

EFFECT OF COLD BREAK DURING REFRIGERATED STORAGE ON CONSERVATION AND QUALITY OF HASS AVOCADOS (*Persea americana* Mill.)

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In order to evaluate the effect of a temperature break on the quality and conservation of stored fruit, Hass avocados were harvested at 2 stages of ripeness (10-12% and 13-15% oil) weighed, refrigerated at $7 \pm 1^\circ\text{C}$ and 90-95% of relative humidity, for 20, 25 and 30 days. On day 15, part of the fruit was subjected to a temperature break, for 24 hours, 50% at 15°C (59°F) and the other half at 25°C (77°F), and another group for 48 hours at 15 and 25°C , respectively, keeping a control with no temperature break. At the end of every storage period, the following was determined: weight loss, pulp resistance to pressure (PRP), epidermis color, physiological disorders and pathological damages. Subsequently, the fruit was left to soften at ambient temperature up to 1.81 kg of PRP, with the same variables being evaluated again. Cold breaks at 15°C (59°F) for 2 days maximum, do not provoke a reduction in the post-harvest life and final quality of the fruit, until 30 days of storage, in both ripeness stages. Cold breaks at 25°C (77°F) for 2 days cause an early softening, a decrease of chroma and brightness with absence of pathogens and physiological disorders. Cold breaks at 25°C for 1 or 2 days cause a greater weight loss than the other treatments, evaluated during the 3 refrigeration periods.

Key words: Maturity, Quality, Post-harvest, Pulp Resistance to Pressure, Softening.

EFFECTO DEL QUIEBRE DE TEMPERATURA EN ALMACENAMIENTO REFRIGERADO SOBRE LA CONSERVACIÓN Y CALIDAD DE PALTAS (*Persea americana* Mill.) CV. HASS

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Para evaluar el efecto que produce un quiebre de temperatura sobre la calidad y conservación de la fruta en almacenamiento, paltas del cv. Hass fueron cosechadas con 2 estados de madurez (10 -12% y 13-15% de aceite), pesadas y refrigeradas a $7 \pm 1^\circ\text{C}$ y 90 – 95% de humedad relativa, por 20, 25 y 30 días. A los 15 días, parte de la fruta fue sometida a un quiebre de temperatura, por 24 horas, el 50% a 15°C y el otro 50% a 25°C , y otro grupo por 48 horas, a 15 y 25°C , respectivamente, manteniéndose un testigo sin quiebre de temperatura. Al término de cada periodo de almacenamiento, se evaluó: pérdida de peso, resistencia de la pulpa a la presión (RPP), color de epidermis, desórdenes fisiológicos y daños patológicos. Posteriormente, la fruta se dejó ablandar a temperatura ambiente hasta 1.84 k de RPP, volviéndose a evaluar las mismas

variables. Quiebres de frío a 15°C, hasta por 2 días, no producen una disminución en la vida de poscosecha y calidad final de la fruta, hasta los 30 días de almacenamiento, en ambos estados de madurez. Quiebres de frío a 25°C por 2 días, producen un ablandamiento prematuro, una disminución del croma y luminosidad, sin presencia de patógenos ni desórdenes fisiológicos. Quiebres de frío a 25°C por 1 ó 2 días, producen mayor pérdida de peso, que los otros tratamientos, evaluados en los 3 tiempos de refrigeración.

Palabras clave: madurez, calidad, poscosecha, resistencia de la pulpa a la presión, ablandamiento.

1. Introduction

Chile has experienced an important increase in the export of avocados, being among the five main producers worldwide, with a production over 160,000 annual tons; such figure should increase within the next years, especially by the area planted which has not been in full production yet (ODEPA, 2007).

In this scenario, an oversupply is expected; therefore, the diversification of exports will be important; where Europe and Japan, although distant, are interesting markets for Chile.

Background information on logistics aspects of refrigeration management, particularly regarding break in the cold chain of the refrigerated storage, is not very known and could be required in the case of very long distances for the fruit, especially for the variation of quality and organoleptic aspects that might affect it.

