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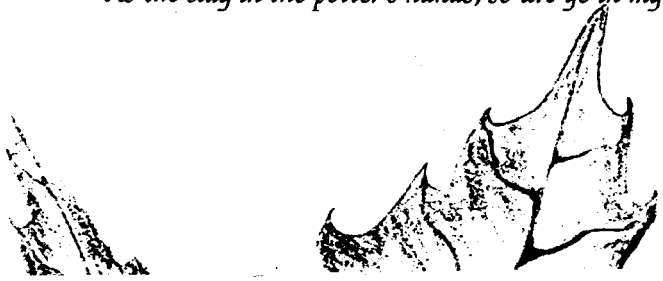
"As the clay in the potter's hands, so are ye in my hand"
(Jeremiah. 18:6)



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Respiration Rate and In-Package Gas Evolution of "Okitsu" Satsuma Fruits held in Shelf-Life Condition

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Abstract

"Okitsu" satsuma fruits, harvested the 20th of October, before being stored for 1 month in shelf-life condition (20°C and 70-75% RH) were first dipped in an emulsion containing 500 ppm of thiabendazole (TBZ) or left untreated, and then either nonwrapped or wrapped in groups of 8 with two different plastic films (Cryovac MD and MY, respectively 19mm and 20mm thickness). In-package atmosphere evolution (CO_2 and O_2) and respiration rate of nonwrapped fruits were monitored daily. In addition at 10-day intervals fruit were inspected for decay, overall appearance, weight loss, and respiration rate and internal atmosphere of wrapped fruits was measured either at the moment of the removal of the film or the day after. An informal panel test of 7 technicians also tasted the fruits for sensory evaluation.

The respiration rate of nonwrapped fruit or in-package CO_2 concentration decreased with the time in storage. The respiration rate of wrapped fruits following removal of the film was higher than that of nonwrapped ones, especially at the time of unwrapping, but the internal CO_2 concentration was always lower than nonwrapped fruits. No important differences were observed between the two different plastic films. Both plastic films gave a positive contribution in reducing weigth loss and in maintaining freshness, even if the incidence of decay was higher in wrapped fruits than in nonwrapped ones, in particular, for fruits which received no fungicidial treatment. In general the panellists found wrapped fruit more acceptable than nonwrapped fruit.

Keywords

Citrus unshiu Mar., carbon dioxide, freshness, oxygen, plastic film, resistance to gas diffusion, weight loss

1. Introduction

"Okitsu" satsuma fruits, as well as with "Miho" and

"Miyagawa" cultivars, represent the earliest ripening citrus fruit in Italy and recently new plantations of these specialty achieve important hectarage. The total crop is aimed for the fresh market, but the high perishability of the fruit, primarily due to shrivelling, can limit long distance distribution if fruit are not properly handled and refrigerated. Wrapping fresh produce can result to be very beneficial in maintaining good quality during distribution and retail conditions (Hardenburg, 1971; Miller and Risse, 1988). D'Aquino *et al.* (1996) found that "Miho" satsuma fruit can be stored for 24 days at 20°C and 70-75% RH without appreciable loss of quality attributes, but they did not study respiration rate and gas accumulation. Usually the most common used plastic films are more permeable to CO_2 than to O_2, but at warm temperatures respiration rate can increase rapidly and the permeability of the films may be inadequate to avoid injury from CO_2 accumulation or possible formation of off-flavour and off-odours.

The objective of our work was to study the influence of two different plastic films on quality attributes and respiration rate of "Okitsu" satsuma fruit, and gas accumulation inside the packages, at 20°C, in simulated marketing conditions.

2. Materials and Methods

Freshly harvested "Okitsu" satsuma fruit (*Citrus unshiu* Marc.) were dipped in a solution of 500 ppm of TBZ at room temperature or left untreated and then wrapped with a 19 mm (Cryovac MD) or a 20 mm (Cryovac MY) thick films, or nonwrapped. The fruit were then stored at 20°C and 70-75% relative humidity (RH) for 10, 20 or 30 days. At harvest ten fruits of uniform size (about 100 g) and 10 packages of each wrapped treatment were chosen to be followed at day intervals (with the exception of the week end) respectively for respiration rate and in-package CO_2 and O_2 evolution. At each inspection time 15 packages of each treatment were opened and immediately 10 fruits were used for respiration rate; respiration rate was also measured the day following the removal of the film in the same fruits. Internal CO_2 and O_2 concentration was measured in 10 fruit of each single treatment either the day of the removal of the film or the next day, but the used fruit were always different.

For respiration rate the fruits were individually closed into 1-liter jars for 2 hours and 20 ml of the head space atmosphere was injected in an O_2/CO_2 analyzer (Servomex), while the in-package atmosphere composition was determined withdrawing a 20 ml sample from the packages.

For determining internal atmosphere of the fruit, after remov-

ing the calyx, a 2-ml sample was withdrawn and CO_2 and O_2 concentration was determined by gas-chromatography, as previously reported by D'Aquino *et al.* (1996).

