omni film was intermediate to the non-wrapped fruits and to those wrapped with MR and MY films.

In non-wrapped fruit and, to a lesser extent, in those wrapped with Omni film, the rapid dehydration of the peel caused a progressive increase in firmness (Table 4), which masked the expected reduction of resistance to penetration. Unlike Omni, in MR and MY wrapped fruits, as a consequence of the structural changes taking place at the cell-wall level of ripening-ageing cells, resistance to penetration of the probe progressively decreased. On the other hand, in non-wrapped fruits and in Omni wrapped fruits the deformation was increasingly higher than in MR and MY wrapped ones, in which the turgidity of the cells let the fruits maintain most of their initial elasticity for the whole storage period.

Water loss also affected the rind thickness (Table 4). In non-wrapped and

Table 3 - Effect of treatments on decay, presence of button and overall appearance of "Salustiana" orange fruits after 2, 4 and 6 weeks of storage at 18°-20°C and 60-65% RH.

Storage Time	Decay (%)	Fruits without button (%)	Overall appearance (Index Number)
HARVEST	0	0	9
2 WEEKS			
Non-wrapped - No Imazalil	0a[1]	55.5d	6.6a
Non-wrapped - Imazalil	0a	47.2c	6.5a
Omni Film - No Imazalil	5.6bc	0a	8.2b
Omni Film - Imazalil	0a	2.7b	8.7b
MR Film - No Imazalil	8.3c	3.3b	9c
MR Film - Imazalil	0a	0a	9c
MY Film - No Imazalil	22.2d	3.3b	9c
MY Film - Imazalil	2.7b	0a	9c
4 WEEKS			
Non-wrapped - No Imazalil	8.3c	85.2d	3.9a
Non-wrapped - Imazalil	2.7b	84.8d	4.5b
Omni Film - No Imazalil	0a	75.6c	6.9c
Omni Film - Imazalil	2.7b	79.5cd	7c
MR Film - No Imazalil	22.2	20.2a	8.4d
MR Film - Imazalil	8.3c	30.4b	8.6d
MY Film - No Imazalil	33.3e	25.3ab	8.1d
MY Film - Imazalil	12.7d	27.5ab	8.3d
6 WEEKS			
Non-wrapped - No Imazalil	9.6b	96.4d	1.8a
Non-wrapped - Imazalil	2.6a	98.3d	2a
Omni Film - No Imazalil	25c	82.4c	4.8b
Omni Film - Imazalil	2.7a	92.5cd	4.9b
MR Film - No Imazalil	50d	60.2a	7.8c
MR Film - Imazalil	4a	64.6a	8c
MY Film - No Imazalil	68e	68.8ab	7.6c
MY Film - Imazalil	28.3c	70.3b	8.1c

ANOVA

Source	df	Mean square	df	Mean square	df	Mean square
Period (P)	2	2,895***	2	1,449*	2	125***
Fungicide (T)	1	6,267***	1	960ns	1	2.86**
Film (F)	3	3,031***	3	1,730**	3	93.6***
PxT	2	387ns	2	297ns	2	0.42ns
PxF	6	462ns	6	3,756***	6	5.43***
TxF	3	1,102*	3	349ns	3	0.17ns
Error	126	307	126	323	126	0.25

[1] Means in columns for each storage period followed by different letters are significantly different at the 5% level by the LSD test.
ns, *,**,*** = non significant or significant at P≤0.05, 0.01 or 0.001, respectively.

Table 4 - Effect of treatments on weight loss, juice content, peel thickness, deformation and firmness of Salustiana oranges stored at 18°-20°C and 60-65% RH for 6 weeks.

Storage Time	Weight loss (%)	Juice content (%)	Peel thickness (cm)	Deformation (mm)	Firmness (g)
HARVEST	-	38.3	1.6	0.95	865
2 WEEKS					
Non-wrapped	8.0c[1]	40.5c	1.2a	1.6c	903b
Omni Film	4.0b	40.4c	1.4b	1.1b	900ab
MR Film	0.8a	38.6b	1.7c	0.7a	847a
MY Film	0.5a	35.4a	1.5c	0.8a	831a
4 WEEKS					
Non-wrapped	11.7c	41.1b	1.0a	2.9c	977c
Omni Film	8.3b	40.2a	1.3b	2.4b	877b
MR Film	1.0a	37.6b	1.6c	1.0a	709a
MY Film	0.9a	38.1a	1.6c	0.9a	734a
6 WEEKS					
Non-wrapped	18.3c	42.8b	0.9a	4.3c	1072c
Omni Film	14.2b	42.2b	1.1b	3.5b	902b
MR Film	2.3a	38.6a	1.6c	1.2a	647a
MY Film	1.8a	37.6a	1.5c	1.4a	712a