Muñoz *et al.* (1998), studying mangoes, mention that rises of temperature produced in the refrigerated storage would cause a faster softening, increased weight loss and anticipated change in colour.

According to Olaeta and Undurraga (1995), the harvest in the Hass variety should not be executed with an oil content below 10.9%, without manifesting change in colour, and regarding storage, the recommended temperature is 5 to 7± 1°C (41 to 44.6 ± 33.8°F) (Faubion *et al.*, 1991; Alique and Zamorano, 1998; Vuthapanich and Hofman, 1998).

According to Muñoz *et al.* (1998), it is expected that temperature breaks in refrigerated storage for avocados may cause similar situations to those detected in mangoes, which would affect its quality of sale in distant markets.

The present work evaluates the effect of the time and temperature of the cold break on the shelf life and final quality of the Hass avocado, harvested with two maturity stages and stored for 20, 25 and 30 days at temperatures of 7±1°C (44.6±33.8 °C).

2. Materials and Methods

At the Experimental Station La Palma of the Faculty of Agricultural Sciences, Pontificia Universidad Católica de Valparaíso, located in the city of Quillota (Latitude 32° 49' S, Longitude 71° 16'W), 300 Hass avocado fruits were harvested, between 200-230 g, 150 with 10 to 12% and 150 with 13 to 15% of oil.

Those 150 fruits, of each maturity stage, were taken to laboratory, weighted and divided into 3 groups in order to form 3 trials in each group. In the first test, the fruits were stored up to 20 days; in the second one up to 25; and in the third, up to 30 days, at $7 \pm 1^\circ\text{C}$ ($44.6 \pm 33.8^\circ\text{C}$) and 90 – 95% of relative humidity.

When reaching 15 days of refrigerated storage, 120 fruits from the first maturity stage were subjected to a temperature break, 60 fruits for 24 hours and 60 for 48 hours: 30 fruits at 15°C and 30 fruits at 25°C, afterwards they were taken back to chamber with the same initial conditions, leaving 30 fruits with no temperature break as control. The above-mentioned was repeated for the second maturity stage, as a whole, 6 tests were conducted.

In each test, the following was evaluated when leaving the chamber: weight loss (%), pulp resistance to pressure (cone penetrometer Effeggi 8 mm of diameter), skin colour (colorimeter MINOLTA CR-200; values expressed in CIElab modified by Mc Guire, 1992), physiological disorders (damage percentage) and pathological damages (damage percentage). Subsequently, the fruit was left to soften at ambient temperature until reaching consumption maturity (1,84 k RPP), evaluating the same variables. In addition a sensory evaluation panel was made, determining through a hedonic scale: taste, pulp colour and consistency (Table 1).

Table 1: Hedonic scale for taste, pulp colour and consistency

Taste and colour of pulp	Consistency	Value
Like it a lot	Very firm	1
Like it	Firm	2
Indifferent	Medium	3
Dislike it	Soft	4
Dislike it a lot	Very soft	5

A Completely Randomized Design was used, where the experimental unit was an avocado, with five replications. The variance analysis was conducted through the Fisher test, and if differences are seen in the treatments, the Tukey Test ($p \leq 0.05$).

The qualitative variables (sensory analysis) were analysed through the non-parametric Friedman test ($p \leq 0.05$).

3. Results and discussion

Regarding the pulp resistance to pressure, in every test no important effect was detected among the treatments on both maturity stages, when leaving the refrigerated storage (Tables 2 and 3).

Table 2: Effect of temperature breaks on the pulp resistance to pressure (k) of Hass avocado harvested with 10 to 12% oil when leaving the refrigerated storage.