At each inspection time fruits were weighed for weight loss and rated subjectively for decay, percentage of rotten fruit, and for overall appearance (freshness), according to a scale ranging from 1 to 5, where 5 was very fresh, 3 the limit of marketability, and 1 very old.

In addition 20 fruit chosen from packages with no rotten fruit and 20 ones from nonwrapped treatments were peeled and divided into segments for sensory overall quality evaluation (acceptability) by 7 untrained panellists, using a rating scale ranging from 1 to 9, where 9 = excellent , 7 = good, 5 = fairly good (limit of edibility), 3 = bad, 1 = very bad.

Data were analysed for each storage period by analysis of variance and means were separated by LSD.

3. Results and Discussion

3.1 In-package atmosphere

In-package CO_2 (Fig. 1A) concentration decreased slightly until the 20th day. After the 20th day it increased and at the end of the trial was higher than 4%. This trend was due to the rotten fruits inside the packages, in fact in the beginning we were able to choose packages with no rot, but after 20 days it was difficult to find packages with no rotten fruit or incipient decay. O_2 concentration (Fig.1A) ranged between 16% and 18%, and only in the last days the values went down to 16%. No differences were noticed between the two plastic films (data not shown), and this was presumably due to the kind of sealing used, which was not perfectly airtight, for this reason the data presented are the average of the two films. In-package atmosphere was pretty similar between TBZ treated fruit and nontreated fruit, only after the second inspection time a little increase and decrease respectively of CO_2 and O_2 occurred in fruit which received no fungicidial treatment, due to the presence of rotten fruit inside the packages.

Eaks reported a similar trend for in-package atmosphere of individually sealed lemons and grapefruit (Eaks, 1990)

3.2 Respiration rate

Respiration rate (Fig. 1B) decreased in storage time in nonwrapped fruit, and the highest reduction occured during the first days, after that it decreased slightly during the storage time. In wrapped fruit at the time of the removal of the film respiration

rate was always significantly higher than in nonwrapped fruit, especially after 30 days of storage, but after one day from the removal of the film it decreased, even if it was always higher than the control. Surely the higher respiration rate of fruit whose wrap was removed was a consequence of the accumulation of the CO_2 inside the packages.

Both Eaks (Eaks, 1990) with lemon and grapefruit fruits, or Ben-Yehoshua (1978) found a lower respiration rate in wrapped fruit than in nonwrapped one, but they measured respiration rate of wrapped fruit without removing the film which created a barrier to the diffusion of CO_2; in contrast we measured the respiration immediately after the removal of the film, and this might let the accumulated CO_2 go out rapidly, giving a misleading response, in fact the day following the removal of the film the respiration rate of unwrapped fruit decreased rapidly.

3.3 Internal gas composition

Internal CO_2 (Fig. 2A) at harvest was about 1%, but by the time in storage it increased progressively reaching concentrations higher than 5% in nonwrapped fruit. In wrapped fruit at the moment of the removal of the film the internal concentration of CO_2 was lower than in nonwrapped fruit and decreased further the following day, indicating that a component of the internal CO_2 measured at the time of wrap removal was due to the barrier created by the film.

Internal O_2 (Fig. 2B) concentration at harvest was almost 19%. During storage, O_2 concentration decreased either in nonwrapped fruit or in fruit whose wrap was removed, but in nonwrapped fruit the decrease was higher than in fruit whose wrap was removed, and after 30 days of storage ranged between 10% and 11%. In fruit whose wrap was removed the amount of O_2, which was already higher than in nonwrapped fruit at the moment of the removal of the film, increased significantly the day after.

The results indicate a clear increase in resistance to gas diffusion by the time in storage, and this increase was much higher in nonwrapped fruit than in wrapped one. Increased

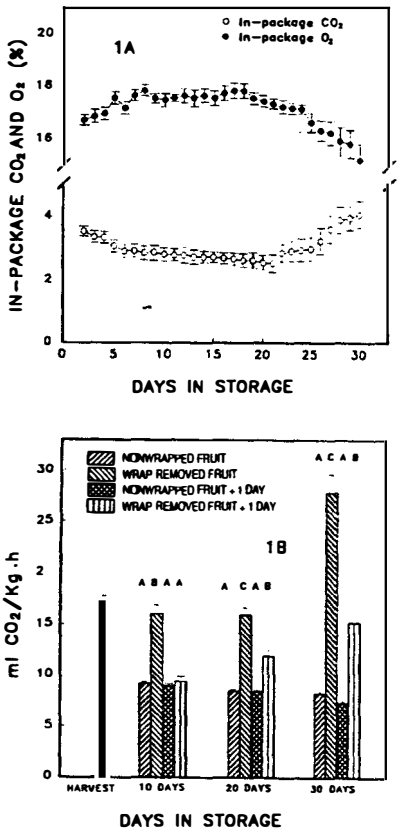

Fig. 1. (A) Changes of in-package CO_2 and O_2 concentration during storage at 20°C and 70-75% RH. Vertical bars indicate SE (n = 10). Respiration rate of nonwrapped and unwrapped (after the removal of the film) of satsuma held at 20°C and 70-75% RH. Means followed by different letters for each storage period are significantly different at the 5% level by the LSD test. Vertical bars indicate SE (n = 10).

