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EFFECT OF TWO COATINGS AND TWO REFRIGERATED STORAGE PERIODS ON POSTHARVEST BEHAVIOUR OF HASS AVOCADOS

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The use of coatings is a technique to increase post-harvest life of the fruit. In order to evaluate the use of carnauba and carnauba plus shellac, in concentration of 100% (commercial product), on the quality of Hass avocados, fruits were harvested at a ripeness stage between 9 – 12% of oil; they were treated with both coatings and refrigerated at 8ºC ± 1ºC for 20 and 40 days. The following were evaluated in every storage period: weight loss; pulp resistance to pressure; color of epidermis; oil percentage; internal appearance; blackening of vascular bundles and browning of pulp under the seed. Then the fruit was left to soften at ambient temperature (20℃) until 1.81 kg of pressure, and the same variables were evaluated again. The carnauba-based coating mainly reduces the weight loss in refrigerated storage, in comparison with the other two treatments. On the 40th day of refrigerated storage, fruit treated with both waxes showed higher values of brightness and chroma compared to the control treatment, that is, they kept the green colour and brightness of fruits for a longer time, respectively. Both vascular bundles and pulp did not show browning.

Key words: waxes, weight loss, colour, pulp browning

EFECTO DE DOS COBERTURAS Y DOS TIEMPOS DE ALMACENAMIENTO REFRIGERADO SOBRE COMPORTAMIENTO POSTCOSECHA DE PALTA CV. HASS

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El uso de coberturas es una técnica para aumentar la vida de poscosecha de la fruta. Con el objeto de evaluar el uso de carnauba y carnauba más shellac, en concentración de 100% (producto comercial), sobre la calidad de palta cv. Hass, se cosecharon frutos con un estado de madurez entre 9 – 12% de aceite, los que fueron tratados con ambas coberturas y refrigerados a 8ºC ± 1ºC por 20 y 40 días. Se evaluaron en cada periodo de almacenamiento: pérdida de peso, resistencia de la pulpa a la presión, color de epidermis, % de aceite, apariencia interna, ennegrecimiento de haces vasculares y pardeamiento de pulpa bajo la semilla. Luego la fruta se dejó ablandar a temperatura ambiente (20ºC) hasta 1.81 Kg de presión, volviéndose a evaluar las mismas variables. La cobertura a base de carnauba reduce en mayor medida la pérdida de peso en almacenamiento refrigerado, en comparación a los otros dos tratamientos. A los 40 días de almacenamiento refrigerado, frutos tratados con ambas ceras presentaron mayores valores de luminosidad y croma en comparación al testigo, es decir, mantuvieron por más tiempo el color verde y el brillo de los frutos, respectivamente. Los haces vasculares y la pulpa no presentaron pardeamiento.

Palabras claves: ceras, pérdida de peso, color, pardeamiento pulpa

1. Introduction

The search of new markets for Chilean avocado such as Europe requires the development of conservation systems, because the long trips by sea diminish the quality of the fruit (Carrillo and Lizana, 1995).

The use of natural waxes as coatings has become more important in the conservation of the fruit in post-harvest (Undurraga and Olaeta, 2004). Waxing treatment extends the storage life of avocados, reducing the water loss and modifying the internal atmosphere of the fruits (Jeong, Huber and Sargent, 2002). This presents advantages for the quality characteristics of the fruit, especially in brightness, allowing an alternative of lower cost and easier application than other conservation systems, such as the modified or controlled atmosphere, which has lately caused a greater attention when used in fruits (Banks, Cutting and Nicholson, 1997).

The consumers' preference towards bright fruits, among other factors, has highlighted the importance of waxing with natural wax in fruits, which is commercially used in South Africa and Israel, since they are countries having distant markets (Durand e*t al*., 1982; Kremer-Köhne and Duvenhage, 1997).

There are different types of natural waxes generated from different sectors of nature such as Shellac, obtained from the gum secretion of the insect *Laccifer laca* Kerr., which feeds on certain trees of India and Southern Asia. Shellac has multiple industrial uses (Wolverine, 2007). This resin gives low protection against dehydration (Hagenmaier and Baker, 1995), provides high brightness and inhibits the gas exchange because of low permeability to O_2 and CO_2 (Hagenmaier and Baker, 1993).

