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HANDLING PRECONDITIONED TREE FRUIT AT THE RETAIL DISTRIBUTION CENTERS

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Temperature Management – While the precise temperature management regime will depend on a particular company’s anticipated sales/consumption schedule (fruit turning schedule), generally all tree fruit should be kept out of the “killing zone” temperature range of

36-50°F. The ideal storage temperature range will be within 32-35°F. This pulp temperature will reduce the incidence of internal breakdown or mealy fruit, fast softening, shriveling, and decay outbreak. The exact temperature management will be part of a broader fruit ripening protocol that takes into account the firmness on arrival of fruit and the fruit turning schedule coordinated with the store level demand.

Fruit Firmness – Fruit firmness reduction is only one component of the tree fruit preconditioning/preripening process and it does not accurately reflect the quality of the preconditioning execution. Cheek firmness is a

good tool to determine ripening stage (“Transfer Point”, “Ready to Buy”, “Ready to Eat”, etc.), while firmness measured at the weakest position (shoulder, tips, or suture) is well related to potential impact and transportation damages. Fruit firmness does not accurately certify the quality of the preconditioning execution.

Preconditioned peaches and nectarines should be arriving at the supermarket distribution center at ~5-8 pounds firmness measured at the weakest point or ~6-8 pounds measured on the cheeks. For preconditioned plums, ~3-8 pounds firmness measured at any position on the fruit are suggested.

When kept at 36°F or below, this product should be shipped out of the distribution center no later than within 4-5 days and ideally within 2-3 days. To the extent that the distribution center does not have rooms that can maintain temperatures at this 36°F and below range, it might make more sense to set up two shipments per week from the shipper to assure better temperature control and extend the market life of the product.

In general, soft fruit are more susceptible to bruising than hard fruit. To reduce potential physical damage occurring during transportation from the distribution centers to retail stores and handling at the retail stores, we suggest transferring fruit to the retail store before fruit reaches no lower than 4-5 pounds measured on the weakest position for tray packed peaches and nectarines. In general, the shoulder position is the weakest point on the mid or late season fruit. For plums, transfer should be done before they reach 3 pounds firmness measured at any position on the fruit.

Temperature conditions for tree fruit during and after ripening should be adjusted according to the desired sales/consumption schedule. We encourage that further fruit ripening, if necessary, be done at the distribution level. The rate of fruit softening (pounds lost per day)

varies among peach, nectarine and plum cultivars, and can be controlled by the storage temperature used. In general, fruit at 68°F lose 2.0 pounds per day and they lose less than 1.0 pound per day when stored at less than 36°F. When the fruit reaches the transfer firmness mentioned above, the rate of softening slows. However, rate of softening also varies according to orchard and season so firmness measurements should be taken to protect fruit integrity during the ripening process. These fruit will reach their “Ready to Eat” firmness of 2-4 pounds (cheek) after 2-3 days at room temperature (68°F dry retail display).

As bruising incidence varies among cultivars, and bruising potential is related to each specific operation, you should fine-tune your own transfer points for your handling situation. Correctly preconditioned fruit will have a longer shelf life even at lower firmness than conventionally packed product; and as such, retailers need to gain confidence in handling preconditioned product with lower firmness than historical experience suggests.

SSC – We do not recommend using SSC as an exclusive measurement for evaluating preconditioned fruit quality at the distribution center. SSC can be used to set a minimum quality index but it varies according to cultivar, season, etc. However, based on our experience, we feel that the appropriate harvest maturity and ground color followed by correct preconditioning predict much better eating quality than SSC and/or firmness alone. A mealy piece of fruit can be within an acceptable range of firmness and have a high SSC reading but still be entirely unsatisfactory to the consumer.

Please understand that these are general handling guidelines but they need to be modified and assessed in light of your particular company’s facilities, logistics and customer requirements.

HANDLING PRECONDITIONED TREE FRUIT AT RETAIL STORES

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What is Preconditioned Fruit?

When you sell preconditioned tree fruit in your store, you are offering consumers peaches, nectarines, and plums that have been preconditioned/preripened to delay mealiness and assure the consumer the peach, nectarine or plum is juicy and tasty. This product will be at a higher stage of ripeness than conventionally packed product and needs to be handled carefully at the retail store level. The preconditioning process does not prevent mealiness, it only delays its development, and, therefore, this product needs to be moved quickly from the distribution center to retail stores in order to assure a satisfactory eating experience for your customers.

Temperature Management

Ideally, preconditioned tree fruit should be transported at 32-35°F from the distribution center and kept at 32-35°F prior to transfer to dry/warm table for display. We refer to the temperature range of 36-50°F as the “killing temperature zone” which increases fruit flesh browning, mealiness, and “off flavors”. To the extent the fruit temperature cannot be maintained below this “killing zone”, it would be preferable to move fruit fast. Firmness measurements need to be considered in the decision-making process.

Fruit Firmness

Preconditioned peaches and nectarines should ideally be arriving from the distribution center to the retail stores with firmness in the 4-6 pound range (weakest position) or 6-8 pound range (cheeks). Preconditioned plum firmness

should be in the 3-5 pound range (at any position on the fruit). This fruit is at the “Ready to Buy” or “transfer point” stage of ripening and within ~48-72 hours at 68°F should be “ready to eat” in the 2-4 pound firmness range. This is the firmness range at which most consumers claim the highest satisfaction when eating tree fruit.

