Active packaging to improve the shelf-life and nutritional quality of strawberries

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randomly divided in punnets (8 punnets/treatment). The treatments were:
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Abstract

Strawberries have a high degree of perishability due to their high respiration rates that lead to the loss of organoleptic traits. High sensory quality and microbiological stability are critical factors in maintaining commercial marketability of fresh products. Active packaging systems in combination with modified atmosphere packaging (MAP) is a technology developed to increase the shelf-life of fresh perishable fruits. In particular, antimicrobial packaging is a promising technology to delay the deterioration process of whole or fresh-cut fruit. In this paper, we refer the results of the application of an innovative packaging, Life⁺ systems (ILIP, Italy), on strawberries. The packaging is based on the use of an anti-microbial active absorbent pad (Sirane Group – LTD - UK) associated with an unvented and anti-mist PET punnet, closed with a heat-sealed micro perforated film (Plastopil - Israel). In the study, strawberries were packed with different Life+ system. Two kind of pads, with a different concentration of antimicrobials, were associated with a film having high gas permeability. During the refrigerated storage (6° C, 8 days) atmosphere composition of the pack, color, firmness, nutritional value, overall appearance and microbiological contamination were evaluated. The results indicated that the Life⁺ system packaging has a positive influence on the visual appearance, the organoleptic traits and the weight loss of strawberries. Finally, active packaging reduced the microbial proliferation and the loss of product.

Keywords: berry, post-harvest, modified atmosphere packaging, life⁺, micro performed film

INTRODUCTION

Strawberry is a fruit with a very short postharvest life due to considerable physiological and biochemical changes. Loss of quality in this fruit is mostly due to its high metabolic activity and sensitivity to fungal decay. The lack of a protective rind and the soft texture make strawberries susceptible to water loss, bruising and mechanical injuries. Postharvest losses can reach high percentages during storage period.

To extend the marketing period it is necessary to improve postharvest storage, limiting losses. Modified atmosphere packaging associated with active packaging is a technology developed to increase the shelf life of fresh perishable fruits. Active packaging is a system that involves interactions between the package or its components and food or internal gas atmosphere. Among the different systems, antimicrobial packaging is one of the most promising technology to delay the deterioration process of whole or fresh-cut fruit. In this paper, we refer the results of the application on strawberries of an innovative antimicrobial packaging associated with a modified atmosphere.

MATERIAL AND METHODS

Raw material

The strawberries, cv Marmolada, were handpicked from a commercial orchard in Cuneo province (Piedmont – Italy) at full ripeness and transported to the laboratory within the same day. They were selected according to visual uniformity. Only defect free strawberries were selected.

Active packaging

Two different active packagings (LIFE+, Ilip, Italy) were studied, both containing a pad releasing the active agent. The packaging consisted of an unvented punnet of polyethylene terephthalate (PET) combined with two different pads, ANTB and ANTBM (Sirane Group – LTD - UK) and laser-perforate film Topaz 424 (Plastopil – Israel). The pads act releasing an anti-microbial agent, which inhibits mould and fungal growth. The difference between the two is the concentration of the active agents. The pads are commercial products, and fulfill the requirements of EU and FDA food laws, which define requirements for materials intended to come into contact with food.

The characteristics of the film are the following:

	Thickness (μm)	Ø holes (μ)	OTR (cc/m2/day)	Permeability (cc/m2/day)
Film Topaz 424	32	70	95	4238,92

Treatments

The strawberries were

- T1: Control - traditional commercial packaging (macro-perforated punnets of PET)
- T2: No pad+film
- T3: Pad ANTB+film
- T4: Pad ANTBM+film

300 grams of fruit were placed in each punnet. The heat-sealed and control samples were stored at 6 ° C for 8 days.

Physico-chemical analysis

Some physico-chemical parameters (atmosphere composition, weight loss, color, firmness and Vit. C content) were monitored during storage to evaluate the effect of the active packaging on strawberries.

Headspace concentrations of O_2 and CO_2 of the packages were measured daily during storage using a Check- Point gas analyzer (PBI Dansensor, Italy). Each day and for each treatment three punnets were analyzed. Samples of headspace atmospheres were taken with a syringe through silicone septa positioned above the film. The headspace atmosphere of the punnets, was determined with a paramagnetic sensor for O_2 concentration and an infrared sensor for CO_2 concentration. The instrument has been calibrated towards air. Results were expressed as percentage of O_2 and CO_2 inside the packages.

