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Reduction of cold damage during cold storage of Hass avocado by a combined use of pre-conditioning and waxing

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ABSTRACT

To reduce cold damage (CD) and loss of quality during cold storage of early season Hass avocados (22.9–26.3% dry matter), a pre-conditioning treatment that consisted on pulp hydrocooling to 6 °C in a 0.3% $CaCl_2$ solution was effective in comparison to a control group of fruit pre-conditioned at 6 °C for 3 days in a cold room. Half of the fruit from both pre-conditioning treatments were waxed and stored at 3 ± 1 °C for 1, 23 and 46 days. After each storage time, quality parameters such as: epidermis and pulp damage, fruit firmness, % weight variation, colour, respiration, ethylene production, ethanol and acetaldehyde were assessed. Results demonstrated that the hydrocooling pre-treatment alone does not completely reduce lenticelosis but in combination with waxing resulted in a three fold reduction of internal damage and retarded fruit colour break. The use of waxing, independently of the initial pre-conditioning treatment, retarded fruit colour break, minimized quality loss, reduced metabolism and ethylene production and allowed to extend the commercialization period of the fruit at room temperature after storage at 3 °C for 46 days.

1. Introduction

The distance between avocado producers and their buyers has led to the creation of systems that extend the postharvest life of the fruit. The uses of refrigeration and/or controlled and modified atmospheres are possible solutions to successfully achieve this goal. It has been observed that storage at low temperature can decrease avocado quality due to the appearance of internal and external cold damage (CD) (Hopkirk et al., 1994; Dixon et al., 2003; Arpaia, 2005). Externally, epidermal browning is the first visible damage symptom, and internally, the discolouration of the mesocarp (grey pulp) and browning of vascular strands (Cutting and Wolstenholme, 1992) are the main problems.

According to Bower and Papli (2006), epidermal browning develops due to early production of anthocyanins as a defence mechanism against low temperature stress. Other authors states that oxidative stress caused by the cold leads to loss of membrane integrity (Wismer, 2003) causing filtration of phenolic compounds from the vacuole to the cytoplasm (Marangoni et al., 1996) and its subsequent oxidation and browning by the action of polyphenol oxidase (Van Rooyen and Bower, 2006).

Preservation of the quality of avocados stored at 5 °C has been achieved for up to 4 weeks (Dixon et al., 2003), indicating that temperatures below 5 °C increase the appearance of CD (Arpaia, 2005) and prolonged storage influences the severity of the symptoms (Hopkirk et al., 1994 and Bower, 2005a). However, Bower (2005a) suggests that storage of avocado cv. Hass at 2–3 °C may be optimal for exportation, providing that water loss is monitored. Water loss directly influences the appearance and severity of CD, thus by minimising water loss, quality can be maintained (Donkin and Cutting, 1994 and Bower, 2005a). Bower (2005b) suggested the use of hydrocooling as a pre-cold conditioning treatment for avocado in order to minimize water loss during initial cooling and with reduction of CD appearance.

Hydrocooling is an artificial cooling process that employs water but can cause lenticel damage (lenticelosis) due to increased sensitivity of the fruit to manipulation due to excess hydration within and between epidermal cells (Everett et al., 2008). But, if the concentration of the cooling solution is increased, over-hydration could be limited, thus limiting the subsequent appearance of lenticelosis. In order to increase the osmotic water concentration, the use of calcium salts has been proposed due to the effect of this element on the appearance of CD (Chaplin and Scott, 1980) and on the firmness of the fruit when absorbed (Witney et al., 1990).

The use of wax on avocado also decreases water loss during cold storage (Undurraga et al., 2007) in addition to the gas exchange reduction (Bower, 2005a), appearance improvement

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(Bower, 2005a; Undurraga et al., 2007) and weight loss decrease during a simulated commercialization period (Undurraga et al., 2007). However, care has to be taken because negative quality effects such as an increased ethanol and acetaldehyde generation have been observed in apples (Bai et al., 2002). In addition, Hofman et al. (2003) and Woolf et al. (2003) tested a quarantine treatment against fruit flies (16 days at 1 °C) by performing low temperature conditioning. The first of these experiments achieved a decrease in external damage while the second posited that the problem could be eliminated altogether. Meir et al. (1996) reported that jasmonates have been implicated in playing an integral role in the signal transduction cascade that operates in plants to induce responses to stress.

Based on the above, we propose that hydrocooling with a calcium salt solution or low temperature conditioning, followed by the application of wax in both cases would avoid the appearance of cold damage in avocado cv. Hass stored at 3 °C for 46 days. The objective of this study was to evaluate the effect of two preconditioning treatments and the application of wax on the appearance of cold damage and on the quality of Hass avocado stored at 3 °C for up to 46 days.