Another one is Carnauba wax, which is obtained from palm trees (*Copernica cerifera*) of South America. It shows a low effect on the permeability to O_2, CO_2 and C_2H_4 (Hagenmaier and Shaw, 1992); therefore, it is used to allow the fruit to breath without causing moisture loss. In addition, it prevents the "whitening" of coating, when the product is condensed in the fruit. The present trial has the objective of determining the effect of these two types of natural waxes, produced by the company Pace International, EXP 28 and EXP 29 (Carnauba and Carnauba plus Shellac, respectively), on the refrigerated conservation and final quality of Hass avocados, harvested at a maturity level between 10 and 12% oil.

2. Materials and Method

Hass avocados with a maturity level between 10 and 12% oil, determined by percentage of moisture (Undurraga and Olaeta, 1995) and of 180 to 220 g of weight, were harvested at the Experimental Station La Palma of the Faculty of Agricultural Sciences, Pontificia Universidad Catolica de Valparaiso, located in Quillota (Latitude 32° 49' S, Longitude 71° 16'W). The fruits were divided into 3 equal groups, 2 two of them were treated with 2 types of waxes, respectively, EXP 29 and EXP 28 (Carnauba 17.2% plus Shellac 1.8% with 24% of total solids and only Carnauba 15% and 18% of total solids, respectively), in 100% concentration of commercial product, whereas the third group remained without treatment as control. All of them were refrigerated at 7ºC ± 1ºC, with 90 – 95% of relative humidity for 20 and 40 days.

For the wax application, the fruits were immersed up to the middle and the waax was manually spread on the rest of the fruit, removing surpluses. Then, the fruit was placed in a row, in plastic trays previously disinfected in chlorinated water. The fruits were dried at ambient temperature, using a low flow fan to speed up the process.

In every storage period, the following was evaluated: weight loss (%), pulp resistance to pressure (EFFEGI FT 327 penetrometer of 8-mm rod in diameter), colour (MINOLTA CR-200 colorimeter and values expressed in CIE Lab and modified by Mc Guire, 1992), pulp appearance, internal browning and blackening of vascular bundles. Then, the fruit was left to soften at ambient temperature (20℃), simulating a commercialization period and when the first group reached 1.81 kg of pulp resistance to pressure, the fruit was evaluated in all the treatments. In the case of the variables loss of weight and colour, the avocados used in each evaluation were the same. The variables of pulp appearance, internal browning and blackening of vascular bundles were visually qualified according to the following table:

Note	**Pulp Appearance**	**Pulp Browning**	**Blackening of vascular bundles**
1	Unripe: Yellowish-green colour. Milky appearance	Without browning	Undamaged bundles
2	Pre-ripe: Soft yellowish colour. Normal appearance	25%	Initial – 25%
3	Ripe: Cream colour. Normal appearance.	50%	50%
4	Overripe: Yellow colour. Oily appearance.	>75%	Black bundles in all the pulp

For the variables: weight loss (%), pulp resistance to pressure and colour, a completely randomized bifactorial design 3x2 was used (3 types of coatings x 2 times of refrigerated storage), with four replications of 8 fruits each. The experimental fruit was one fruit. The variables were analysed by Fisher's F-Test. The separation of means was made through Duncan's multiple range test ($p \leq 0.05$). Internal appearance, blackening of vascular bundles and internal browning were analysed by the Kruskal-Wallis non-parametric test ($p \leq 0.05$).

3. Results and Discussion

Regarding the pulp resistance to pressure, an interaction between the factors in both at the end of cold treatment and simulated commercialization was determined. On day 20 of cold storage, the control showed the lower values of pulp resistance to pressure, whereas the waxes did not show any differences between them (Table 1). However, on day 40, no significant differences were observed among the treatments.

Table 1: Effect of the interaction between coatings and period of refrigerated storage on the pulp resistance to pressure (kg) in Hass avocados, when leaving the cold chamber

Wax Application	**Storage period (days)**	
	20	**40**
Control	3.75 a	0.75 a
EXP 29	12.25 b	1.20 a
EXP 28	12.25 b	2.11 a

Different letters show significant differences (Duncan $p \leq 0.05$).