Weight loss was determined by weighing the numbered punnets of each treatment at the beginning of the experiment and daily during the storage. The values were reported as percentage of weight loss per initial punnets weight.

Color of strawberries was measured individually on 30 fruits per treatment at the beginning of the experiment and then after 8 days of storage. Surface color was analyzed with a Minolta Chroma Meter CR-400 (Konica Minolta, Osaka, Japan). Color was expressed as changes in L* (lightness) and h° (hue angle) during cold storage.

Textural measurements were carried out before and after 8 days of cold storage, on 15 fruits/treatments randomly selected. Before the analysis, samples were warmed to room temperature (20 C°) for 3 h. Fruit firmness was determined using a Texture Analyzer TaxT2i (Stable Micro System, Godalming, UK) as described by Whitaker et al. (2012). The force required to compress the fruit by 3 mm was recorded in N.

The vitamin C content was abalyzed at day 0 and after 8 days of storage according to the methods of Gonzalez Molina et al.. (2008). Fruit flesh (10 g) was homogenized in 10 ml of methanol/water (5:95 v/v) using an Ultra-Turrax T-25 for 3 min. Then, the pH was adjusted to 2.2–2.4, and the extract was filtered through a C18 Sep-Pak cartridge (Waters Associates, Milford, MA, USA). The resultant solution was combined with 1,2-phenylenediamine dihydrochloride (Fluka Chemika,Neu-Ulm, Switzerland) for 37 min before HPLC analysis. Three replicate analyses of 10 fruits were performed for each treatment. The chromatographic system (Agilent) was equipped with a diode array detector and Kinetex-C18 column (4.6 x 150 mm, 5 µm, Phenomenex., Torrance, CA, USA) and controlled through HPLC online software (Agilent). The mobile phase (isocratic) consisted of 50 mM monobasic potassiumphosphate and 5 mM cetrimide (Sigma-Aldrich Corporation, Saint Louis, USA) in methanol:water (v/v) 5:95. The flow rate of 0.9 ml/min. The temperature was 40 °C, and the detector was set at 261 nm for ascorbic acid (AA) and 348 nm for dehydroascorbic acid (DHAA). The vitamin C content (AA and DHAA contents) was expressed as mg*100 g^{-1} of fresh weight.

Visual analysis and Microbiological contamination

Subjective quality evaluation of strawberries was performed every day during 8 days. The quality evaluations (based on color, shriveling and stem freshness) were conducted using a 1 to 5 visual rating scale (Do Nascimento Nunes, 2015).

The incidence of diseased fruits (%) was calculated for each treatment daily.

Statistical analysis

Data were analyzed by the analysis of variance, using statistical procedures of the STATISTICA ver. 6.0 (Statsoft Inc., Tulsa, OK).The sources of variance are treatments and storage. Tukey's HSP test (honest significant differences) was used to determine significant differences amongst treatment means. Mean values were considered significantly different at $p < 0.05$.

RESULTS

Changes in O_2 and CO_2 within packages

Without filling any other gas, the atmosphere in the package depended on the gas permeability of packaging material and the respiration of strawberries. The changes in O_2 and CO_2 within packages during storage are displayed in Figure 1. In the first hours of product storage, the respiration rate is high due to the greater amount of O_2 available for fruits. In this study the O_2 concentration decreased from 20.9% to 13.2%, 15% and 14.8% in T2, T3 and T4 respectively after 2 days of storage. After 3 days of storage, the values remained almost stable due to a reached respiration rate equilibrium. Among treatments, the T3 packages showed the highest O_2 concentration (14%) at the end of storage (8 days).

Meanwhile, CO_2 content showed an opposite changing pattern. The CO_2 concentration increased quickly in the first two days of storage and then slowly until the end of storage. Among treatments, the lowest CO_2 accumulation during storage period was detected in T3 samples. This result was probably related to the inhibitory effect on fruits respiration of pad ANTB.

