EFFECT OF ACTIVE PAPER SHEETS WITH ENCAPSULATED ESSENTIAL OILS ON LEMON QUALITY DURING ITS REFRIGERATED CONSERVATION

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Abstract: *Essential oils (EOs) are highly appreciated plant products in the food industry as sustainable alternative preservatives due to their high antimicrobial activity. For this reason, active packaging with EOs is a strategy with high potential for the preservation of fresh fruit and vegetables. In this work, the evolution of the physicochemical quality of lemons (var. Verna) in boxes with active paper sheets (EOs encapsulated in β-cyclodextrins) was studied for 5 weeks at 8 ºC, with supplementary commercialization simulation periods (5 days at room temperature). Lemons with active packaging showed less weight loss (1.3 %) compared to control samples (2.1 %), and maintained 30 % more firmness after 5 weeks, while color was not affected (p >0.05). In conclusion, the packaging of lemons with active paper sheets can be considered as an excellent conservation alternative, since it releases EO in a controlled manner preserving the lemon quality during both refrigerated and commercialization periods.*

Keywords: *carvacrol; eugenol; inclusion complex; cyclodextrins; active packaging.*

1. INTRODUCTION

The lemon production in Spain represents more than 50 % of the total citrus production, being harvested the "Verna" variety from March to July. Spain is the third-largest lemon producing country in the world and the first in Europe with a production of 1,137,000 tons in 2020 [1].

The lemon is a non-climacteric fruit and has a low production of CO_2 and ethylene, which allows it to have a long shelf life compared to other fruits. The factor that most influences the loss of lemon quality is the weight loss due to transpiration and respiration [2]. Throughout the fruit ripening process, the activities of the enzymes pectinmethylesterase and polygalacturonase increase, producing a softening of the fruit wall due to the disruption of the pectin molecules, affecting the firmness of the fruit [3]. Then, the shelf life of lemon can be extended by controlling the transpiration and respiration rates of the fruit, by means of waxes, for example. Citrus fruits have layers of natural wax on the surface of the fruit, which are degraded during washing (drenchers used in the citrus processing plants) prior to entering the processing line. For this reason, the application of waxes (waxing) is a very common method in citrus processing plants to reduce the product dehydration and also control its respiration during its postharvest storage [4]. However, other postharvest technologies can be applied to further extend the shelf life of the lemon.

Essential oils (EOs) are natural plant extracts with high antimicrobial and antioxidant properties. On the other hand, they also have the ability to inhibit enzymes responsible for the quality loss of fruits and vegetables [3]. These properties of EOs are linked to their components, such as terpenes, terpenoids, and low molecular weight aromatic and aliphatic compounds

[5]. However, EOs easily evaporate and degrade (oxidations, etc.), and their application in liquid form is very limited due to their insolubility in water. To counteract this disadvantage, EOs can be encapsulated in cyclodextrins (CDs) (forming inclusion complexes), thus remaining protected, while a time-controlled release of these EOs is achieved. Then, the incorporation of encapsulated EOs within active packaging may extend the shelf life of fresh fruits and vegetables [6]. In addition, such EOs release from active packages is increased at higher relative humidity, like those of refrigerated rooms for storage of fruit and vegetables [7].

The objective of this study was to analyze the quality changes of lemons during conservation using active packaging with encapsulated EOs (inclusion complex with -CDs) up to 5 weeks of refrigerated conservation at 8 ºC (relative humidity (RH) of 88 %), and supplementary commercialization periods (5 days at room temperature).

2. MATERIALS AND METHODS

2.1. Materials

Lemons (*Citrus* × *limon*, var. Verna) were supplied by the company Fruca Marketing S.L. (Beniaján, Murcia) in April 2021. Lemons were waxed with carnauba wax at the company's facilities. Fruits were subsequently transported to the cold storage rooms of the food technology pilot plant of the Universidad Politécnica de Cartagena, where they were distributed within active packaging (including EOs-active paper sheets) and control packaging (box without active paper sheets). The active paper (Kraft paper) sheets were previously coated with 1 g m^{-2} of inclusion complex of a mixture of EOs (carvacrol: eugenol 80:20 *weight* (*w*):*w*) with β-cyclodextrins as previously described [8]. Each box contained 16 lemons. Boxes were stored at 8 ºC and 88 % RH for 5 weeks, with supplementary commercialization periods of 5 days at room temperature after each week of refrigeration. Three replicates (3 boxes) were made for each sampling time and packaging treatment (control or active).