Display Suggestions

- Produce managers need to be educated about this new “Ready to Buy” type of fruit (preconditioned).
- Minimize mechanical damage and expedite an effective rotation (first in, first out).
- The dry tables should be labeled as preconditioned or “Ready to Buy/Eat” and consumers should understand that this fruit is riper than conventionally packed tree fruit.
- In order to protect preconditioned fruit, the display should be no more than two layers deep. In box display should be attempted.
- As tree fruit will continue to ripen on the display warm/dry table, they should be checked often and the softest fruit be placed at the front of the display.
- Fruit that reaches the “Ready to Eat” ripeness of 2 to 3 pounds cheek firmness need to be sold quickly or placed in refrigeration to extend their shelf life.
- Consumers should be instructed that this type of fruit should be refrigerated if fruit are not going to be consumed within 3 days of purchase.

More information on this subject can be found on the following websites:

<http://www.uckac.edu/postharv/>;
<http://postharvest.ucdavis.edu/>;
<http://fruitsandnuts.ucdavis.edu/>;
<http://pom.ucdavis.edu/>; and
<http://caltreefruit.com/>

POST-HARVEST TECHNOLOGICAL TREATMENTS OF POMEGRANATE AND PREPARATION OF DERIVED PRODUCTS

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From: Options Méditerranéennes, Serie A: Séminaires Méditerranéennes, Numero 42. Production, processing and marketing of pomegranate in the Mediterranean region: Advances in research and technology. Session IV: Post-harvest treatments and obtention of derived products.

Summary

During the last few years, the activity in research and development on pomegranate fruit has aimed at the application of new post-harvest storage technologies to extend the storage life of pomegranates, keeping the original quality of the freshly harvested fruits. In this way research has focused on the application of controlled atmospheres, the use of modified atmosphere packaging in polymeric films and the application of thermal treatments during the refrigerated storage. These technological treatments were applied to alleviate chilling injury symptoms which occur during the storage of pomegranates below 5°C. Although the industrial processing of pomegranate is still scarce, research on the development of new products such as minimally processed seeds, jams, juices and jellies has been carried out. This new sector of pomegranate industrial processing will allow the use of fruits with low commercial quality fruits (small size, bruised husks, non-commercial varieties, sun-burnt husks, etc.), that cannot be commercialized today in spite of having good quality juice and seeds, to the preparation of these new products.

Key words: Pomegranate, *Punica granatum*, Puniceae, post-harvest treatments, chilling, intermittent warming, curing, modified atmospheres, minimally processed seeds, juice, jam, jelly.

Introduction

The activity of research and development on pomegranate has aimed in the last years at two main targets. Firstly, to the application of new refrigerated storage technologies (controlled atmospheres, modified atmosphere packaging, intermittent warming, curing, etc.), to extend the commercial life of pomegranates keeping, or even increasing in some instances, the original quality of the freshly harvested fruit. This kind of research has an immediate application, as pomegranates are mainly commercialized for the fresh fruit market, and in the case of Spain, is mainly for exportation to other European markets. On the other hand, research has also aimed at the search of new pomegranate-derived food products. These products are not yet commercially important, due to the lack of technological development for the industrial processing of pomegranates. However research has aimed at the production of new processed products, that can exploit those fruits with low visual quality (bruised, cracked, sun-burnt, small size), and those varieties that, although they have seeds and juice with enough quality, are not suitable for commercialization in the fresh-fruit market.

Post-Harvest Treatments for Pomegranate Storage

Pomegranate commercial life means the time that this fruit can keep a certain quality level under specific storage conditions.

The physiological status and development of the fruit play an important role in the refrigerated storage and handling processes, aiming to minimize the quality loss. As a non-climacteric fruit, pomegranate does not ripen after harvest, and for this reason it has to be

harvested when is fully ripened, when it shows the optimal organoleptic characteristics.

In pomegranates, the more intense the respiration, the faster is the decay. Temperature, relative humidity and atmosphere composition, are the environmental factors that, depending on the desired storage period, can be used to reduce the respiration and minimize the physiological and fungal decay losses (Ben-Arie *et al.*, 1984; Kader *et al.*, 1984).

It is evident that one of the main ways to extend the post-harvest life of pomegranates is reducing as much as possible the mechanical damage (bruises, scrapes, cuts, compression, etc.), with careful handling.

Another essential way to prolong the commercial life of pomegranates is optimizing the environmental conditions that will maintain the quality specifications of the fruits within economic margins.

Previous studies have demonstrated that temperature is the most important factor to control the respiratory activity, transpiration and the development of microbial pathogens. A fast pre-refrigeration using forced air is one of the simplest ways to extend pomegranate commercial life. This temperature has to be around 5°C to prevent the production of physiological disorders, during 2-3 months storage (Kader *et al.*, 1984; Artés, 1992).

The relative humidity is the second factor in importance. The key concept is the deficit in vapor pressure or difference between relative humidity of the environment. Temperature and relative humidity are closely related and the objective is minimizing the weight loss without increasing the microbial development and decay. As pomegranates are commercialized without post-harvest treatments (washing, waxing, fungicides), the fruits must be gently brushed, and kept with a relative humidity around 90-95% if the fruits are healthy and clean (Artés, 1992).