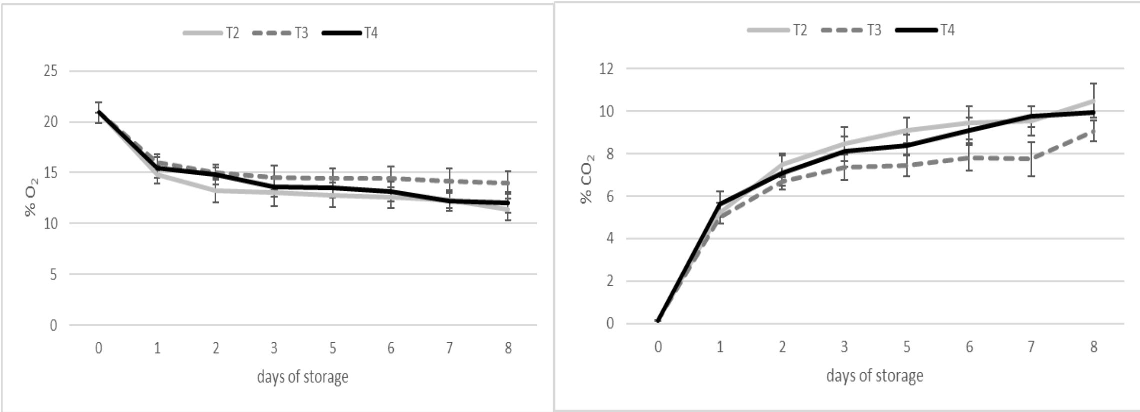

Fig. 1. Effect of pad application in combination with MAP on oxygen and carbon dioxide concentration (%) (means of three replicates ± S.D.) of strawberries during storage at 6°C. No pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4).

Weight loss

Weight loss of fresh produce is an important parameter because it leads to economic losses. Weight loss of strawberries packed in MAP is shown in Table 1. Pad application and MAP affected weight loss during 8 days of storage at 6°C. Significant differences ($P < 0.05$) in weight loss were observed among the MAP treatments (T2, T3 and T4) and traditional commercial packaging (T1) during all the storage period. The strawberries in MAP lost very little weight during storage, approximately 0.09% compared to the weight loss of the traditional commercial packaging that was about 3.74% at the end of storage. The reason for the considerable water loss is dehydration that could be limited by storage in a MAP, according to our results and other studies (Nielsen and Leufven, 2008; Fu et al., 2015; Mohammadi and Hanafi, 2014).

Table 1. Effect of pad application in combination with MAP on weight loss (%) (means of three replicates ± S.D.) of strawberries during storage at 6°C. Traditional commercial packaging (T1); no pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4). Mean in the same column with different letters are significantly different ($p \leq 0.05$).

treatments	days of storage					
	1	2	3	5	6	7	8
T1	0.8 ± 0.1^{A}	1.05 ± 0.5^{A}	1.27 ± 0.8^{A}	1.86 ± 0.5^{A}	2.32 ± 0.3^{A}	3.12 ± 0.4^{A}	3.74 ± 0.6^{A}
T2	0^{B}	0.01 ± 0.01^{B}	0.03 ± 0.01^{B}	0.05 ± 0.01^{B}	0.08 ± 0.02^{B}	0.08 ± 0.03^{B}	0.09 ± 0.02^{B}
T3	0^{B}	0.01 ± 0.01^{B}	0.03 ± 0.01^{B}	0.04 ± 0.01^{B}	0.07 ± 0.03^{B}	0.08 ± 0.02^{B}	0.08 ± 0.01^{B}
T4	0.01 ± 0.03^{B}	0.02 ± 0.01^{B}	0.02 ± 0.02^{B}	0.05 ± 0.02^{B}	0.06 ± 0.01^{B}	0.07 ± 0.01^{B}	0.09 ± 0.02^{B}

Color

Color is one of the most important parameter of quality in the marketing of strawberry. Changes in the skin color of the control and MAP strawberries were evaluated measuring the lightness (L*) and hue angle (h°) (Tab. 2). At the end of storage, the control and MAP samples showed significant lower lightness values of the skin ($p < 0.05$). Among treatments, the use of MAP packaging has a positive impact on strawberries lightness, with significant higher L* values of MAP strawberries compared to control sample.

