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ACTIVE RPET PACKAGING INCLUDING ENCAPSULATED ESSENTIAL OILS IMPROVES THE QUALITY OF FRESH CHILLED STRAWBERRIES

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Abstract: *Active packaging is being considered as a postharvest technique with high potential to better preserve the fruit and vegetable quality during refrigerated storage. In particular, the released plant essential oils (EOs) from active packaging may extend the product shelf life due to the high antimicrobial and antioxidant properties of EOs. Hence, the effects of EOs active packaging (containing an encapsulated carvacrol:oregano EO:cinnamon EO mix at 70:10:20) were studied on the main quality parameters (firmness, decay incidence, microbial growth and sensory scoring) of strawberries stored at 4 ºC up to 7 days. The strawberry firmness was 23% better preserved with the active packaging compared to the control packaging after 7 days. No decay incidence of strawberries after 7 days was observed with the active packaging, while decay incidence reached 20% with the control packaging. In particular, mould yeast loads of strawberries within the active packages were 0.8-1 log units lower than control packaging. In addition, strawberries of active packages were better scored than control packages, mainly owed to the higher-scored texture. In conclusion, the studied EO active package has a high potential to preserve the postharvest quality of strawberries during refrigerated storage.*

Keywords: *carvacrol, oregano, cinnamon, food safety, quality.*

1. INTRODUCTION

Spain is the second-biggest strawberry grower in the world and the top producer in Europe, accounting for 50% of all strawberries produced in the continent during the past 20 years due to the remarkable growth of strawberry production in Spain. As a result, Andalusia produced 97% of all strawberries in Spain in 2022. In particular, during the relevant year, the stated autonomous community produced 314,800 tons of this fruit [1]. The strawberry belongs to the family *Rosaceae*. It is notable for having high levels of minerals (K, P, Ca, Na, and Fe), organic acids (citric, malic, oxalic, salicylic, and ellagic), tannins, flavonoids, anthocyanins, catechin, quercetin, and kaempferol), pigments, and essential oils [2].
In the field, *Botrytis cinerea* infects the strawberry, which then becomes dormant until the right climatic conditions are met for spore production. When it rains, these spores disperse and reside in various plant sections. They are first apparent at the base of the receptacle, at the level of the flower, but they become visible throughout the post-harvest period as the fruit matures. At last, when the circumstances are ideal, it develops quickly and destroys the fruit completely [3].
Essential oils (EOs) are natural plant extracts with strong antibacterial and antioxidant qualities. However, they also possess the capacity to block the enzymes that cause quality loss of fruit and vegetables [4]. These characteristics of EOs are associated with constituents including low molecular weight aromatic and aliphatic

chemicals, terpenes, and terpenoids [5]. However, because EOs are insoluble in water, their use in liquid form is very limited. Furthermore, they easily evaporate and deteriorate (oxidations, etc.). To counteract this limitation, EOs can be safeguarded while obtaining a time-controlled release by encapsulating them in cyclodextrins (CDs) and producing inclusion complexes. Then, active packaging including encapsulated EOs could increase the fresh produce's shelf life. Additionally, the high relative humidity of cold storage rooms of fruit and vegetables allows a controlled release of EOs from the active packaging [6].

2. MATERIALS AND METHODS

The strawberries (*Fragaria* × *ananassa*) were produced by the company Cuna de Platero (Huelva, Spain), and acquired in January 2022 in a local supermarket (Cartagena, Spain). The strawberries (category I) were of the "San Andrea" variety, characterized by their great resistance to diseases and harsh environmental conditions.
Fruit processing was accomplished in a clean room (Class 10,000 according to the FS 209 E standard) being fruit packaging conducted inside a laminar flow hood (class 100). The temperature of the clean room was set at 12 º C. In this research, a total of 40 commercial containers were used (20 for control packaging and 20 for active packaging).
Active packaging consisted of rPET containers (400 mL of capacity) including a polyamide pad on the bottom to avoid mechanical damage to the fruit. This active packaging was fabricated by Ondupet S.A. (Badajoz, Spain) including a coating of an encapsulated mix of 70:10:20 (volume (*v*):*v*:*v*)) carvacrol, oregano EO, and cinnamon EO sprayed on the rPET surface at 1 mg/m^2. The encapsulated (inclusion complex of EO:βCD) EO mix powder was fabricated by Bio-iPack (Fuente Álamo, Murcia, Spain). Carvacrol, oregano EO and cinnamon EO were obtained from Esencias Lozano (Caravaca de la Cruz, Spain). As a control packaging treatment, common commercial plastic non-active containers were used.
A quantity of 150 g of strawberries was introduced in each container and covered with a lid of the same material. Five replicates (packages) were prepared for each packaging treatment and storage time. Subsequently, packaged samples were stored for up to 7 days at 4 ºC and 90% relative humidity in the cold room.