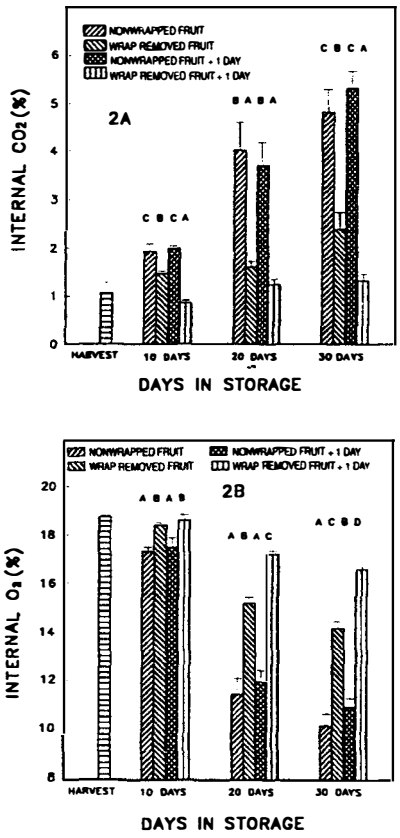

Fig. 2. Effect of wrapping on endogenous CO_2 (A) and O_2 on "Okitsu" satsuma fruits stored at 20°C and 70-75% RH. Means followed by different letters for each storage period are significantly different at the 5% level by the LSD test. Vertical bars indicate SE (n = 10).

resistance to gas diffusion with the time in storage has been observed previously by other authors (McDonald *et al.*, 1993), and are presumably to ascribe to drying of the peel, as reported by Ben-Yehoshua (1969).

3.4 Weight loss

Weight loss (Table 1) was significantly influenced by film wrapping. Nonwrapped fruits lost 5.5% of the initial weight after 10 days, 12.8% after 20 days and 18.6 after 30 days, while wrapped fruit lost 1.4% only after 30 days. This result confirms what has been observed by other researcher with other citrus fruits (Ben-Yehoshua *et al*, 1979; D'Aquino *et al*, 1996,)

3.5 Subjective analysis

Wrapped fruit maintained their freshness during the full storage period, while nonwrapped fruit since after 10 days of storage showed signs of senescence and after 20 days of storage mostly appeared old and not marketable (Tab.1). The panellists found wrapped fruit more acceptable than nonwrapped fruit (Tab.1), and after 30 days they found the presence of off-flavour only in nonwrapped fruit.

Decay development was adequately controlled by TBZ treatment, especially in non-wrapped fruit (about 1% of rotten fruit), while in wrapped treated fruit the amount of rotten fruit (5%) was similar to that of nonwrapped nontreated fruit (7%), conversely decay incidence was rather high in wrapped nontreated fruit (18%).

4. Conclusion

The data obtained indicate the beneficial effect of plastic film in maintaining the quality of wrapped fruit. In cases as that of satsumas which (being early ripening fruit) are intended to the fresh market, the use of plastic film can be very beneficial in reducing the rate of deterioration of high perishable citrus fruits, such as satsumas, and allow to keep the fruits in retail conditions

Table 1. Effect of wrapping on weight loss, overall appearance (freshness) and sensory evaluation (acceptability) in Okitsu satsuma fruits stored for 10, 20 or 30 days at 20°C and 70-75% relative humidity (RH)

Treatments	Storage Period	Weight loss (%)	Freshness[1] (index number)	Acceptability[2] (index number)
	Harvest	-	5.0	9.0
Nonwrapped	10 days	5.60b*	3.5a	9.0a
Wrapped	10 days	0.71a	5.0b	9.0a
Nonwrapped	20 days	12.80b	2.8a	7.0a
Wrapped	20 days	0.95a	4.9b	8.6b
Nonwrapped	30 days	18.60b	2.1a	4.7a
Wrapped	30 days	1.40a	4.7b	7.8b

* Means in columns for each storage period followed by the same letter are not significantly different at the 5% level by the LSD test.

[1] Freshness evaluated subjectively according to a scale ranging from 1 to 5, where: 5 = fruit very fresh, 3 = fairly fresh (limit of marketability), and 1 = very old.

[2] Sensory overall quality (acceptability) evaluated subjectively using a rating scale ranging from 1 to 9, where 9 = excellent, 7 = good, 5 = fairly good (limit of edibility), 3 = bad, 1 = very bad.

for a months without appreciable loss of quality attributes and avoiding the refrigeration. The little increase in resistance to gas diffusion of wrapped fruit compared to nonwrapped fruit, reduced the accumulation in the flesh of metabolites produce in anaerobic conditions, in fact the panellists noticed the presence of off-flavour and off-odours only in non-wrapped fruits.

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