2.2. Analysis and determinations

Weight loss was determined by weight difference of the boxes throughout storage. The color of the samples was measured using a colorimeter (Chroma Meter CR-400, Konica Minolta, Tokyo, Japan) at D65 illuminant, 2° observer, and 8 mm viewing aperture. Three color measurements were made for each lemon on its surface, and were automatically averaged by the device. Color measurements were expressed according to the CIELab system in the spatial coordinates *L** (brightness), *a** (green-red) and *b** (blue-yellow). The Chroma index was determined according to [9]. Fruit firmness was determined with a texturometer (TA-XT Plus TA Instruments model; Surrey, United Kingdom), by means of the applied compression force (N) with a cylindrical probe (5 cm diameter) moved at 20 mm min^{-1} for 10 mm after contacting the fruit skin.

2.3. Statistic analysis

Statistical analysis was performed using the SPSS software program (v.19 IBM, New York, USA) using multivariate analysis of variance (ANOVA) (treatment × storage time) with Tukey's test (p=0.05).

3. RESULTS AND DISCUSSION

3.1. Weight loss

The results showed a lower weight loss in the lemons stored with the active sheets with values of 1.3 % after 5 weeks of refrigerated storage compared to those levels of control samples (2.1 %) (Figure 1A). The observed weight losses of this lemon cultivar was lower

than those previously reported for other lemon cultivars stored at 8 ºC for 5 weeks [10].

During the commercialization period (Figure 1B), weight losses of lemons with active sheets were lower than control samples. The controlled release of EOs from the active sheets could be responsible of reducing the fruit respiration and transpiration, according to the observed reduced weight losses, as previously observed [11]. Similarly, the released EOs from active packaging was able to reduce the activities of enzymes involved in the product respiration processes [12].

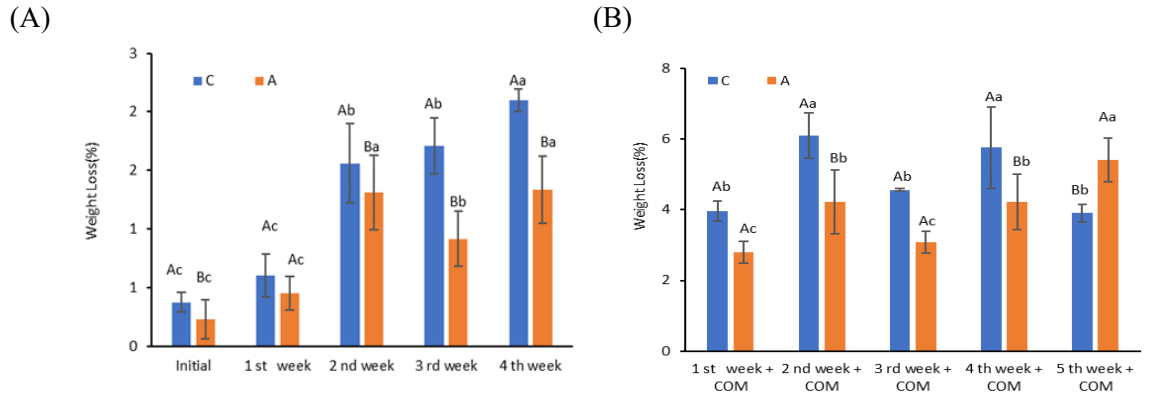

Figure 1. Weight loss of lemons stored in active (A) and control packages (C) for 5 weeks at 8 ºC (88% RH) (A) and after supplementary commercialization periods (5 days at room temperature) (B). Different capital letters denote significant differences between packaging treatments for the same storage time. Different lowercase letters denote significant differences between storage times for the same packaging treatment.

3.2. Color

Initial color of lemons was 56.01, 71.66, -0.48, and 56.34 for Chroma, *L**, *a** and *b**, respectively, which are similar to those previously published [13]. No significant chroma differences ($p>0.05$) were observed between active and control samples at the different storage times (either refrigerated storage or commercialization periods) (Figure 2). Accordingly, the EOs release from the active paper sheets did not affect the color of lemons. In the same way, previous studies showed that active packaging did not negatively affect the fruit color [14].