In case of EXP 28, it may be observed that the pulp resistance to pressure is within the consumption level when leaving the storage on day 40, which would even allow some days of commercialisation.

In the simulated commercialisation (Table 2), no differences were detected among the treatments in any of the evaluated periods, indicating that up to 20 days, the refrigeration as well as wax delay maturity.

Table 2: Effect of the interaction between coatings and refrigerated storage period on the pulp resistance to pressure (kg) in Hass avocados, during the period of simulated commercialisation.

Wax Application	**Storage period (days)**	
	20 + 4	**40 + 3**
Control	0.51 a	0.50 a
EXP 29	0.96 a	0.69 a
EXP 28	0.85 a	0.86 a

Different letters show significant differences (Duncan $p \leq 0.05$).

It is also observed when comparing Tables 1 and 2 that the reduction of the pulp resistance to pressure is very sharp in the commercialisation period, after 20 days of cold storage, which ratifies the importance of the refrigeration to keep this parameter.

In the percentage of weight loss, interaction was detected among the factors (Table 3 and 4), with the control presenting the highest weight values, in comparison with the two types of wax applied, which did not show any differences during the cold storage. This would indicate that the softening occurred on day 40 of refrigeration was not only influenced by moisture loss, possibly with increments in enzymatic levels of the pectinase type, which would have caused the absence of differences in such parameter when leaving cold storage. On day 40 of storage, plus 3 of simulated commercialisation, a difference in the weight loss of waxes, which could be provoked by greater impermeability of EXP 29 wax on the rest, due to probably its level of solids and especially by the presence of Shellac in its formulation. Anyhow, it can be observed that the weight loss in 40 days plus 3 of commercialisation, in the wax treatments, does not exceed the level in which the fruit exhibits symptoms of wilt.

Table 3: Effect of the interaction between coatings and refrigerated storage period on the weight loss (%) in Hass avocados at the end of every refrigeration period at 7 ± 1ºC

Wax application	**Storage period (days)**	
	20	**40**
Control	2.92 b	4.60 c
EXP 29	1.50 a	2.69 b
EXP 28	1.93 a	3.38 b

Different letters show significant differences (Duncan p≤ 0.05).

Table 4: Effect of the interaction between coatings and refrigerated storage period on weight loss (%) in Hass avocados, between simulated commercialisation period and day 0

Wax application	**Storage period (days)**	
	20 + 4	**40 + 3**
Control	5.86 cd	10.09 e
EXP 29	2.91 a	4.79 b
EXP 28	3.57 a	6.49 d

Different letters show significant differences (Duncan p≤ 0.05).

For the variables of colour, an interaction between refrigerated storage period and application of coatings was observed.

Regarding brightness, the three treatments decreased it during refrigerated storage until 40 days, but finally both waxes with values higher than those of the control did not show differences between them (Table 5), which demonstrates that both coatings allow keeping for a longer period the brightness of the fruit, coinciding also with the high contribution in brightness, especially of EXP 29.

Table 5: Effect of the interaction between coatings and refrigerated storage period on brightness (L) in Hass avocados when leaving the cold refrigerated chamber

Wax application	**Storage period (days)**	
	20	**40**
Control	28.9 cd	26.4 ab
EXP 29	33.1 e	30.4 d

EXP 28	33.2 e	29.5 cd

Different letters show significant differences (Duncan p≤ 0.05).

During the period of simulated commercialisation, the three treatments presented a reduction of brightness; however, the EXP 29 wax presented the highest values of brightness on day 40 plus 3 (Table 6), keeping for a longer period the brightness of the fruit although this is ripe, probably by the presence of Shellac in its composition.

Table 6: Effect of the interaction between coatings and refrigerated storage period on brightness (L) in Hass avocados during the period of simulated commercialisation

Wax application	**Storage period (days)**	
	20 + 4	**40 + 3**
Control	24.7 ab	27.6 b
EXP 29	26.9 b	32.1 cd
EXP 28	22.2 a	28.4 bc

Different letters show significant differences (Duncan p≤ 0.05).

Regarding chroma, no differences were detected between waxes, until the 40 days of refrigerated storage, so both coverings kept for a longer period the green colour of the fruits, in comparison with the control (Table 7).

