Alleviation of cold storage disorders in nectarines by modified atmosphere packaging

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Abstract — Introduction. Prolonged storage of nectarines leads to development of physiological disorders, mainly woolliness. Controlled atmosphere with elevated CO_2 levels have proved effective for various fruits in reducing such disorders and effective modified atmosphere was sought for a better nectarine storage. **Materials and methods**. Experiments were conducted with three nectarine varieties (Summer Diamond, August Red and Flamekist) kept for 30 d in cold storage followed by a shelf-life period at 20 °C up to ripeness. Modified atmosphere packaging (MAP) treatments included bags made from three microperforated films and from a low permeability film, along with a control treatment without MAP. **Results and discussion**. Treatments using microperforated films were able to attain, in packaging, desired gas levels (> 15 % CO_2; not less than 4 % O_2), allowing thus an adequate control of physiological disorders. Further, such materials seem able to partially compensate for inadequate temperature regime at the beginning of cold storage period. Some microperforated films resulted in higher fruit water loss than did low permeability film, but all MAP treatments gave better results than control. However, high rotting incidence in MAP treatments, attributed to particular experimental conditions during shelf life, justify further work before recommendations can be given. © Éditions scientifiques et médicales Elsevier SAS

Chile / nectarines / postharvest physiology / cold storage / browning / packaging equipment / controlled atmosphere storage

Contrôle des problèmes liés au stockage de nectarines à basse température, par utilisation d'emballage à atmosphère modifiée.

Résumé — introduction. Le stockage prolongé des nectarines mène au développement d'anomalies physiologiques, aboutissant principalement à une consistance farineuse de la chair. L'atmosphère contrôlée à teneur élevée en CO_2 s'est avérée efficace pour réduire de tels désordres chez certains fruits et une atmosphère modifiée adaptée a donc été recherchée pour la conservation de la nectarine. **Matériel et méthodes**. Une expérimentation a été menée avec les fruits de trois variétés de nectarine (Summer Diamond, August Red et Flamekist) entreposés 30 d au froid (0 °C), puis conservés à 20 °C jusqu' à leur maturité. Les emballages sous atmosphère modifiée (EAM) testés ont porté sur l'utilisation de sacs constitués de trois types de films en polyéthylène à microperforations et d'un film à basse perméabilité ; les fruits témoins ont été entreposés en atmosphère normale. **Résultats et discussion**. Les traitements utilisant des films à microperforations ont permis d'obtenir, dans l'emballage, des taux de gaz satisfaisants (> 15 % de CO_2 et pas moins que 4 % d'O_2), permettant de ce fait un bon contrôle des désordres physiologiques. De plus, de tels matériaux semblent capables de compenser partiellement des régimes de température peu satisfaisants intervenant en début de période d'entreposage au froid. Certains films à microperforations ont entraîné, pour les fruits, une perte d'eau plus élevée que celle observée lors de l'utilisation du film de faible perméabilité, mais tous les traitements d'EAM ont donné de meilleurs résultats que le traitement témoin. Cependant, l'observation, dans des traitements d'EAM, de fruits pourris qui résulteraient de conditions expérimentales de conservation particulières, justifie que d'autres travaux soient entrepris avant que des recommandations puissent être données. © Éditions scientifiques et médicales Elsevier SAS

Chili / nectarine / physiologie après récolte / stockage au froid / brunissement / matériel de conditionnement / stockage en atmosphère contrôlée

1. introduction

Prolonged cold storage/transport leads to occurrence of physiological disorders (mainly woolliness characterized by lack of fruit juiciness), thereby seriously impairing eating quality of many nectarine varieties [1] as occurring typically in fruit exported from Chile to distant markets, i.e., Europe.