Treatments	20 days	25 days	30 days
Control	12.24 a	12.24 a	12.24 a
Break at 15°C 1 day	12.24 a	12.24 a	12.24 a
Break at 25°C 1 day	12.24 a	12.24 a	12.24 a
Break at 15°C 2 days	12.24 a	12.24 a	12.24 a
Break at 25°C 2 days	12.24 a	11.93 a	12.24 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

Table 3: Effect of temperature breaks on the pulp resistance to pressure (k) of Hass avocado harvested with 13 to 15% oil when leaving the refrigerated storage

Treatments	20 days	25 days	30 days of R.S.
Control	12.24 a	12.24 a	12.24 a
Break at 15°C 1 day	12.24 a	12.24 a	12.24 a
Break at 25°C 1 day	12.24 a	12.24 a	12.24 a
Break at 15°C 2 days	12.24 a	12.24 a	12.24 a
Break at 25°C 2 days	12.24 a	12.24 a	12.24 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

After the softening period, a significant effect of treatments was determined in avocados harvested with 10 to 12% oil, only in tests with avocados stored for 20 and 25 days (Table 4). However, on the second maturity stage, no differences were noticed among treatments, in every test (Table 5).

The above mentioned could suggest that at earlier maturity stages avocados would be more susceptible to temperature fluctuations that might occur during its refrigerated storage.

Table 4: Effect of temperature breaks on the pulp resistance to pressure (k) of Hass avocado harvested with 10 to 12% oil after softening.

Treatments	20 days (14)	25 days (12)	30 days (10)
Control	0.49 ab	0.20 a	0.32 a
Break at 15°C 1 day	0.61 a	0.18 ab	0.23 a
Break at 25°C 1 day	0.53 ab	0.13 b	0.23 a
Break at 15°C 2 days	0.45 ab	0.15 b	0.19 a
Break at 25°C 2 days	0.42 b	0.14 b	0.24 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

The No. between parentheses indicates the days passed between the refrigerated storage and sensory evaluation.

Table 5: Effect of temperature breaks on the pulp resistance to pressure (k) of Hass avocado harvested with 13 to 15% oil after softening

Treatments	20 days (10)	25 days (8)	30 days (7)
Control	0.38 a	0.22 a	0.30 a
Break at 15°C 1 day	0.36 a	0.76 a	0.29 a
Break at 25°C 1 day	0.36 a	0.21 a	0.35 a
Break at 15°C 2 days	0.32 a	0.26 a	0.30 a
Break at 25°C 2 days	0.86 a	0.38 a	0.27 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

The No. between parentheses indicates the days passed between the refrigerated storage and sensory evaluation.

Regarding the percentage of weight loss on both maturity stages, the highest losses were determined to occur in the treatments that had temperatures higher than the temperature break (25°C – 77°F). The above mentioned is basically produced by transpiration, due to the reduction of vapour pressure caused by higher temperature of the external atmosphere surrounding the fruit (Milne, 1997), which coincides with Aguirre (1994) who mentions that weight loss is mainly caused by water loss through transpiration (Figure 1 and 2).

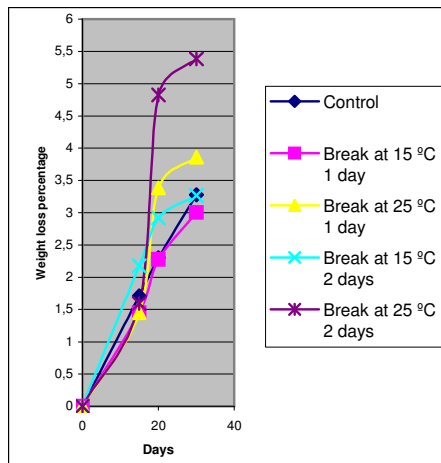


Figure 1: Effect of temperature breaks on the evolution of the percentage of weight loss of Hass avocados when leaving refrigerated storage (10 – 12%).