Table 7: Effect of the interaction between coatings and refrigerated storage period on chroma (C*) in Hass avocados when leaving the refrigerated chamber

Wax application	**Storage period (days)**	
	20	**40**
Control	10.3 d	5.3 b
EXP 29	14.9 e	7.5 c
EXP 28	13.9 e	6.9 c

Different letters show significant differences (Duncan p≤ 0.05).

During the period of simulated commercialisation on day 20 + 4, the EXP 29 wax presented the highest values of chroma; therefore, it kept for a longer period the green colour of the fruit. However, on day 40 + 3, no differences among the three treatments were detected, because probably the situation of maturity was already very advanced (Table 8).

Table 8: Effect of the interaction between coatings and refrigerated storage period on the chroma (C*) in Hass avocados, during the period of simulated commercialisation.

Wax application	**Storage period (days)**	
	20 + 4	**40 + 3**

Control	4.9 b	4.0 a
EXP 29	6.8 c	3.3 a
EXP 28	5.0 b	3.8 a

Different letters show significant differences (Duncan $p \leq 0.05$).

With regard to the hue, when reaching 40 days of refrigerated storage, the EXP 29 wax kept for a longer period the green colour of fruits, in comparison with the control and EXP 28 (Table 9).

Table 9: Effect of the interaction between coatings and refrigerated storage period on hue (hº) in Hass avocados, when leaving cold chamber

Wax application	**Storage period (days)**	
	20	**40**
Control	178.75 b	181.24 d
EXP 29	179.06 c	178.56 a
EXP 28	179.00 c	181.38 e

Different letters show significant differences (Duncan $p \leq 0.05$).

During the 20+4 period of simulated commercialisation, the fruits treated with EXP 29 wax showed a greater conservation of green colour of epidermis, in comparison with the control and EXP 28 wax; however, on day 40 + 3 days, EXP 29 could only be different from the control (Table 10) probably because of the maturity advance that goes beyond the effect of wax.

Table 10: Effect of the interaction between coatings and refrigerated storage period on hue (hº) in Hass avocados, during the period of simulated commercialisation

Wax application	**Storage period (days)**	
	20 + 4	**40 + 3**
Control	181.32 e	181.25 e
EXP 29	178.60 a	181.06 d
EXP 28	181.27 e	181.19 de

Different letters show significant differences (Duncan $p \leq 0.05$).

Regarding the pulp appearance, no significant differences between the treatments were observed in the evaluation dates when leaving refrigeration. However, in the period of simulated commercialisation, after 20 days of refrigerated storage (Table 11), it was observed that the waxes kept the appearance closer to pre-maturity than the control, which reached a qualification of ripe.

On day 40+3 of simulated commercialisation, all the fruit had overripe maturity characteristics.

Table 11: Effect of the coatings on the pulp appearance in Hass avocados, during the period of simulated commercialisation

Wax application	Storage period (days)	
	20 + 4	**40 + 3**
Control	3.4 b	4.0 c
EXP 029	2.1 a	3.9 c
EXP 028	2.4 a	3.9 c

Different letters in the same column indicate significant differences (Kruskal Wallis p≤ 0.05).
1= unripe; 2= pre-ripe; 3= ripe; 4= overripe

With regard to pulp, EXP 29 presented the lowest values on day 40 of refrigeration possibly by the presence of Shellac in its formulation, which generates more impermeability of the wax to gases that react in the respiration, which is only expressed after a longer period of storage (Table 12).

Table 12: Effect of the coatings on the pulp browning in Hass avocados when leaving refrigerated chamber

Wax application	Storage period (days)	
	20	**40**
Control	1.2 a	1.9 b
EXP 029	1.0 a	1.4 a
EXP 028	1.0 a	1.5 b

Different letters in the same column indicate significant differences (Kruskal Wallis p≤ 0.05).
1= without browning; 2= 25% browning; 3= 50% browning; 4= >75% browning

In spite of the above, during the period of simulated commercialisation, no significant differences were detected among the treatments in any of the evaluation periods, reaching on day 40 + 3 a pulp browning equal to 50% (Table 13). This would indicate that the physiological reaction of the fruit in the storage would be influenced by the refrigeration temperature besides wax.