New Technologies and Pomegranate Storage

In the last few years research on pomegranate post-harvest storage has been addressed to the search of new physical treatments to prolong the commercial life of pomegranates. These treatments must keep the original quality of the fruit, avoiding fungal development, and the loss of quality characteristics (color, flavor, texture) and nutritional properties (vitamins, antioxidants, health-promoting agents, etc.). These treatments modify the environmental conditions of pomegranate storage, and have an effect on the fruit physiology and biochemistry and on the development of micro-organisms that contaminate the fruit surface. In this way, the possible application of atmospheres with a gas composition different from the air (CO₂ enriched and/or reduced in O₂) has been explored. In addition, the use of thermal treatments for fruit conditioning and curing, and intermittent warming during cold storage to avoid fungal development and the physiological disorders that can develop as a consequence of the storage in temperatures below 5°C, have also been studied.

Controlled and modified atmospheres

It has been reported that during the post-harvest storage of pomegranates from Israel at temperatures below 6°C, chilling injury is observed, with symptoms including the appearance of depressions and browning in the fruit husk. This cold damage can be inhibited by storage in atmospheres with 2-4% O₂ and temperatures between 2 and 6°C (Ben-Arie and Or, 1986). The effect of post-harvest storage at 5°C under controlled atmospheres on pomegranate quality and incidence of chilling injury has been recently studied (Artés *et al.*, 1996). Pomegranates of cultivar 'Mollar' were stored up to 8 weeks at 5°C and under 95% relative humidity, and were later transferred to 20°C during 6 days to simulate the commercialization period. Different controlled atmospheres were tested and the quality of the fruits was compared to that of the fruits stored

in air. Storage under controlled atmospheres (10% O₂ and 5% CO₂; 5% O₂ and 5% CO₂; 5% O₂ and 0% CO₂) reduced weight loss, fungal decay and husk surface scald. The storage in controlled atmospheres, however, reduced the vitamin C and sugars contents. Other studies on 'Wonderful' pomegranates stored in air enriched with 10 or 20% CO₂ showed that the color of the seeds stored in air increased during refrigerated storage (10°C, 6 weeks), while the seed pigmentation was less intense in those of pomegranates stored in 10% CO₂, and even decreased in those fruits stored in 20% CO₂. This increase in seeds pigmentation was well correlated with the PAL activity of pomegranate seeds, a key enzyme of phenolic metabolism (Holcroft *et al.*, 1998). Nevertheless, these authors found that storage under atmospheres with a moderate CO₂ composition (10%) prolonged the storage life of pomegranates and kept the original quality, including an adequate seed color.

The use of plastic packaging of whole pomegranates, or even pomegranate arils, in micro-perforated polypropylene bags, has also been studied. In these cases the respiration of pomegranates inside the bags, and the selective permeability of the polypropylene films for the different gases, in bags that are hermetically sealed, a modified atmosphere is generated around the fruit, an atmosphere which is enriched in CO₂ and poor in O₂. It is important using films that allow reaching the adequate gas levels, to produce the expected beneficial effects, without triggering the fermentative metabolism that will lead to off flavors. In this context, very promising preliminary results have been obtained. Thus, it is possible to prolong the storage life of the fruits with an acceptable quality, and the water loss is considerably reduced as well as their effects on the fruit surface, showing the fruits an exceptional appearance during the commercialization period. The modified atmosphere packaging technique has also been used with success for the storage of minimally processed pomegranate seeds (Gil *et al.*,

1996a,b), and for their preparation a patent has been developed in the Post-harvest and Refrigeration laboratory of the CEBAS (CSIC) Institute (Artés *et al.*, 1995).

Thermal treatments during cold storage

The studies on the storage of pomegranates under refrigeration has received little attention, although this fruit has a wide harvesting period in areas with moderate climates, and refrigeration is the only means to prolong the storage life of the fruit up to three months.

Pomegranate harvest starts in Spain in mid September to end in the middle of November for the late cultivars. Pomegranates are normally stored refrigerated for several weeks to extend the commercialization until Christmas. However, during their storage several physiological and enzymatic disorders, and fungal attacks, can affect seriously the quality attributes. Spanish 'sweet' pomegranates can suffer chilling injury if they are stored for more than two months at temperatures below 5°C. This injury includes symptoms like browning of the rind, pitting, scald, an increased sensitivity to fungal development and decay, and internal discoloration and browning of the seeds (Artés, 1992). Some cultivars, i.e. 'Wonderful', can be stored without problems for 2 months at 5°C. The minimal safe temperature to store sweet pomegranates is 7.5°C (Kader *et al.*, 1984). This temperature, however, does not prevent fungal development. Previous studies have demonstrated that the conventional storage of 'Mollar' pomegranate at 5°C and 90-96% R.H. up to eight weeks, leads to an acceptable decrease in fungal decay losses, but the risk of chilling injury was not completely prevented. Storage under controlled atmospheres (5% CO₂ and 5% O₂) at 5°C and above 95% relative humidity for two months improved the quality attributes of the freshly harvested pomegranate, although a moderate husk scald was observed (Artés *et al.*, 1996).