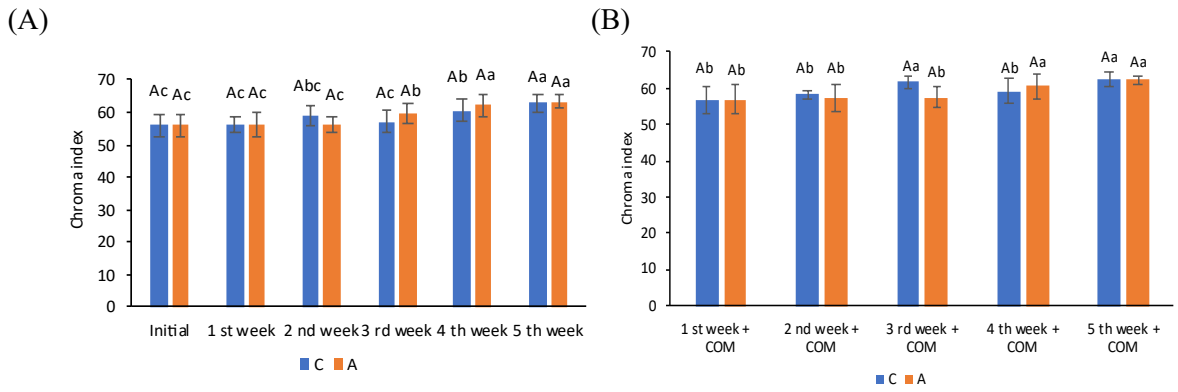

Figure 2. Chroma index of lemons stored in active (A) and control (C) packages for 5 weeks at 8 ºC (88 % RH) (Figure 2A) and after supplementary commercialization periods (5 days at room temperature) (Figure 2B). Different capital letters denote significant differences between packaging treatments for the same storage time. Different lowercase letters denote significant differences between storage times for the same packaging treatment.

3.3. Firmness

Lemons showed initial firmness values of 29.2 N (Figure 3), which are slightly higher than those previously reported for the same lemon variety [15]. It could be explained by different maturity stage of the fruits and different methodologies to determine the lemon firmness. Firmness of lemons stored with active sheets was 30 % better preserved than control samples 5 weeks of refrigerated storage (Figure 3A).

After the commercialization periods (Figure 3B), lemons with the active sheets also showed higher firmness compared to control samples. The better firmness preservation of lemons with the active sheets may be due to the inhibiting activity of EOs against enzymes responsible for the degradation of pectin from the cell wall, such as pectinmethylesterase and polygalacturonase [3][16]. Similarly, active packaging with encapsulated EOs reduced the activities of pectinmethylesterase and polygalacturonase in flat peaches during refrigerated storage and supplementary commercialization periods [3].

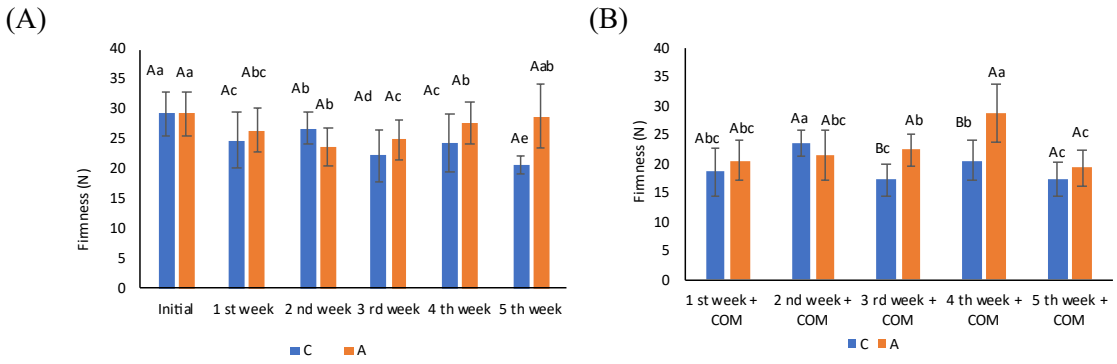

Figure 3. Firmness of lemons stored in active (A) and control (C) packages for 5 weeks at 8 ºC (88 % RH) (Figure 3A) and supplementary commercialization periods (5 days at room temperature) (Figure 3B). Different capital letters denote significant differences between packaging treatments for the same storage time. Different lowercase letters denote significant differences between storage times for the same packaging treatment.

4. CONCLUSIONS

The use of waxes is a common method to reduce transpiration of citrus fruit extending their shelf life. Nevertheless, complimentary postharvest techniques like active packaging may increase such benefits. According to the results of this study, the use of active paper sheets (including encapsulated EOs) withinboxes of lemons during refrigerated storage can be considered an effective technology to preserve the quality of this fruit, whose firmness was better preserved with lower weight losses, while color remained unaffected. In addition, a similar effect was observed after supplementary commercialization periods at room temperature following the previous refrigerated storage.