Previous research in Chile [2, 3] and other countries [4, 5] has shown the potential of high CO_2 controlled atmosphere (CA) and modified atmosphere packaging (MAP) to reduce such disorders. CA storage during export is mainly carried out by using CA-containers, an expensive solution requiring availability of such equipment. MAP, being less expensive and widely available, could thus constitute an interesting alternative. While conventional low permeability MAP materials allow the accumulation of high CO_2 levels, they do this with a considerable risk of anaerobiosis due to low O_2 levels inside the bags [2]. Therefore, novel microperforated materials able to provide high CO_2 without depleting O_2, which have been tried for other fruits [6], seem interesting for this particular application. The aim is to obtain desired gas levels of more than 15 % CO_2 with O_2 reaching not less than 4 %, which would avoid potential anaerobic conditions. Further, keeping the fruit at temperatures as close as possible to 0 °C is paramount in avoiding higher incidence of woolliness [7]. However, MAP could introduce an additional problem in keeping such temperature especially at the beginning of the export procedure.

The objective of this work was to test the effect of MAP, especially by using novel microperforated films, on physiological disorders and quality of nectarine fruit.

2. materials and methods

Experiments were carried out in the 1998–1999 season with nectarines of the cultivars Summer Diamond, August Red and Flamekist. These varieties were chosen as they are important for Chilean export and have shown high incidence of physiological disorders [3].

For MAP studies, films of different permeability to gases were used, i.e.:

– microperforated films with low permeability indices to CO_2: three microperforated Xtend film grades (Xt A, B and C; Stepac Ltd., Israel), with four microperforations of 0.4 mm diameter each, were used to test the behaviour of the three cultivars,

– a polyethylene film with low permeability (LP) to both CO_2 and O_2 and without microperforations was used with the Summer Diamond and August Red cultivars.

The control treatment consisted in nectarines stored without MAP.

Microperforated bags were closed manually, while LP bags were heat-sealed by using a pneumatic equipment (PAC Vacuum Impulse Sealer, Packaging Aids Corporation, San Rafael, CA).

Fruit was harvested in an orchard 80 km south of Santiago and transported to a nearby packing house facility (15 km) where it was hydrocooled, sorted, packed in 5 kg boxes (including MAP materials) and air-cooled prior to cold transport to storage. This was performed in Santiago for 30 d at the Postharvest Unit, La Platina Research Station, normally at 0 °C (or 5 °C in other chamber during the first 7 d, for August Red cv.) and 80–85 % RH, with MAP bags being then opened with fruit kept in for a shelf life period at 20 °C up to ripeness.

Concentrations of CO_2 and O_2 were periodically measured during cold storage on a 5 ml-gas sample of the inside atmosphere of the bags by using a MAPtest 4 000 gas analyzer (Hitech Inc., England). After cold storage, firmness and soluble solids were evaluated on a sample of five fruits per box. Fruit was kept a given number of days at 20 °C until reaching eating ripening stage as judged by firmness around 1 kg force (9.8 N). Following parameters were then evaluated as in [2]: a) fruit firmness by penetrometer in ten fruits per carton; b) soluble solids by refractometer in five fruits per carton; c) physiological disorders: occurrence and severity of woolliness and internal browning were determined in all fruits from the carton (excluding rotted ones) by cutting by half and submitting them to subjective evaluation (juiciness and flesh discoloration) for woolliness and internal browning, respectively; d) rotting: occurrence was measured by percentage of fruit showing symptoms of decay per box ($n = 50$); e) weight loss: five fruits per carton, individually marked and weighed at the beginning of the experiments, were weighed again after cold storage.

The experiments corresponded to a complete randomized experimental design with five treatments and four replicates of one box each. Results were submitted to ANOVA, and Duncan´s multiple range test if statistical differences were determined. Values in percentage were transformed by using arc sin transformation for statistical analysis.

3. results and discussion

3.1. Summer Diamond cultivar

For the Summer Diamond cultivar tested with Xtend films, a marked increase in CO_2 and reduction of O_2 were rapidly attained (*figure 1*), with O_2 reaching desired levels (above 4 %) after 4 d. For each of these films, gas levels did not show ample variation around the mean value (data not shown). LP treatment was not able to reach high CO_2 levels in this particular trial, probably because of poor sealing.