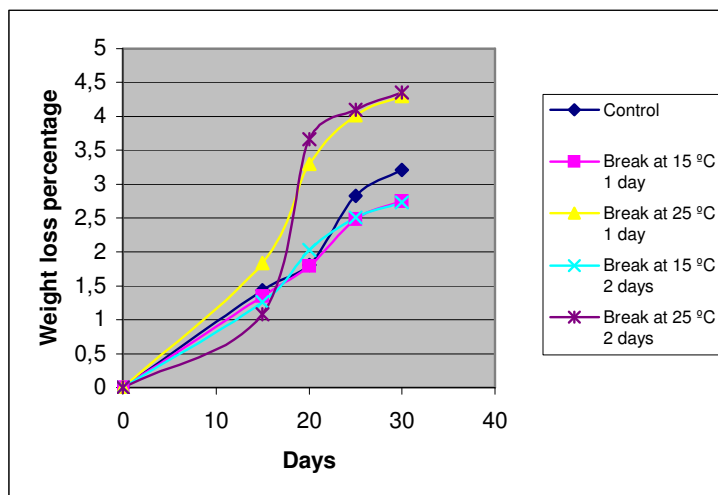


Figure 2: Effect of temperature breaks on the evolution of the percentage of weight loss of Hass avocados when leaving refrigerated storage (13 – 15%)

With regard to the colour intensity (chroma), it was determined on the first maturity stage that in the tests on 20 and 25 days of refrigerated storage, the lowest chroma value (darkest) was noticed in the treatment with cold break at 25°C (77°F) for 2 days showing differences only with the treatment of cold break for one day at 15°C (59°F) (Table 6). However, on the second maturity stage, the cold breaks did not generate differences of chroma when leaving the refrigerated chamber (Table 7).

This behaviour is similar to that observed in the pulp resistance to pressure in the same treatments.

Table 6: Effect of temperature breaks on the chroma when leaving refrigerated storage for each test with fruit harvested with 10 to 12% oil.

Treatments	20 days	25 days	30 days
Control	17.81 ab	16.26 ab	14.64 a
Break at 15°C 1 day	19.16 a	16.89 ab	15.51 a
Break at 25°C 1 day	14.68 ab	17.56 a	15.85 a
Break at 15°C 2 days	15.81 ab	17.98 a	14.41 a
Break at 25°C 2 days	12.91 b	11.60 b	13.95 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

Table 7: Effect of temperature breaks on chroma when leaving refrigerated storage for each test with fruit harvested with 13 to 15% oil

Treatments	20 days	25 days	30 days
Control	12.37 a	12.92 a	17.09 a
Break at 15°C 1 day	12.62 a	14.69 a	13.08 a
Break at 25°C 1 day	11.14 a	10.44 a	11.82 a
Break at 15°C 2 days	17.20 a	16.15 a	16.80 a
Break at 25°C 2 days	13.91 a	13.16 a	14.47 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

By comparing the fruit chroma when leaving the refrigerated storage with the fruit at the moment of the sensory evaluation, it may be stated that as this ripens, its colour intensity decreases; therefore, it may be concluded that there is a tendency to reduce chroma as the break intensity increases, regarding temperature and days (Table 8 and 9). This would be influenced by rises of temperatures, which might be responsible of speeding up the maturity process, causing the destruction of chlorophyll generated by the action of enzymes (chlorophyllases), which would make the fruit change colour since pigments, according to Madrid, Boronat and Rosauo (1998), would be related to the ripening process of the fruit, provoking typical changes of colour produced during ripening, which would explain the decrease in the colour intensity.

At the sensory analysis for the first maturity stage, no significant effect of the treatments on the tests was detected.

Table 8: Effect of temperature breaks on chroma at the moment of sensory evaluation for each test with fruit harvested with 10 to 12% oil

Treatments	20 days (14)	25 days (12)	30 days (10)
Control	5.01 a	2.95 a	3.06 a
Break at 15°C 1 day	5.49 a	2.95 a	2.79 a
Break at 25°C 1 day	4.55 a	2.99 a	2.07 a
Break at 15°C 2 days	5.13 a	2.49 a	2.81 a
Break at 25°C 2 days	3.90 a	2.66 a	2.44 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

The No. between parentheses indicates the days passed between the refrigerated storage and sensory evaluation.

Table 9: Effect of temperature breaks on chroma at the moment of sensory evaluation for each test with fruit harvested with 13 to 15% oil

Treatments	20 days (10)	25 days (8)	30 days (7)
Control	2.34 a	2.28 a	1.73 a
Break at 15°C 1 day	2.45 ab	2.54 a	1.55 a
Break at 25°C 1 day	1.90 a	2.29 a	1.39 a
Break at 15°C 2 days	2.33 a	2.53 a	1.74 a
Break at 25°C 2 days	4.18 b	3.57 a	1.76 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

The No. between parentheses indicates the days passed between the refrigerated storage and sensory evaluation.