Intermittent warming treatments, that have proved useful in the prevention of chilling injury symptoms in other products, have been recently applied to pomegranates (Artés *et al.*, 1998a). In this case, 'Mollar de Elche' pomegranates were stored at 0°C and 5°C and 95% R.H., for 80 days. Intermittent warming treatments at 20°C were applied in cycles, one day every six days storage, followed by a commercialization period of 7 days at 15°C and 70% R.H. While intermittent warming during the storage at 0°C prevented fungal development, although increased susceptibility to chilling injury symptoms, like pitting and husk surface scald, storage at 5°C reduced considerably the chilling injury symptoms although the fungal attack was not completely inhibited. The warming treatments led to very good results keeping the quality of pomegranates, especially when they were applied to pomegranates stored at 0°C.

Another technological treatment that is starting to be used with success in pomegranate is the pre-conditioning at moderate temperature (30-40°C) and high R.H. (90-95%) for a short period of time (1-4 days), a technique also known as curing, that is applied before the conventional refrigerated storage. As recently reported, a pre-treatment at 35°C and 90-95% R.H. applied for three days previously to a refrigerated storage during 80 days at 5 or 2°C and 90-95% R.H., reduced considerably the pitting and husk superficial scald (produced by the enzyme polyphenol oxidase) compared to control pomegranates without the pre-conditioning treatment. The effects observed were more marked when the conservation was carried out at 2°C than at 5°C, particularly during the additional period of one week at 15-20°C and 70-75% R.H., applied to simulate the retail sale period (Artés *et al.*, 1998b,c).

New Products Derived from Pomegranate

In the last few years there has also been an increasing interest in the search for new pomegranate derived food products. As a

result of this research new products have been developed. Among them we should mention the minimally processed pomegranate seeds ("ready-to-eat"), jams and marmalades, single-strength juices, jellies, juice concentrates, frozen seeds, seeds in syrup, etc.

For the production of most of these products it is important to develop a method for the industrial peeling of pomegranates, that makes possible the preparation of these products at a reasonable cost. There is already a pilot plant for the industrial peeling of pomegranates, that was developed by the Escuela Politecnica Superior de Orihuela, and that is actually under experimental process for the preparation of several of these products (P. Melgarejo, pers. comm.).

One of the main nuisances of pomegranate as a fruit is the relative difficulty in peeling, that makes difficult and tedious the preparation of its seeds. In addition, during hand-peeling, and due to the high content of polyphenols and oxidative enzymes in the fruit rind, the skin of the hands is stained brown, making this process an even more annoying task. It is for this reason that the development of "ready-to-eat" pomegranate seeds has been a challenge that has been approached by several research groups in Spain (Artés *et al.*, 1995) and the USA. Once the peeling problem is solved, the seeds have to be washed with solutions that guarantee the sanitation of the product reducing the microbial load, and that ensure their quality characteristics. These solutions include chlorine (100 mg/kg), ascorbic acid (5 g/l), citric acid (10 g/l), and combinations of these (Gil *et al.*, 1996a). The best results with the cultivar 'Mollar de Elche' were obtained washing the seeds with the chlorine solution, followed by a mixture of ascorbic and citric acids, and storing the seeds at 1°C in polypropylene films that allowed the formation of a modified atmosphere appropriate for the conservation of these seeds. The preparation of seeds under very clean conditions and at temperatures close to 0°C prolonged the life of

this product and maintained its quality (Gil *et al.*, 1996a). Storage at higher temperatures (4-8°C) produced seeds with lower quality and a shorter commercial life. When the effect of minimal processing and the subsequent storage on pomegranate seeds pigmentation were studied, an increase in pigments was observed during the storage at 0°C, while these decreased both at 4 and 8°C (Gil *et al.*, 1996b). Studies with the cultivar 'Wonderful' have shown that those seeds that had suffered mechanical damage during seed preparation, appeared soft and aqueous and were much more susceptible to microbial spoilage (Hess-Pierce and Kader, 1997). Seeds were stored in air and in controlled atmospheres of air with added CO₂ at 10, 15 and 20%, and at temperatures of 5 and 10°C. The commercial life of the prepared seeds was 8 days at 10°C and 12 days at 5°C. Atmospheres enriched in CO₂ helped to prolong the commercial life of the seeds.

In the field of pomegranate jams and marmalades, the stability of anthocyanin pigments in these products and the effect of thermal treatments on the quality of the products have been studied. As a general rule, it is necessary to establish the optimal thermal treatment (time/temperature), which guarantees the commercial sterilization of the product and the inactivation of the oxidative enzymes, but preventing the production of brown polymers as a consequence of the Maillard reaction and the anthocyanin degradation. In general, the products obtained show an appealing color, but a flavor which is quite dull, and for this reason we have suggested the use of pomegranate juice as an ingredient providing color to other products that have an intense flavor, but a lack of pigmentation (strawberry jams) (Zafrilla *et al.*, 1998).