After cold storage Summer Diamond cv. fruit was firmer for MAP treatments, but it was able to soften normally during shelf-life (*table I*). Similarly, high CO_2 in controlled atmosphere has been shown to reduce softening during cold storage [2]. As expected, weight loss was reduced particularly with low permeability bag, but all MAP

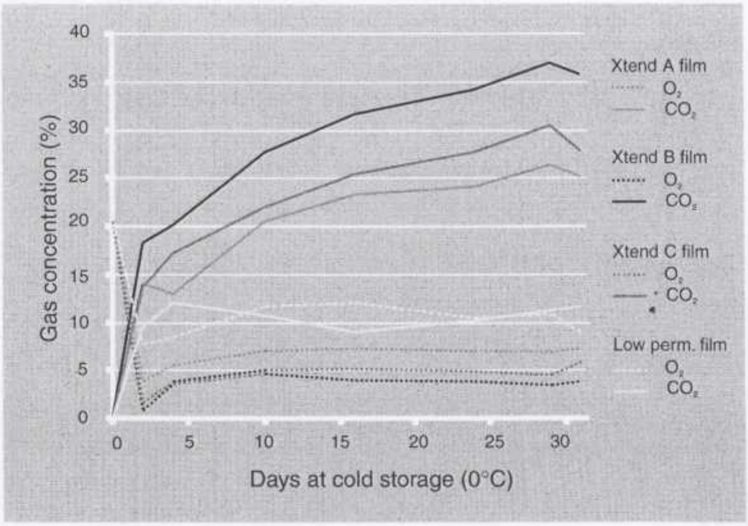

Figure 1.
Changes in O_2 and CO_2 concentrations during cold storage of nectarines cv. Summer Diamond, within bags made from three microperforated films (Xtend A, B and C) and from a low permeability film.

Table I.
Firmness and weight loss in nectarines cv. Summer Diamond stored in a modified atmosphere packaging (MAP) including bags made from three microperforated films (Xtend A, B and C) and from a low permeability film (LP). The control treatment was without MAP. Fruit firmness at harvest was 6.3 kg force.

Treatment	Firmness (kg force)[1]		Weight loss (%) after 30 d at 0 °C
	After 30 d at 0 °C	Eating stage after shelf-life[2]	
Xtend A	5.0 ab	0.7 a	3.2 d
Xtend B	5.5 b	1.1 a	1.4 b
Xtend C	5.1 ab	0.9 a	2.1 c
LP	4.9 ab	0.7 a	0.3 a
Control	4.4 a	1.0 a	7.1 e

Means with the same letter are not significantly different ($p < 0.05$).
[1] 1 kg force = 9.8 N.
[2] Fruit was evaluated after 30 d at 0 °C plus a shelf-life period (6 d at 20 °C), except in the control treatment (4 d at 20 °C).

Table II.
Postharvest determinations in nectarines cv. Summer Diamond after storage, 30 d at 0 °C plus a 6 d shelf-life period (20 °C), in a modified atmosphere packaging (MAP) including bags made from three microperforated films (Xtend A, B and C) and from a low permeability film (LP). The control treatment was without MAP.

Treatment	Soluble solids (°Brix)	Rotting (%)	Internal browning (%)	Woolliness (%)
Xtend A	11.8 a	4.5 a	4.9 ab	40.6 b
Xtend B	11.7 a	8.5 ab	0.0 a	28.0 a
Xtend C	11.9 a	21.5 c	0.0 a	25.3 a
LP	11.5 a	26.2 c	8.9 b	43.6 b
Control[1]	12.1 a	11.9 b	16.8 c	95.3 c

Means with the same letter are not significantly different ($p < 0.05$).
[1] For the control treatment, the shelf-life period lasted only 4 d.

treatments reduced dehydration during cold storage compared with control.

After shelf life, no differences were determined for soluble solids. High incidence of rotting was measured for some MAP treatments while one Xtend treatment showed significantly less rotting than control (*table II*). Significant reductions in both woolliness and internal browning were obtained by MAP treatments, particularly with Xt B and C that reached the highest CO_2 levels, relating thus effectiveness of MAP treatments in controlling physiological disorders to the attainment of high levels of CO_2, as shown before in controlled atmosphere [2] and modified atmosphere [3] experiments. However, alleviation of the disorder by MAP treatments alone was not effective enough as to consider it as commercially acceptable.