The hue angle value significantly increased in all treatments during the storage. After 8 days it was possible to detect differences among treatments, in particular T1 and T2 samples had dark red fruits while the remaining treatments had brilliant red fruits. The parameter was also positively influenced by the action of the active packaging.

Table 2. Effect of pad application in combination with MAP on lightness (L*) and Hue angle (h°) (means of 30 replicates ± S.D.) of strawberries during storage at 6°C. Traditional commercial packaging (T1); no pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4). Means sharing the same letters in rows (A, B, C) and in column (a, b, c) are not significantly different from each other (Tukey's HSD test, $p \leqslant 0.05$).

	Treatments	day 0	day 8
(L*)	T1	37.41 ± 2.85^{A}	29.55 ± 1.84^{bB}
	T2	37.41 ± 2.85^{A}	32.32 ± 2.14^{aB}
	T3	37.41 ± 2.85^{A}	32.09 ± 1.93^{aB}
	T4	37.41 ± 2.85^{A}	31.66 ± 2.52^{aB}
(h°)	T1	26.36 ± 4.23^{B}	28.82 ± 2.10^{bA}
	T2	26.36 ± 4.23^{B}	$29.67 \pm 3.38a^{bA}$
	T3	26.36 ± 4.23^{B}	$30.26 \pm 2.78a^{bA}$
	T4	26.36 ± 4.23^{B}	30.93 ± 3.45^{aA}

Firmness

Table 3. Effect of pad application in combination with MAP on firmness (N) (means of 30 replicates ± S.D.) of strawberries during storage at 6°C. Traditional commercial packaging (T1); no pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4). Means sharing the same letters in rows (A, B, C) and in column (a, b, c) are not significantly different from each other (Tukey's HSD test, $p \leqslant 0.05$).

	Treatments	day 0	day 8
(N)	T1	6.64 ± 1.38^{A}	2.55 ± 0.62^{bB}
	T2	6.64 ± 1.38^{A}	3.4 ± 0.56^{aB}
	T3	6.64 ± 1.38^{A}	3.16 ± 0.94^{abB}
	T4	6.64 ± 1.38^{A}	2.98 ± 0.66^{abB}

Flesh firmness is one of the most important parameters to be preserved during storage. Strawberries are soft fruits which firmness decrease very quickly during postharvest (Tab. 3). In this work, loss of firmness was observed in all treatments and, at the end of the storage period, the firmness was significantly lower than at the start in all samples. Moreover, there were differences among treatments. In control samples (T1) was observed the lower flesh firmness, while in T2 the highest. There was no statistic differences between the two pads. So, on this parameter, the MAP has been more effective than the pads.

Vitamin C content

The ascorbic acid of fruits is one of their most important nutrient quality parameters, but it is known to be highly perishable (Oz, 2010). In this work, over the storage period, the ascorbic acid content was on a decreasing trend (Tab. 4). Losses of vitamin C in control and film samples were significant. On the contrary, in samples storage with pad, no significant differences were noticed during storage. In this case, pad can help to reduce vitamin C losses. Such results might be attributed to better modification of the atmosphere inside the packages+pad respect to the O_2 concentration (Agrahari et al., 2001). This might be due to the oxidation and irreversible conversion of ascorbic acid to dehydroascorbic; similar results were also obtained in previous works (Kirad et al., 2007, Panda et al., 2017).

Table 4. Effect of pad application in combination with MAP on vitamin C content ($mg*100g^{-1}FW$) (means of 3 replicates ± S.D.) of strawberries during storage at 6°C. Traditional commercial packaging (T1); no pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4). Means sharing the same letters in rows (A, B, C) and in column (a, b, c) are not significantly different from each other (Tukey's HSD test, $p \leqslant 0.05$).

	Treatments	day 0	day 8
mg VitC *100 g^{-1} FW	T1	52.77 ± 5.63^{A}	42.25 ± 3.11^{aB}
	T2	52.77 ± 5.63^{A}	43.84 ± 2.45^{aB}
	T3	52.77 ± 5.63^{A}	46.18 ± 1.62^{aA}
	T4	52.77 ± 5.63^{A}	46.23 ± 2.29^{aA}

Visual quality

The visual quality of all strawberry samples decreased during storage (Tab. 5). Based on the strawberry chart of do Nascimento Nunes (2015), MAP samples (T2, T3, T4) showed bright and glossy red color, stiff and green calyx, no signs of bruising or shriveling and the fruits appeared very fresh until the third storage day. Then the visual quality decreased particularly in T2 samples. After 8 days of storage, the higher visual quality attributes were found in T3 samples (MAP+pad ANTB), in this case the strawberries appeared dark colored with slight loss of brightness and glossiness, but overall with an acceptable quality. Therefore, the use of this combination MAP+pad ANTB improves the visual quality of strawberries during storage.