2.1. Firmness

A texture analyzer (model TA.XT plus; Stable Micro Systems, Surrey, UK) with a load cell of 5 kg was used to analyze the strawberry firmness. Previously, the fruit was cut by its central longitudinal part and the cut part was settled on the texture meter platform. A penetration test of 7 mm from the berry surface was carried out using a probe of 4 mm diameter with a test speed is 0.5 mm/s and an activation force of 10 g. The pre- and post-test velocities were 2 and 5 mm/s, respectively. Ten fruits from each replicate (package) with uniform colour and consistency were assayed. Firmness was expressed in g.

2.2. Microbial analysis and decay incidence

Microbial quality was conducted by mixing (stomacher for 30 s) samples in buffered peptone water (1:10 weight:v ratio). Subsequently, pertinent dilutions in buffered peptone water were made before pour plating in the correspondent agar media for mesophiles (plate count agar), psychrophiles (plate count agar) and enterobacteria (violet red bile dextrose agar), followed by incubation at 31 ºC/48 h, 7 ºC/7 days and 37 ºC/48 h respectively [7]. Results were expressed in colony-forming units (CFU) per sample surface area (cm^2).
The decay incidence was expressed as % of rotten fruits from the total number of fruits.

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

3.1. Firmness

The texture analysis (Figure 1) showed firmness ranges between 250 and 400 g. Samples within active packages showed higher firmness than control packaging. This indicates greater durability of the product, which may be explained by the inhibitory activity of EOs against cell wall degrading enzymes (i.e. polygalacturonase and pectinmethylesterase) as previously observed by our Group in other fruits [11] [12].

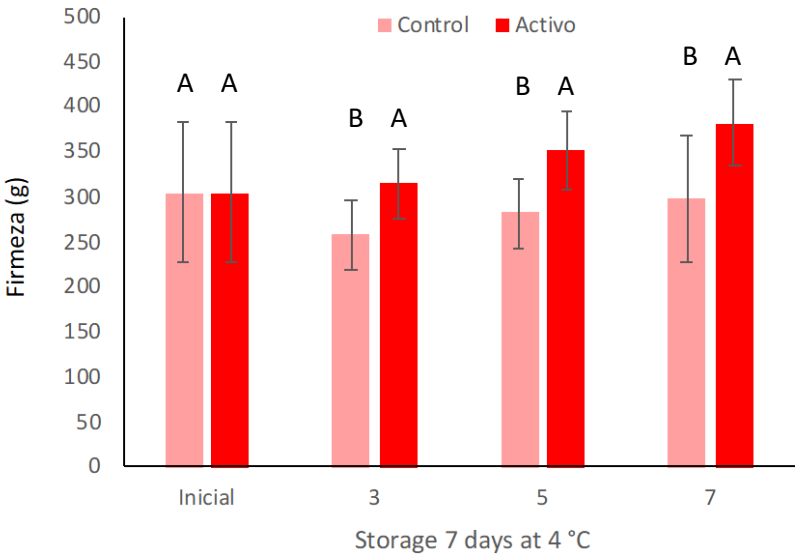

Figure 1. Strawberry firmness after 7 days of conservation at 4 ºC using active and control packaging treatments (mean (n=3) ± SD). Different letters denote significant differences ($p<0.05$) between control and active packaging.