2. Materials and methods

2.1. Initial fruit quality and treatments

A total of 928 avocado fruits of the cultivar Hass were harvested on November 15th during the morning starting at 9 am from the Experimental Station La Palma located in Quillota, V Region, Chile (32°53′S, 71°13′W). Fruit had 22.9–26.3% dry matter corresponding to early season fruit. Their weight ranged from 170 to 220 g. The fruits were green with the stem attached and showed no damage or deformities. They were selected and separated into 4 groups (232 avocados per group) and then weighed. The first two groups were preconditioned in water at 1 °C containing 0.3% $CaCl_2$, following the findings of a prior experiment. These two groups will be referred to as íHydroí. When the pulp of the fruits reached 6 °C, the avocados were removed from the hydrocooling and placed in trays to remove the excess water. A thin layer of wax (17.2% Carnauba, 1.8% Shellac and 24% total solids) was manually applied to half of these fruits, while the rest were packed directly into 11.2 kg boxes. For the low temperature conditioning (LTC), the remaining fruit corresponding to the other two groups were stored at 6 °C and then removed from the chamber after 3 days and half were packed into 11.2 kg cardboard boxes, while the other half were waxed before packing. Finally, all the preconditioned fruit (Hydro and LTC) with or without wax were stored at 3 °C and evaluated after 1, 23 and 46 days, giving a total of 12 treatments.

Previous experiments carried out by the authors during the 2009 and 2010 seasons revealed that hydrocooling alone resulted in lenticelosis in Hass avocado as previously reported by Everett et al. (2008). However, during the season 2012, experiments carried out that included the use of different $CaCl_2$ concentrations, revealed that 3% of $CaCl_2$ in the hydrocooling solution was effective to reduce lenticelosis thus keeping fruit quality. Higher concentrations of $CaCl_2$ resulted in fruit appareance damage (unpublished results).

2.2. Evaluations

2.2.1. Fruit quality upon removal from cold storage (CS) and after a simulated commercialization period (SCP)

Pulp pressure resistance (PPR) (kg) was measured upon removal from CS using a TMS-Pro texture analyser with a 7 mm probe. The external colour (EC) was expressed as hue angle (°) according to L × C × h units (Mc Guire, 1992) using a Konica Minolta CR-400 colorimeter. The weight (% variation) was also measured upon removal from CS (after 1, 23 and 46 days) and after the SCP. For each treatment, the latter period corresponded to the number of days after removal from cold storage that 80% of the fruits took to become soft (1–2 kg), with the weight recorded at 20 °C and at 50% relative humidity.

Calcium content was determined by atomic absorption spectroscopy, recording absorbance using a Phillips Pye Unicam SP9 spectometer at 422.7 nm, in accordance with the procedures described by Chapman and Pratt (1961).

2.2.2. Respiration and ethylene production

Upon removal from CS (1, 23 and 46 days), respiration rate ($mL\,CO_2\,Kg^{-1}\,h^{-1}$) was evaluated in 750 mL chambers at 20 °C and 760 mm hg, using a PBI Dansensor CheckMate gas analyser, while ethylene production ($\mu L\,C_2H_4\,Kg^{-1}\,h^{-1}$) was measured using a Shimadzu GC-8A gas chromatograph with a Supelco 80/100 Porapak Q glass column (2.5 ft 5 mm × 3 mm), with the injector temperature at 150 °C, oven temperature at 40 °C and detector temperature at 150 °C, respectively.

2.3. Stress and damage indicators

Upon removal from CS, polyphenol oxidase activity (UA PPO mg^{-1} tissue) was measured using the Bradford method (Bradford, 1976). Acetaldehyde content (μg acetaldehyde g^{-1} tissue) and ethanol content (μg ethanol g^{-1} tissue) were measured using a Hewlett–Packard 5890 gas chromatograph in accordance with Davis and Chace (1969). Jasmonic acid content (ng g^{-1} of tissue) was measured in a Variant CP 3800 gas chromatograph coupled with a Variant Saturn II spectrometer with a multiple ionic detector. The chromatography conditions were 60 °C (1 min) up to 280 °C (9 min) at increments of 25 °C per minute. Helium was used at a flow rate of 1 mL min^{-1}.

2.3.1. Visible damage upon removal from CS and after the SCP

Internal and external cold damage (ID and ED, respectively) were both evaluated as the percentage of damaged area, considering browning or discolouration of the pulp and/or blackening of vascular strands for internal damage and epidermal browning and/or lenticelosis for external damage. The evaluation was done with percentage ranges of the damaged areas: 0, <24, 25–49, 50–74, >75% upon removal from CS and after the SCP.

2.4. Statistical design

A fully randomised design was used with four repetitions. For the variables, PPO activity, acetaldehyde and ethanol three replicates were used, while for respiration and ethylene production, four replicates were used. For the variables related to damage: external hue angle and PPR, 6 independent fruits were evaluated and for weight loss, 10 individual fruits were tested. Factorial ANOVA was evaluated between storage time (1, 23 and 46 days), preconditioning (Hydro or LTC) and wax (with or without), using the Tukey's test ($p \leq 0.05$) as post-hoc test.

3. Results

3.1. Fruit quality upon removal from refrigeration

Weight variation upon removal from refrigeration was affected by the interactions of storage time/preconditioning, storage time/waxing and preconditioning/waxing (Table 1).

In the first interaction, it was observed that as storage time increased, weight loss also increased. After 1 day of refrigeration the