On the contrary, in T1 sample the strawberries visual quality decreased faster, compared to other treatments and was still acceptable only for 6 days of storage. At the end of storage period, T1 strawberries appeared very dark with the calyx dry and wilted, fruits were very soft, overripe and dry (poor to very poor quality, not salable).

Table 5. Effect of pad application in combination with MAP on visual quality of strawberries during storage at 6°C. Traditional commercial packaging (T1); no pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4).

Treatments	days of storage							
	0	1	2	3	5	6	7	8
T1	5,0	4,5	4,5	3,5	3,0	2,5	1,5	1,5
T2	5,0	5,0	5,0	5,0	4,0	3,5	3,0	2,5
T3	5,0	5,0	5,0	5,0	4,5	3,5	3,0	3,0
T4	5,0	5,0	5,0	5,0	4,5	3,5	3,0	2,5

Diseases incidence

Diseases occurred from the fifth day of storage in T1 samples and there has been a continuous increase up to the term of the storage (Fig. 2). No diseases were observed in the other treatments until the seventh day when some occurred in T2 samples. At the end of the storage, diseases were releveled in all treatments, but the incidence was very different, ANTB and ANTBM made to record the lower percentages, meaning that the antimicrobial pads were effective to reduce the fruit loss. On the contrary, the only MAP was not enough effective to control decays. Moreover, if the total incidence of diseases is considered, T1 samples are these with the greatest discard.

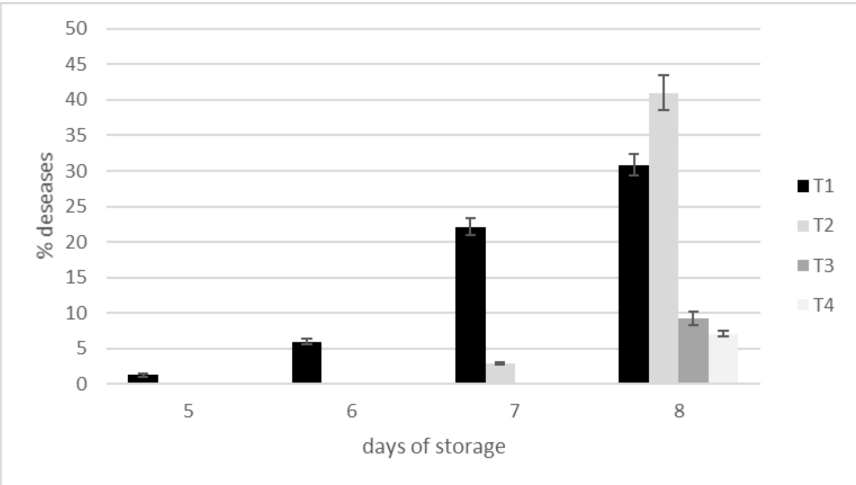

Fig. 2. Effect of pad application in combination with MAP on disease incidence (%) (means of three replicates ± S.D.) of strawberries during storage at 6°C. Traditional commercial packaging (T1); no pad + film (T2); pad ANTB + film (T3); pad ANTBM + film (T4).

CONCLUSION

The storage temperature (6°C) chosen in this trial is the most frequently found in strawberries supply-chain. The packaging Life$^+$ system, used at this temperature condition, showed to be useful to preserve strawberries quality for 8 days. In particular, there was a positive effect on weight loss, visual appearance, organoleptic traits and diseases incidences. The MAP not associated with active pad had a positive effect on some parameters (weight loss, firmness, color) but was not effective in preserving fruit from decay.

ACKNOWLEDGEMENTS

Work supported by ILIP S.r.l. (Italy). The authors thank Dr. Luigi Garavaglia for technical assistance.

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