ANOVA

Source	df	Mean square	df	Mean square	df	Mean square	df	Mean square	df	Mean square
Period (P)	2	2147.9***	3	22.8*	3	0.5***	3	50.9***	3	1,270,950***
Fungicide (T)	1	59.1ns	1	7.4ns	1	0.009ns	1	0.07ns	1	36,341ns
Film (F)	3	6,380.6***	3	45.6***	3	20.5***	3	42***	3	580,416***
PxT	2	53ns	4	0.9ns	3	0.02ns	3	0.24ns	3	30,887ns
PxF	6	403***	10	9.2ns	9	0.34***	9	9***	9	104,249***
TxF	3	53.5*	3	6.1ns	3	0.06ns	3	0.28ns	3	49.2ns
Error	750	21.1	72	6	297	0.07	297	0.27	297	13,354

[1] Means in columns for each storage period followed by different letters are significantly different at the 5% level by the LSD test.
ns, *,**,*** = non significant or significant at P≤0.05, 0.01 or 0.001, respectively.

Omni-wrapped fruits there was a progressive and significant reduction from harvest time to the end of the trial, whilst negligible variations occurred in MR and MY wrapped fruits.

The increase in juice during storage which occurred only in non-wrapped and Omni-wrapped fruits, confirms, as previously demonstrated by BEN-YEHOSHUA *et al.* (1979), that most of the water lost during storage comes from the peel.

During storage important changes regarding the colour parameters L* a* b* occurred, especially in non-wrapped fruits. As reported in Table 5, the greatest changes took place in non-wrapped fruits and those wrapped with Omni film. There was a decrease in L* values which means a reduction of brightness, and a

concomitant rise in a* and b*, which represents an increase in red and yellow, respectively, indicating a loss of chlorophyll. Since the changes in all three parameters are usually associated with ageing, we can deduce that the application of the films gave a positive contribution to delaying senescence of the fruits and prolonging brightness of the peel. A similar response was obtained by wrapping lemons (HALE *et al.*, 1983) and grapefruits (KAWADA and ALBRIGO, 1979).

Changes in chemical and sensory quality

Results of chemical analysis are reported in Table 2. During storage a significant variation in titratable acidity (TA) and vitamin C content and a concomitant increase in pH occurred, whereas the levels of total soluble solids (TSS) remained quite stable. As a general trend, wrapped fruits underwent the highest loss of TA, TSS and vitamin C and the

Table 5 - Changes in peel colour of "Salustiana" oranges stored at 18°-20°C and 60-65% RH for 6 weeks.

HARVEST Storage Time	L 65.56 ΔL	a 20.73 Δa	b 70.10 Δb
2 WEEKS			
Non-wrapped	-1.47c	1.58c	0.25a
Omni Film	-1.10bc	1.11b	0.35a
MR Film	-0.80b	0.32a	0.53a
MY Film	-0.47a	0.58a	0.22a
4 WEEKS			
Non-wrapped	-2.21b	2.20c	1.38b
Omni Film	-1.94b	1.27b	1.70b
MR Film	-1.15a	0.69ab	0.67a
MY Film	-1.13a	0.25a	0.54a
6 WEEKS			
Non-wrapped	-2.84b	4.81c	2.67b
Omni Film	-1.86a	1.34b	2.27b
MR Film	-1.50a	0.86a	1.24a
MY Film	-1.67a	0.65a	1.11a

ANOVA

Source	df	Mean square	df	Mean square	df	Mean square
Period (P)	2	152***	2	102***	2	429***
Fungicide (T)	1	23ns	1	0.1ns	1	52ns
Film (F)	3	68*	3	285***	3	103**
PxT	2	12ns	2	14ns	2	33ns
PxF	6	38ns	6	37**	6	54*
TxF	3	31ns	3	18ns	3	29ns
Error	558	23	558	12	558	25

[1] Means in columns for each storage period followed by different letters are significantly different at the 5% level by the LSD test

ns, *,**,*** = non significant or significant at P≤0.05, 0.01 or 0.001, respectively.

greatest increase in pH. These variations were important, from the quality point of view, only in fruits wrapped with MY film, in which the greatest chemical alteration occurred. No influence due to imazalil was observed. Our results confirm those reported by PURVIS (1983).

As reported in Fig. 4, no appreciable variation in sensory quality was detected by the panelists after 2 weeks of storage. After 4 weeks important differences were noted. In particular, there was a significant increase in off-flavour, a loss of sweetness, acidity and freshness in fruits that had been wrapped with MY film and these fruits were judged unedible. Non-wrapped fruits and Omni film wrapped fruits, even if judged as having a better taste especially for sweetness, had a slight off-flavour which, in general, was not considered as positive. They were not as fresh and crisp as at harvest. On the other hand, until the end of the trial the fruits packaged with MR film were as fresh as the fruit at harvest.