A related product that has been recently studied has been pomegranate jelly. In this case, the percentage of sugar added is smaller than that of jams and marmalades, and addition of jelling agents (pectins, agar, etc.) is necessary

for the preparation of jellies, that generally maintain very well the color characteristics of the original juice. The effect of the pH is essential for pigment stability and the color of the prepared jellies. Therefore, it has been shown that jellies prepared with juices from sour pomegranates have better color and pigment stability than those produced with sweet pomegranates of cultivar 'Mollar'.

In the case of pomegranate juice, it has been shown that both the extraction and clarification process and the pH of the obtained juice (juices added of organic acids to decrease the pH), have marked effects on juice stability. Storage of frozen juice permits prolonging the juice life considerably, although it does not completely prevent pigment degradation and browning.

Other products such as frozen seeds, seeds in syrup, pomegranate spirits, etc. have also been studied, but not very intensely, and offer a very wide range of pomegranate derived products that will allow the use of low quality fruits that are presently discarded.

Finally we have to mention the possible use of pomegranate industrialization wastes and residues for the extraction of phytochemicals that have an interest for nutrition and pharmacy. Pomegranate rinds are very rich in polyphenolic compounds (ellagitannins) which, as naturally occurring compounds, or as compounds obtained by transformation of the natural compounds, have a very intense antioxidant activity, and these could be used as ingredients in dietetic formulations. In addition, the ring and the seeds are very rich in fiber, whose nutritional quality has to be evaluated. These residues are also rich in alkaloids, aromatic compounds, and are an interesting source of enzymes. For these reasons, the field of pomegranate by-products is an interesting field to be exploited, once pomegranate industrialization has become a reality.

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BIOCHEMICAL BASIS OF SUPERFICIAL SCALD ON 'WONDERFUL' POMEGRANATES

Betty Hess-Pierce, Bruno Defilippi, Bruce Whitaker, and Adel Kader

Superficial scald is a physiological disorder that limits long-term storage of pomegranates. The symptoms develop mainly on the stem-end of the fruit as brown discoloration of the skin and can cover up to 60% of the fruit surface without affecting the internal tissues. Usually, this disorder is not observed until after about 3 months in storage at 5 to 7°C, then its severity increases with storage duration and after transfer to 20°C for a few days to simulate retail marketing conditions. During the 2003 harvest season, we tested incidence and severity of superficial scald on California-grown 'Wonderful' pomegranates that were harvested on October 20 (mid-season) and November 18 (late season), then stored at 7°C and 90 to 95% relative humidity for up to 6 months. The following treatments were tested:

- 1) Control, stored in air.
- 2) Stored in 1% O₂ + 99% N₂ (CA-1).
- 3) Stored in 1% O₂ + 15% CO₂ + 84% N₂ (CA-2).
- 4) Stored in 5% O₂ + 15% CO₂ + 80% N₂ (CA-3).
- 5) Dipped for 1 minute in 1100 ppm diphenylamine (DPA), stored in air.
- 6) Dipped for 1 minute in 2200 ppm DPA, stored in air.
- 7) Exposed to 1 ppm 1-methylcyclopropene (1-MCP) for 24 hours at 7°C, then stored in air.
- 8) Combination of treatments 5) and 7).

Superficial scald incidence and severity were greater in the pomegranates harvested on November 18 than in those harvested on October 20 (Table 1), indicating that this disorder may be associated with senescence. All pomegranates from the 11/18 and 10/20 harvests that were kept in air exhibited some superficial scald after 4 and 6 months, respectively. Neither the DPA nor 1-MCP alone or together reduced scald incidence and severity. In contrast, the three CA storage conditions significantly reduced scald incidence and severity on pomegranates from both harvest dates for up to 6 months at 7°C. However, the two CA with 1% O₂ resulted in greater accumulation of fermentative volatiles (acetaldehyde, ethanol, and ethyl acetate) than

the CA with 5% O₂, especially in the October 20th-harvested pomegranates. In addition to the fungistatic effects of 15% CO₂, it appears to be critical to inhibition of scald development on pomegranates. These results confirm our recommendation of 5% O₂ + 15% CO₂ as the optimal CA for pomegranates at 7°C and 90-95% relative humidity.

It appears that the biochemical basis of superficial scald in pomegranates is different from that in apples. No alpha-farnesene or its conjugates were found in the peel of pomegranates. We are examining the possible involvement of fatty acids oxidation in the development of superficial scald on pomegranate skin (Table 1).

Table 1. Incidence of superficial scald on 'Wonderful' pomegranates kept at 7°C for up to 6 months.

Treatment	Scald incidence (%)					
	10/22 Harvest			11/18 Harvest		
	4 mo	5 mo	6 mo	4 mo	5 mo	6 mo
Control	0	0	30	70	100	90
1% O ₂	0	0	0	17	10	40
1% O ₂ + 15% CO ₂	10	0	0	0	0	0
5% O ₂ + 15% CO ₂	0	0	0	0	0	0
DPA (1100 ppm)	0	0	27	57	63	87
DPA (2200 ppm)	0	0	33	100	93	100
1-MCP (1 ppm, 24h)	0	0	17	10	57	93
1-MCP + DPA	0	0	100	23	57	100

ABSTRACTS

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Effects of 1-Methylcyclopropene on Stone Fruits

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1-Methylcyclopropene (1-MCP) is an ethylene action inhibitor, which prevents plant tissue from perceiving and responding to ethylene. It

is generally effective in concentrations of 1 micromolar or less, and can retard many ripening processes that depend on ethylene for their induction. These processes include softening, color development, loss of titratable acidity and increase in volatile compounds. The active compound is a gas (as is ethylene) and the treatment is given after harvest. The effect of 1-MCP on apricots, cherries, nectarines, peaches and plums has been investigated.