3.2. Microbial analysis

In the case of total mesophilic and psychrophilic aerobic microorganisms (Figure 3), we observed an approximate value of 6 logarithmic units. Between active and control packaging methods, no significant differences were observed for these microorganisms.

Finally, we find the microbial count of moulds and yeasts, where we find ranges between 5 and 6.5 log units. There were significant differences ($p<0.05$) in the case of moulds and yeasts between control and active treatments. There was a difference of approximately 1 CFU Log between the control and the active in the case of moulds. In the case of yeasts, the significant differences were 6.39 and 5.57 log units for the control and active treatments. The values obtained were lower than those obtained by [3].

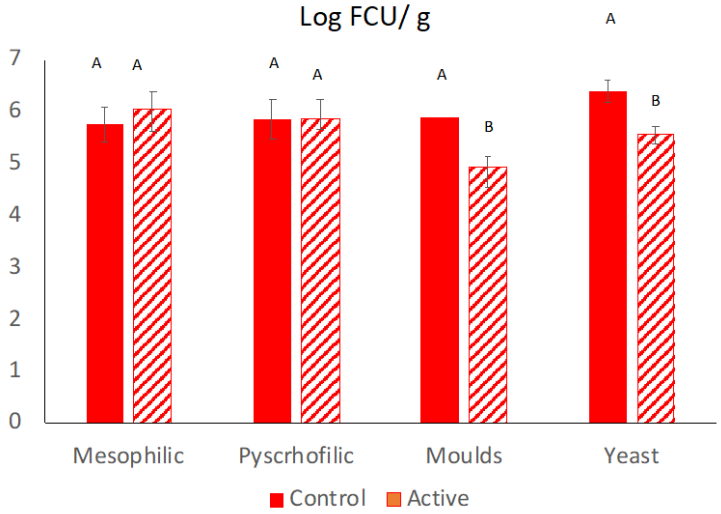

Figure 2. Microbial loads for mesophiles, psychrophiles, moulds and yeasts after 7 days of conservation of strawberries at 4 ºC using active and control packaging treatments (mean (n=3) ± SD). Different letters denote significant differences ($p<0.05$) between control and active packaging.

3.1. Decay incidence

The fruits under the control packaging showed a decay incidence of 18.8% after 7 days, while no rotten fruits were observed within the active packages (Figure 3). Other studies on active packaging with strawberries carried out by [8] demonstrated a lower incidence of mould-related rot using antimicrobial active packaging

with levels of 30% and 8% after 15 days for control and active packaging, respectively. This lower microbial decay incidence may be closely related to the better firmness of samples avoiding leakage of intracellular sugar components that may promote microbial growth.

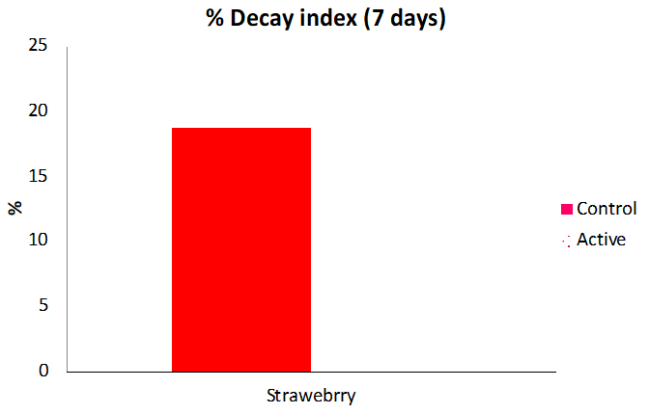

Figure 3. Decay incidence of strawberry after 7 days of conservation at 4 ºC using active and control packaging treatments.

4. CONCLUSIONS

The use of the active packaging highly reduced the decay incidence of strawberries. It was correlated with a better microbial quality of fruits within the active packaging, with markedly lower mould counts compared to control samples. In addition, firmness of samples within the active containers was better preserved during storage. Therefore, it can be concluded that the conservation of strawberries with the EOs active packaging during cold storage preserved the fruit quality.

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