CONCLUSIONS

The objective of this trial was to check the biochemical and physiological changes occurring in "Salustiana" oranges held continuously in S-L conditions using different plastic films, and to determine if it was possible to maintain the fruits for the entire storage time without important alterations in the overall quality.

Film application created a barrier to vapor exchange which acted positively in reducing ageing and senescence of the peel by minimizing weight loss and shrinkage, and, consequently, sustaining the turgidity of the outer layer of peel cells. All this led to lengthening of the juvenile stage of the peel, probably maintaining a higher level of endogenous gibberellins and cytokinins (BEN-YEHOSHUA, 1987). As a result, fruits wrapped with MY (the least permeable to gases and water) and MR films preserved their initial visual appearance. But, the barrier to gas exchange reduced the availability of oxygen to the inner tissue, cre-

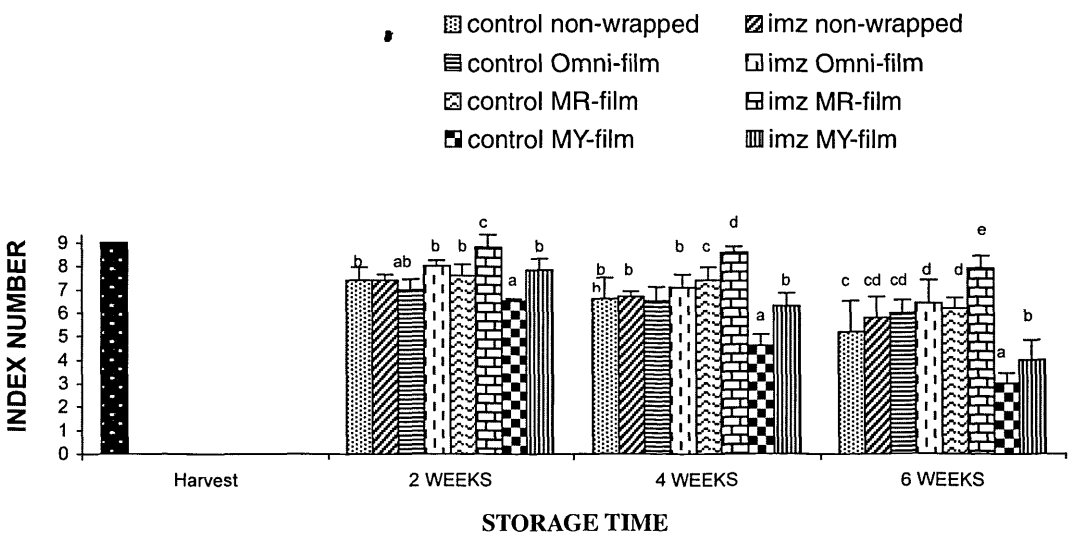

Fig. 4 - Acceptability of the taste of "Salustiana" oranges as affected by imazalil and plastic films. The values are the average of the score given by ten panelists, according to a subjective scale ranging from 1 to 9, where 9 represented the highest appreciation and 1 the worst, assuming 5 as limit of edibility. Vertical bars indicate standard error (n=10). For each storage time, values with different letters differ significantly at P≤0.05 by the LSD test.

ating asphyxiating conditions. This resulted in a shift towards anaerobic metabolism which hastened the break down of acids, sugars and vitamin C. This promoted the build up of off-flavours, especially in fruits wrapped in MY film, which, in spite of their good visual appearance, were unsuitable for eating after the second week of storage. In addition, the high level of in-package humidity caused a significant loss due to decay in wrapped fruit not treated with imazalil, indicating that it is not possible to store the fruit at room temperature without the application of an effective fungicide.

The rapid water loss in non-wrapped and Omni-wrapped fruits caused early ageing and shrinkage of the peel, rendering them flaccid and unmarketable from the 2nd and the 4th week of storage, respectively. In addition, the increased resistance to gas diffusion due the desiccation of the peel (BEN-YEHOSHUA *et al.*, 1985), which reduced the availability of oxygen to the inner tissue, promoted anaerobic metabolism to some extent and the build-up of off-flavour.

Analysing all the aspects considered the best results were obtained combining MR film with imazalil. This treatment, in fact, limited loss due to decay to about 1%, inhibited weight loss and preserved the visual appearance, without altering the chemical and sensory characteristics from those at harvest time.

ACKNOWLEDGEMENTS

The authors contributed equally to this study. Research supported by the National Research Council of Italy. The authors wish to thank Mr. D. Mura for his technical assistance.

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Paper received December 17, 1999 Accepted March 20, 2000