Apricots responded to 1-MCP by slowing their softening, peel color change and loss of titratable acidity. However, ethylene production

and respiration were not affected, and the treatment with 1-MCP enhanced internal flesh browning. Cherries are a non-climacteric fruit and treatment with 1-MCP had no effect on their postharvest life. Peaches and nectarines responded to 1-MCP treatment in a similar manner to apricots by slower softening, color change and loss of titratable acidity, with only minor inhibition of ethylene production. However, after storage, fruit which had received a 1-MCP treatment developed more flesh disorders, particularly bleeding, than untreated fruit. Plums, both European and Japanese, responded positively to 1-MCP. Ethylene production was inhibited, as was softening, color change and loss of titratable acidity. There were fewer storage disorders, such as internal browning and gel breakdown in 1-MCP treated than non-treated fruit.

The use of this compound can help to elucidate the role of ethylene in the development of physiological storage disorders and in regulation of ethylene biosynthesis in different types of stone fruit.

Differential Expression of the Chilling-Injury Induced Physiological Disorder of Woolliness in Peaches and Nectarines

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Expression of the chilling injury disorder known as woolliness or mealiness is common in peaches and nectarines exported from Chile, as they are submitted to prolonged exposure to cold temperatures during transport to the markets.

A project has been initiated to study aspects of functional genomics as related with induction and expression of the disorder in a number of varieties of peaches and nectarines selected according to presumed differential susceptibility to the problem.

Differential expression of woolliness within each variety has also been attained by submitting the fruit to different storage periods and temperatures, with a temperature not resulting in chilling injury, i.e. 10°C, and two temperature levels leading to subsequent problems, using 0°C and 4°C to induce and to attain maximal expression, respectively. Thus, the different varieties of peaches and nectarines did actually show differences in propensity to the physiological disorder, leading to characterization of expression of the lack of juiciness in fruits attaining the ripe stage by using the objective free-juice method (Crisosto and Labavitch, 2002) and correlating such results with subjective determinations as normally performed in similar studies.

Active Packaging Development to Improve ‘Starking’ Sweet Cherry Post-Harvest Quality

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‘Starking’ sweet cherry is considered a late season cultivar in Alicante (Spain) with several problems for commercialization mainly due to incidence of decay and a fast loss of sensory quality, both for fruit and green stem. Based on this issue, an active packaging has been developed based on the addition of 1 mL eugenol (essential oil from oregano) to trays and then sealed with polypropylene bags to generate a MAP. Also, cherries in MAP (without eugenol) and non-packaged fruits were selected and served as controls. Both bags and non-packaged cherries were stored during 16 days at 2°C and 90% RH. Samples were taken after 2, 6, 9, 13 and 16 days in which the internal atmosphere composition, weight loss, color, °Brix-titratable acidity ratio, firmness and visual aspect of the stem were evaluated.

Steady state atmosphere was reached after 9 days of cold storage with 2-3% of CO₂ and 10-11% of O₂ with no significant differences between treated and control. When fruit quality parameters were determined, those treated with eugenol showed a significant reduction in weight loss compared with control, either under MAP or not. Contrarily, color parameter L* and fruit firmness remained significantly higher during storage in treated cherries than in controls, under MAP or not, while no significant differences were obtained in relation to °Brix-titratable acidity ratio. When the stem was evaluated, this remained green in cherries stored in MAP, while they became brown in control. Finally, the microbial analysis showed that eugenol treatment reduced yeast, mold and total aerobic mesophylic colonies 2 and 3-log CFU compared with control under MAP or not, respectively. In conclusion, the use of MAP in combination with eugenol is an effective tool in maintaining cherry fruit quality and reducing the occurrence of decay.

Simulating Calcium Dip Effect on Post Harvest Quality of Peaches

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Peaches during the post harvest operations such as sorting, packaging and transportation are subjected unintentionally to bruises and compressive forces, which affect adversely the shelf life of the peaches.

Peaches of 'Harvester' and 'Juneprince' cultivars were dipped in calcium chloride solution just after harvest and its effect on post harvest quality parameters of firmness and mass was investigated. The control peaches were not dipped. Peaches were stored at 0, 4, 10, and 22°C at RH of 95 + 1% for three weeks. Mass and firmness of the stored peaches were measured at regular time intervals. Firmness was measured using non-destructive compressive test using Instron® testing

machine. A replication was carried out and models were developed from the slopes of firmness and mass values plotted against time for the five temperatures. The models were validated using another harvest. The models were further converted into a user-friendly computer simulation for predicting peach quality during distribution. The simulation predicts the quality parameters at each link of a typical supply chain. The temperature profile, percent firmness and percent mass for a system with or without the calcium dip are simulated and plotted upon data entry.

The simulation enables farmers as well as owners of various links of the supply chain to see graphically the effects of their actions of dipping in calcium and storing at various time-temperature combinations. The producers can quantify the benefit of lowering temperatures during cooling delays and of dipping in calcium. It can act as a decision support system to enable the producers to take decisions regarding calcium dip and storage conditions in conjunction with other economic considerations.