Table 13: Effect of the coatings on the pulp browning in Hass avocados during the period of simulated commercialisation

Wax application	Storage period (days)	
	20 + 4	**40 + 3**
Control	1.1 a	3.1 b
EXP 029	1.1 a	2.9 b
EXP 028	1.2 a	2.5 b

Different letters in the same column indicate significant differences (Kruskal Wallis p≤ 0.05).
1= without browning; 2= 25% browning; 3= 50% browning; 4= >75% browning

Finally, regarding the blackening of vascular bundles, the trial determined that no effect of the waxes was observed on this parameter, with avocados reaching on day 40 and after a simulated commercialisation period a uniform level near 50% blackening of vascular bundles.

4. Conclusion

The wax coatings, EXP29 and EXP28, applied in Hass avocados, harvested with 10 to 12% oil, maintain on day 20 of refrigerated storage (7 ± 1ºC and 90 – 95% of relative humidity), a greater pulp resistance to pressure compared to non-waxed fruits, without influencing in the post-refrigeration softening. The same waxes do not keep this difference in 40 days of refrigerated storage.

EXP 28 and EXP29 reduce the weight loss and keep in a better way colour and brightness of Hass avocados, harvested with 10 to 12% oil, during refrigerated storage (7 ± 1ºC and 90 – 95% relative humidity) until 40 days, plus 3 of commercialisation, with EXP 29 being more effective during in this last period than EXP 28 in reducing the loss of weight and colour.

EXP 29 and EXP 28 applied on Hass avocados harvested with 10 to 12% oil do not have an effect in reducing the vascular blackening or pulp browning. They do not influence on the appearance of the pulp in storage until 40 days at 7 ± 1ºC and 90 – 95% of relative humidity. Fruits treated with both coatings finish on day 40 plus 3 of simulated commercialization with an overripe pulp level.

5. References

Banks, N. Cutting, J. and Nicholson, S. 1997. Approaches to optimising surface coatings for fruits. New Zealand Journal of Crop and Horticultural science. 25: 261-272.

Carrillo, C. y Lizana, L. 1995. Almacenaje de frutos de palto (*Persea americana* Mill.) cv. Fuerte en atmósfera controlada. Cuarto simposio internacional de manejo, calidad y fisiología postcosecha de frutas. Lizana, A. ed. Santiago, Universidad de Chile, Facultad de ciencias agrarias y forestales. pp. 109 – 114. (Publicaciones Misceláneas Agrícolas, Nº 42).

Durand, B. Orcan, L. Yanko, U. Zauberman, G. and Fuchs, Y. 1982. Effects of waxing on moisture loss and ripening of Fuerte avocado fruit. HortScience 19(3):421-422.

Hagenmaier, R. and Shaw, P. 1992. Gas permeability of fruit coating waxes. Journal of the American Society for Horticultural Science 117:105-1 09.

Hagenmaier, R. and Baker, R. 1993. Reduction in gas exchange of citrus fruit by wax coatings. Journal of Agricultural and Food Chemistry 41 :283-286.

Hagenmaier, R and Baker, R. 1995. Layered coatings to control weight loss and preserve gloss of citrus fruit. HortScience 30(2):296-298.

Jeong, J.; Huber, D. and Sargent, S. 2002. Delay of avocado (*Persea americana* Mill.) fruit ripening by 1-methylcyclopropene and wax treatments. Postharvest Biology and Technology. 28:247-257.

Kremer-Kohne, S and Duvenhage, J. 1997. Alternatives to polyethylene wax as postharvest treatment for avocados. South African Avocado Growers Association Yearbook. 20: 97-98.

Mc Guire, R. 1992. Reporting of Objetive Color Measurements. HortScience, 27(12): 1254-1255.

Undurraga, P. y Olaeta, J. 1995. Fresh avocado pulp (*Persea americana* Mill.) stored under modified atmosphere using vacuum, CO_2 and N_2 in low density polyethylene bags. Proceedings of The World Avocado Congress III. 370 – 373.

Undurraga, P. y Olaeta J. 2004. Coberturas Naturales: Un avance en la calidad de la conservación de frutas y hortalizas de Chile, para los mercados internacionales. Avance Agrícola 131: 2-5.

WOLVERINE. 2007. What is shellac?. Disponible en: http://www.shellac. org/shellac.html