5. REFERENCES

[1] Perez-Perez JG, Castillo IP, Garcia-Lidon A, Botia P, Garcia-Sanchez F. Fino lemon clones compared with the lemon varieties Eureka and Lisbon on two rootstocks in Murcia (Spain), Scientia Horticulturae, 2005, 4 :530–538

[2] Kaewsuksaeng S, Urano Y, Aiamla-or S, Shigyo M, Yamauchi N. Effect of UV-B irradiation on chlorophyll-degrading enzyme activities and postharvest quality in stored lime (Citrus latifolia Tan.) fruit, Postharvest Biology and Technology, 2011, 2–3 :124–130.

[3] López-Gómez A, Navarro-Martínez A, Martínez-Hernández GB. Active paper sheets including nanoencapsulated essential oils: A green packaging technique to control ethylene production and maintain quality in fresh horticultural products—A case study on flat peaches, Foods, 2020, 12.

[4] Njombolwana NS, Erasmus A, van Zyl JG, du Plooy W, Cronje PJR, Fourie PH. Effects of citrus wax coating and brush type on imazalil residue loading, green mould control and fruit quality retention of sweet oranges, Postharvest Biology Technology, 2013, 86: 362–371.

[5] Burt S. Essential oils: Their antibacterial properties and potential applications in foods - A review, International Journal of Food Microbiology, 2004, 3: 223–253.

[6] López-Gómez A, Ros-Chumillas M., Antolinos V, Buendía-Moreno L, Navarro-Segura L, Sánchez-Martínez M, Martínez-Hernández GB, Soto-Jover S. Fresh culinary herbs decontamination with essential oil vapours applied under vacuum conditions, Postharvest Biology Technology, 2019, 110942.

[7] Ponce Cevallos PA, Buera MP, Elizalde BE. Encapsulation of cinnamon and thyme essential oils components (cinnamaldehyde and thymol) in -cyclodextrin: Effect of interactions with water on complex stability, Journal of Food Engineering, 2010, 1: 70–75.

[8] Mourtzinos I, Salta F, Yannakopoulou K, Chiou A, Karathanos VT. Encapsulation of olive leaf extract in β-cyclodextrin, Journal Agricultural Food Chemistry, 2007, 20 :8088–8094.

[9] Castillo S, Pérez-Alfonso CO, Martínez-Romero D, Guillén F, Serrano M, Valero D. The essential oils thymol and carvacrol applied in the packing lines avoid lemon spoilage and maintain quality during storage, Food Control, 2014, 1:132–136.

[10] Ramakrishnan SR, Jo Y, Nam HA, Gu SY, Baek ME, Kwon JH. Implications of low-dose e- beam irradiation as a phytosanitary treatment on physicochemical and sensory qualities of grapefruit and lemons during postharvest cold storage, Scientia Horticulturae, 2018, 245: 1–6.

[11] López-Gómez A, Ros-Chumillas M, Buendía-Moreno L, Navarro-Segura, Martínez- Hernández GB. Active cardboard box with smart internal lining based on encapsulated essential oils for enhancing the shelf life of fresh mandarins, Foods, 2020, 5:1–23.

[12] Navarro-Martínez A, López-Gómez A, Martínez-Hernández GB. Potential of Essential Oils from Active Packaging to Highly Reduce Ethylene Biosynthesis in Broccoli and Apples, ACS Food Science & Technology, 2021, 6 :1050–1058.

[13] Sun Y, Singh Z, Tokala VY, Heather B. Harvest maturity stage and cold storage period influence lemon fruit quality. Scientia Horticulturae, 2019, 249: 322–328.

[14] López–Gómez A, Ros–Chumillas M, Buendía-Moreno L, Martínez–Hernández GB. Active Cardboard Packaging With Encapsulated Essential Oils for Enhancing the Shelf Life of Fruit and Vegetables, Frontiers Nutrition, 2020.

[15] Nasrin TAA, Rahman MA, Arfin MS, Islam MNM, Ullah A. Effect of novel coconut oil and beeswax edible coating on postharvest quality of lemon at ambient storage. Journal of Agriculture and Food Research, 2: 100019.

[16] López-Gómez A, Ros-Chumillas M, Navarro-Martínez A, Barón M, Navarro-Segura L, Taboada-Rodríguez A, Marín-Iniesta F, Martínez-Hernández G. Packaging of fresh sliced mushrooms with essential oils vapours: A new technology for maintaining quality and extending shelf life, Foods, 2021,6.