Modified Atmosphere Packaging of May Glo Nectarines

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May Glo nectarines were over wrapped with 12.5, 14 and 16µ thick PVC films and 15µ thick polyolefin films and kept at 6 or 10°C for 20 days. Percent weight loss, fruit color (L, a, b), fruit flesh firmness (kg force), total soluble solids (%TSS), pH, acid content (g malic acid/100 ml fruit juice), physiological and fungal disorders were determined at day 4, 8, 16 and 20. 15µ thick polyolefin film resulted in the lowest weight loss at both temperatures for 20 days. Fruit flesh firmness decreased at higher rate at 10°C than 6°C. Fruits packaged with modified atmosphere packaging films

(MAP) maintained higher fruit flesh firmness than control fruits. Control fruits had the highest TSS content. Acid content of fruits were higher at 6°C than 10°C while pH was higher at 10°C than 6°C. Fruit packaged with 14 and 16 μ PVC film had higher pH than others. L, a, b values of peel color was higher in fruits packaged with 12.5 and 14 μ thick PVC films.

1-MCP Use on *Prunus* Spp. to Maintain Fruit Quality and to Extend Shelf Life During Storage: A Comparative Study

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This work shows a summary on the role of 1-MCP applied at different doses (0.25 to 1 μ L L⁻¹) on two apricot (*Prunus armeniaca* L. cv. Currot and cv. Bulida), two early season plum (*Prunus salicina* Lindl. cv. Santa Rosa and cv. Golden Japan) and two late season cultivars (*Prunus domestica* L. cv. President and cv. Reina Claudia), the latter harvested at two ripening stages. All 1-MCP treatments were performed at 1°C for 24 h. Fruit were stored for several periods at 1°C and subsequent days at 20°C and 90% RH.

1-MCP reduced ethylene production for all cultivars, and prevented the autocatalytic production of ethylene, especially during shelf life at 20°C. High correlations were found between the 1-MCP dose applied and the reduction of ethylene emission.

1-MCP treatment was effective delaying fruit quality parameter evolution, the highest dose being the most effective during cold storage and shelf life. The correlation between 1-MCP concentration and parameter such as weight loss, color changes, softening delay and °Brix-titratable acidity ratio permit to suggest that an ethylene dependent and an ethylene independent processes are involved during the ripening. The 1-MCP effect was greater in the

more advanced ripening stage, when the sensorial and quality attributes are higher from the point of view of consumers.

In conclusion, 1-MCP could be a good mean to prolong the storability of *Prunus* spp., such as apricot and plum, in which after harvesting no more than 7-10 days of cold storage could be expected with optimal fruit sensory attributes. In terms of extension of shelf life, between 2 and 3 weeks more were achieved in 1-MCP treated fruits compared with controls.

Postharvest CA and Heat Treatments of Sweet Cherries

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Losses during marketing of sweet cherries in Norway are estimated to be above 20%. The major causes of these losses are water loss, fruit rots and decay (overripe). To avoid losses due to fruit rots, the fruits in commercial orchards are sprayed with fungicides close to harvest. Alternative treatments are sought as the consumers are growing more aware of pesticide residues, and the losses are affected by other factors than fruit rots.

Sweet cherries (*Prunus avium* L., cvs Van and Lapins) were dipped for 2 minutes in: 1) Distilled water at 20°C; 2) 1% Ca(OH)₂-solution at 20°C; 3) Distilled water at 50°C and 4) 1% Ca(OH)₂-solution at 50°C. The fruit quality was registered as soluble solids content, titratable acidity, color and firmness. Overall quality and off flavors were analyzed by a panel of trained judges. Fruits were stored at 2°C and 20°C up to 2 weeks. Every 4 days samples were analyzed as described above. The number of fruits with fruit rots was registered, and the fruits discarded. Weight losses were registered. Ca treated fruits tended to have higher contents of soluble solids and titratable acidity. No changes in color were observed. After storage heated fruits were less firm than

unheated fruits. The decrease in firmness, however, was less in Ca treated fruits. The Ca and heat treatments did not affect the sensory evaluations. Ca and heat treated fruit were less susceptible to fungal attacks. The weight losses during storage were higher in heated fruits.

Results from related experiments with alternative treatments in sweet cherries and plums will be referred.

Post-Harvest 1-MCP Treatment Affects Shelf Life Depending upon Storage Temperature in Nectarines: Relationship with Polyamine Titres

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1-methylcyclopropene (1-MCP) inhibits ethylene action and fruit quality achievement by binding to ethylene receptors. Developmental stage, timing and concentration and storage temperature may modulate MCP effects. In preclimacteric nectarines a single MCP treatment induced a decrease in ethylene production and biosynthesis, while repeated treatments retarded the induction of ethylene emission and ACS1 and ACO1 transcript accumulation (Mathooko et al. 2001 PBT 21: 265-281). Plants may overcome MCP action through synthesis of new receptors (Rasori et al. 2002 JEB 53: 2333-2339). Ethylene and the growth regulators polyamines (PAs) share the precursor S-adenosylmethionine. An inverse relationship has been suggested in several physiological processes. At ripening in peach, as well as in other climacteric fruit, PA levels are at their minimum. Exogenous PA treatment in pre-harvest inhibited ethylene production and fruit softening in peaches and nectarines with effects on ACS and ACO transcript levels (Bregoli et al. 2002 *Physiol Plant* 114: 472-481,

Torrigiani et al. 2004 PBT, in press). A role for PAs in post-harvest is also emerging probably correlated with their antisenescence and antistress properties.