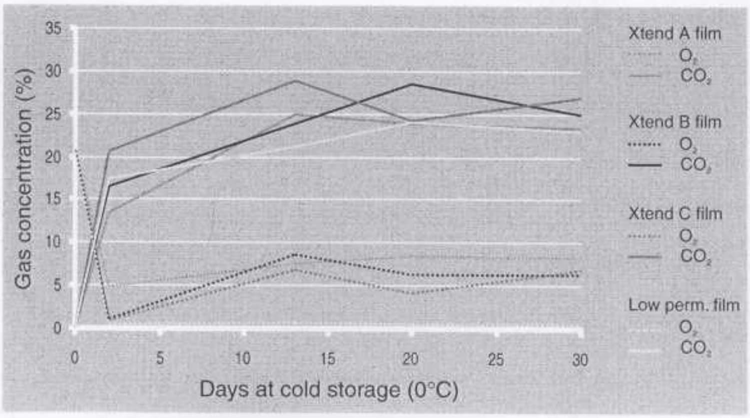

Figure 2.
Changes in O_2 and CO_2 concentrations during cold storage (the first 7 days at 5 °C and the rest of the period at 0 °C) in nectarines cv. August Red, within bags made from three microperforated films (Xtend A, B and C) and from a low permeability film.

3.2. August Red cultivar

For August Red cv. fruits stored with temperature fluctuation (first 7 d at 5 °C, and the rest of the period at 0 °C), LP bag was not able to recover desired O_2 levels, once fruit was transferred to 0 °C conditions, as it is observed for Xtend treatments (*figure 2*). Thus the development of off flavour as derived from anaerobic conditions risks to occur.

At final evaluation, higher incidence of rotting was apparent for MAP treatments, which could be related with fruit being kept within the opened bags under high humidity conditions for the entire shelf-life period (*table III*). As expected, both browning and woolliness were higher in control treatment subject to temperature fluctuation, as it has been demonstrated that keeping fruit at refrigeration temperatures higher than 0 °C results in increased physiological disorders [7]. In general, MAP treatments reduced browning and woolliness significantly under such conditions, being able to partially counteract increased potential of physiological disorders as derived from higher temperature.

3.3. Flamekist cultivar

Evolution of gas levels in Flamekist cv. was less pronounced than in Summer Diamond cv., pointing out probably to a reduced respiration rate, but eventually

Table III.
Postharvest determinations in nectarines cv. August Red after cold storage with fluctuation (7 d at 5 °C + 23 d at 0 °C) or without fluctuation (30 d at 0 °C), plus a 6 d shelf-life period (20 °C), in a modified atmosphere packaging (MAP) including bags made from three microperforated films (Xtend A, B and C) and from a low permeability film (LP). The control treatment was without MAP.

Treatment	Fluctuation	Rotting (%)	Internal browning (%)	Woolliness (%)
Xtend A	No	10.4 c	4.3 a	31.5 bc
	Yes	15.2 c	8.7 de	39.7 cd
Xtend B	No	9.1 c	2.6 bc	39.3 cd
	Yes	12.9 c	9.9 e	15.7 a
Xtend C	No	5.6 abc	0.8 a	23.4 ab
	Yes	9.6 c	0.8 a	13.8 a
LP	No	5.6 abc	3.8 cd	37.1 bcd
	Yes	9.7 bc	0.0 a	29.4 bc
Control	No	0.0 a	16.1 e	48.9 de
	Yes	1.1 ab	25.8 f	63.7 e

Means with the same letter are not significantly different ($p < 0.05$).

reaching desired CO_2 levels (*figure 3*). Unlike other trials, in this variety MAP treatments showed less effect in controlling internal browning (*table IV*). Rotting incidence was low and not increased by MAP treatments. Again, woolliness was reduced by MAP with microperforated films as compared with control treatment.

4. conclusions

MAP conditions leading to high CO_2 levels were able to significantly reduce, without preventing altogether, incidence of physiological disorders in the nectarine varieties under study. These results were similar to those obtained previously by controlled atmosphere [2] and would warrant further trials prior to commercial application.

Microperforated films (Xtend films) were able to accumulate CO_2 up to the desired levels (> 15 %). Additionally, they offered advantages, as compared with conventional low permeability film, of allowing initial temperature fluctuations without resulting in permanent depleted O_2. Further, they do not require special equipment for sealing the bags.