The sensory evaluation panel determined for both maturity stages that cold breaks did not have any effects in taste, consistency and colour of pulp in all the tests. For these purposes, this would indicate that temperature breaks and its total length, in all the tests, were not responsible of causing damage in the final quality of the fruit. The results changed from “indifferent” to “good” with regard to taste and colour of pulp, and regarding consistency from “firm” to “soft” (Table 10 and 11).

Table 10: Effect of temperature breaks on taste, consistency and pulp colour for each test at the moment of sensory evaluation for each test with fruit harvested with 10 to 12% oil

Treatments	Taste			Consistency			Pulp colour		
	20 days (14)	25 days (12)	30 days (10)	20 days (14)	25 days (12)	30 days (10)	20 days (14)	25 days (12)	30 days (10)
Control	3 a	2.8 a	3 a	4 a	2.8 a	3 a	3.2 a	3 a	3.4 a
Break at 15°C 1 day	3.2 a	3 a	3 a	4 a	2.2 a	3 a	3.6 a	3 a	2.8 a
Break at 25°C 1 day	2.6 a	3 a	3 a	4 a	3 a	3 a	3.2 a	3 a	2.8 a
Break at 15°C 2 days	3.2 a	3.2 a	3 a	4 a	3 a	3 a	4 a	3 a	3 a
Break at 25°C 2 days	3 a	3 a	3 a	4 a	3 a	3 a	3 a	3 a	3 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

The No. between parentheses indicates the days passed between the refrigerated storage and sensory evaluation.

Table 11: Effect of temperature breaks on taste, consistency and pulp colour for each test at the moment of sensory evaluation for each test with fruit harvested with 13 to 15% oil

Treatments	Taste			Consistency			Pulp colour		
	20 days (10)	25 days (8)	30 days (7)	20 days (10)	25 days (8)	30 days (7)	20 days (10)	25 days (8)	30 days (7)
Control	3.8 a	3.8 a	3 a	4.2 a	2.8 a	3 a	4 a	3.6 a	3.2 a
Break at 15°C 1 day	4.4 a	2.4 a	3.2 a	3.8 a	2 a	2.8 a	4 a	3.2 a	2.8 a
Break at 25°C 1 day	3.8 a	3 a	3.6 a	3 a	3 a	3 a	4 a	3 a	3.4 a
Break at 15°C 2 days	4 a	3 a	3 a	3 a	2.8 a	3.2 a	4 a	3.8 a	3 a
Break at 25°C 2 days	4 a	3.8 a	3.2 a	4 a	3.4 a	3 a	4 a	4.4 a	3.6 a

Means with the same letters in the same column do not show any significant differences in accordance with the variance analysis according to the Tukey Test ($p \leq 0.05$).

The No. between parentheses indicates the days passed between the refrigerated storage and sensory evaluation.

No tests detected the presence of pathogens or physiological disorders during the refrigerated storage or during the softening period, indicating that cold breaks would not cause any effect on these parameters.

4. Conclusions

Cold breaks, generated when reaching 15 days of refrigerated storage ($7 \pm 1^{\circ}\text{C}$) at 15°C (59°F), until a period of 2 days, in Hass avocados harvested with 10-12 or 13-15% oil, do not cause a reduction in post-harvest life and final quality of the fruit, until 30 days of storage.

Cold breaks produced when reaching 15 days of refrigerated storage ($7 \pm 1^{\circ}\text{C}$), at 25°C (77°F) for 2 days, in Hass avocados harvested with 10-12% oil, cause an early softening, a decrease of chroma, without presence of pathogens or physiological disorders.

Cold breaks produced when reaching 15 days of refrigerated storage ($7 \pm 1^{\circ}\text{C}$), at 25°C (77°F) for 1 or 2 days provoke higher weight loss, evaluated in 3 refrigeration periods (20, 25 and 30 days), in both maturity stages.

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