To clarify the role of ethylene and its relationship with PAs, MCP effects on post-harvest have been studied at 25 and 4°C in Stark Red Gold nectarines. At 25°C, MCP strongly inhibited ethylene production, and ACS and ACO expression, and caused an increase in PA levels. At 4°C ethylene production was not altered, although ACS and ACO mRNAs were affected, while PA concentration was further enhanced. A transient PA increase is associated with MCP treatment at both temperatures, independent of ethylene production, suggesting a correlation with MCP- and/or cold stress. MCP is more active at 25°C, but effects on quality are also observed at 4°C. PAs could help in maintaining fruit quality.

Forced Hot Air Treatment of Stone Fruit to Inhibit the Development of Mealiness

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Conditioning stone fruit by allowing a 48-hour period of ripening at 20°C prior to cold storage is being increasingly practiced in California as a means to enhance fruit quality following storage by reducing the incidence of mealiness and flesh browning. Conditioning, while very effective, takes a relatively long time to implement and results in fruit that are more susceptible to handling damage and decay. Treatment with forced hot air was tested as a potential alternative to this practice. Conditioned fruit (CF) or nonconditioned fruit (NF) of 'Elegant Lady', a peach cultivar that is susceptible to becoming mealy, were treated with forced hot air using a heating rate of 12°C h⁻¹ and a final chamber temperature of 46°C prior to cold storage for 2 to 4 weeks at 1°C. Following storage fruit were ripened and

evaluated for mealiness by determining the percentage of free water (FW) present in the fruit. Fruit stored for 2 weeks were juicy regardless of treatment, although CF maintained an average FW of 57.3% versus 47.2% for NF. After 3 weeks of storage NF that had not been heated had a FW value of 26.9% as compared to 49.6% for nonheated CF and had become mealy. Heating slowed the loss of FW and maintained juiciness, although 3 hours of heating or more was required to have an effect and the FW value for the NC fruit heated for 4 hours was still 7% less than that from nonheated CF. Both CF and NF had become mealy by the end of 4 weeks of storage and had low FW values. Forced hot air can effectively reduce the incidence of mealiness but further research is needed to determine if the technique could be useful commercially.

Investigation on Early Softening of Kiwifruit

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Early softening is the main problem for the exports of Chilean kiwi fruit. It has been related to orchard condition and to harvest and postharvest handling. In this investigation, experiments were carried out to test the influence of growing conditions and some fruit characteristics on the softening rate of kiwi fruit, from different orchards in the central zone of Chile. Fruits from all orchards were harvested at 6.2-6.5 soluble solid content, and kept under the same storage condition (0°C, air). Samples were taken every 15 days to determine softening index (S.I.), which was calculated by the initial firmness minus final firmness, divided by the days until the fruit reached 2 kg of firmness.

There was a large variation in I.S. between orchards and also in the same orchard. In the best orchard the fruits were stored for 135 days

having S.I. 0.116; in the worst for 60 days and S.I. 0.257. The tested fruit characteristics were size, position, and illumination of fruit in the plant. For this purpose fruit from the same plants were harvested and tested in the same way as described before. The influence of size on early softening was found in 3 of the 4 orchards tested, having the larger fruit (>115 g) the lowest S.I. The position of the fruit on the plant (distances from the base of the cane) had no influence on S.I. The fruit better illuminated on the plant had higher initial firmness, but also higher softening index during storage. Nevertheless the final firmness was higher in the better illuminated fruit.

Rootstock and Storage Regime Influence Summit Cherry Quality

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Summit sweet cherries from five-year old trees grown on four rootstocks were collected and preserved under normal cold storage (NCS) and under different kinds of controlled atmosphere (CA: 1-2.5% O₂+10% CO₂; 2-2.5% O₂+15% CO₂; 3-3.5% O₂+20% CO₂).

Fruit samples were analyzed and their quality evaluated at harvest and 42 days later. At the end of the storage periods, tasting panels evaluated fruit attractiveness and flavor. Rootstock and storage regime significantly influenced all the studied quality parameters: fruit weight, shape, firmness, juice pH, titratable acidity (malic acid), soluble solids content, and fruit/peduncle color (CIE L*a*b*; L*C*H°). Fruit size and titratable acidity were higher on invigorating rootstocks, because of their lower productivities. Fruit ripeness occurred later on Gisela 5, with L*C*H° values being superior to those corresponding to the other rootstocks.

As expected, soluble solids content was higher after NCS than after CA, owing to greater mass loss. Fruits stored under CA 3 maintained a better quality, with greenish peduncles, a light red to pink color (higher H°), a better

attractiveness and more brightness. Fruits from Cab 11E ripened earlier and offered better attractiveness after storage. Tasting panels did not distinguish between fruits from CA 3 and CA 2.

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