Despite that some microperforated bags allowed higher water loss than low permeability film, MAP treatments in general were more effective than control treatment in preventing fruit dehydration.

Rotting incidence, probably associated with water condensation during shelf-life even within opened bags, should be cleared before recommendations for using MAP materials can be given.

Figure 3.
Changes in O_2 and CO_2 concentrations during cold storage of nectarines cv. Flamekist, within bags made from three microperforated films (Xtend A, B and C).

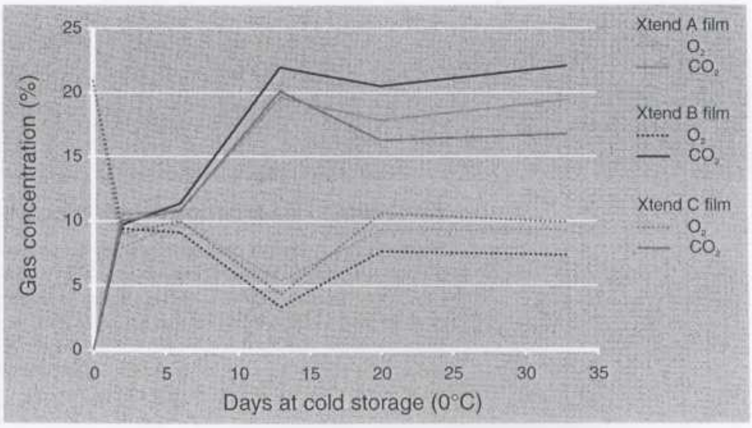

Table IV.
Postharvest determinations in nectarines cv. Flamekist after storage, 30 d at 0 °C plus a 6 d shelf-life period (20 °C), in a modified atmosphere packaging (MAP) including bags made from three microperforated films (Xtend A, B and C). The control treatment was without MAP.

Treatment	Soluble solids (°Brix)	Rotting (%)	Internal browning (%)	Woolliness (%)
Xtend A	11.2 a	1.1 a	21.5 b	33.0 ab
Xtend B	10.6 a	0.0 a	21.6 b	29.7 a
Xtend C	11.1 a	6.2 b	11.7 a	46.7 b
Control	11.1 a	4.2 ab	23.0 b	63.4 c

Means with the same letter are not significantly different ($p < 0.05$).

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Control de desórdenes fisiológicos en nectarines por atmósfera modificada.

Resumen — **Introducción**. El almacenamiento prolongado de nectarines ocasiona el desarrollo de desórdenes fisiológicos, especialmente harinosidad. La atmósfera controlada con elevados niveles de CO_2 se ha probado como efectiva para evitar tales desórdenes y se busca el desarrollo de atmósfera modificada efectiva. **Material y métodos**. Se llevaron a cabo experimentos con tres variedades de nectarines (Summer Diamond, August Red y Flamekist) mantenidas por 30 días en almacenamiento refrigerado seguidos por un período de vida en anaquel a 20 °C hasta madurez de consumo. Los tratamientos de atmósfera modificada incluyeron bolsas confeccionadas con tres materiales microperforados y un material de baja permeabilidad, además de un tratamiento testigo sin atmósfera modificada. **Resultados y discusión**. Los tratamientos utilizando materiales microperforados fueron capaces de alcanzar niveles deseables de gases (> 15 % de CO_2; no menos de 4 % de O_2), permitiendo así un adecuado control de desórdenes fisiológicos comparados con los tratamientos utilizados hasta el momento. Además, tales materiales parecen ser capaces de compensar parcialmente un régimen de temperaturas inadecuado al comienzo del período de almacenamiento refrigerado. Algunos materiales microperforados permitieron mayor pérdida de agua de la fruta que el material de baja permeabilidad, pero todos los tratamientos de atmósfera controlada fueron mejores que el control. Sin embargo, la alta incidencia de pudrición en los tratamientos de atmósfera modificada durante la vida de anaquel justifica investigación adicional antes de dar recomendaciones.

Chile / nectarina / fisiología postcosecha / almacenamiento en frío / oscurecimiento / maquinaria de embalaje / almacenamiento en atmósfera controlada