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New active packaging for improving the shelf life and quality of tomato

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Abstract: Packaging materials play an important role in the quality preservation during postharvest storage and shelf life of fruits and vegetables. The properties of film can affect the gas composition and the physiology of the products. The Group Research Labs of SAES Getters S.p.A. have developed, in collaboration with its affiliate company SAES Coated Films S.p.A. a packaging system highly selective for ethylene, including a coating (1-2 µm), with good transparency and an additional anti-fog function, which can be deposited on various plastic films. The objective of the work was the evaluation of this new active packaging on 'cherry' type tomato berries during storage. The control consisted of a macro-perforated polypropylene film used for flow-pack packaging. Two experimental tests were conducted, the first during cold storage (10 ± 2°C) and the second at room temperature (22 ± 2°C). The analyses included visual appearance, weight loss, gas exchanges, relative humidity, volatile organic compounds (VOC), colour, titratable acidity, refractometric index (° Brix) and the concentration of lycopene and β-carotene. The use of the innovative packaging did not alter the main quality indicators of the tomato and the parameter that had the greatest impact on the product metabolism was the storage temperature. The VOC concentration was influenced by packaging, with a greater accumulation in the samples packed with active packaging compared to the control. Moreover, the same material determined a reduction in weight loss, a greater accumulation of CO_2 and a significant reduction in O_2, especially at 22°C. At the end of the storage, the berries stored in the active packaging showed higher levels of lycopene, compared to controls, and a reduction in β-carotene, indicating an active role of the material in modulating the content of bioactive compounds in the fruits. It can be concluded that the use of this innovative material can represent an effective tool for improving the postharvest management of tomato berries.

1. Introduction

The preservation of produce quality during postharvest depends on the packaging materials and storage conditions. The postharvest performance of produce is affected by pre-harvest factors and quality at harvest (Sharma *et al.*, 2014; Tyagi *et al.*, 2017). It is well known that quality is obtained in the field and depends on growers choices and agronomic management. Nevertheless, postharvest stresses can induce different transcriptional and metabolic changes that may accelerate the senescence processes (Cavaiuolo *et al.*, 2017). During storage the products are still considered as living organs or tissues, thus their metabolism must be maintained active. Sugar content in the produce plays an important role for keeping the basal metabolism after harvest and higher sugar concentrations can allow longer shelf life, without compromise the quality. The main physiological processes that are associated with the postharvest performance are respiration rate and ethylene production (Colelli and Elia, 2009). Ethylene plays an important role in climacteric fruits and its effect depends on tissue sensitivity. In the most of climacteric products, lowering both processes, respiration and ethylene production greatly extend the storage and shelf life of the produce. Tomato (*Solanum lycopersicum* L.) is one of the most important products in the fresh vegetables market, particularly relevant in Italy, which is the first producer in Europe and among the ten most important producing countries in the world (Faostat, 2018). On a biological point of view, tomato is a climacteric fruit which has been widely studied as a model fruit for the production and sensitivity to ethylene accompanied by the characteristic rise in the respiratory rate during ripening. On a practical point of view, tomato berries are considered as a perishable product which can be easily subjected to quality loss during storage and shelf life, mainly because of the ethylene production and rise in respiration. For these reasons, innovative solutions and suitable packaging systems able to extend storability and shelf life of fresh produce with high transpiration rates such as tomato are needed (Agudelo-Rodriguez *et al.*, 2020). In fact, the packaging materials can play an important role in regulating gas exchanges between the environment and produce. The combination of gas modulation and optimal storage temperature can greatly extend the shelf life of produce (Fagundes *et al.*, 2015). Today, different solutions are available on the market for the preservation of fruit and vegetables using active packaging, with very different principles of action and effectiveness. The chemical and physical properties of the packaging materials can provide a barrier modifying the gas composition in the headspace or around the produce (Exama *et al.*, 1993). The gas composition of headspace in the boxes or in bags depends from the film gas permeability and produce respiration and ethylene production rates. Therefore, the film gas permeability and product physiology define the gas composition that both are affected by the storage temperature (Mangaraj *et al.*, 2009). In order to improve the film properties different materials can be added during the film extrusion or can be applied in one side of it. A good packaging film must keep its proprieties at different intervals of temperature, but especially at the low temperatures (Exama *et al.*, 1992). The packaging materials can help in reducing the water losses by reducing the transpiration and can also reduce the weight losses. These are key factors for the commercial quality of stored horticultural products. The barrier effect of the film can passively reduce the oxygen concentration and increase the carbon dioxide inside the package. The modification of the inner atmosphere by the action of the packaging material is also known as modified atmosphere packaging (MAP). MAP reduces respiration and ethylene production, thus is widely applied in the postharvest management of various fruits and vegetables. However, it is important to avoid hypoxic conditions that would derive from the oxygen depletion inside the package. This would result in the development of off-odours due to the triggering of a fermentative metabolism. Several additives can be included into the packaging film with various functions including the reduction of condensation (anti-fog additives) or the removal of specific gases such as ethylene. There are several ethylene absorbers that can be used for removing or reducing the concentration of this important plant hormone inside the packaging (Álvarez-Hernández *et al.*, 2018).

The Group Research Labs of SAES Getters S.p.A. have developed, in collaboration with SAES Coated Films S.p.A., and its affiliate company, a highly selective packaging system for ethylene, including an integrated absorber in the form of a coating (1-2 µm), with good transparency and an additional anti-fog function, which can be deposited on various plastic films.

The aim of this work was to evaluate the efficacy of this new film in improving the shelf life of tomato berries during shelf life.

2. Materials and Methods

Plant material and storage conditions

The experiment was conducted on tomato fruits (*Solanum lycopersicum* L. var. *cerasiforme*). Freshly harvested berries were selected based on uniformity in size and lack of defects, which were estimated by a visual evaluation. Moreover, the colour uniformity was assured by selecting berries which showed similar hue and chroma values, which were measure by a colorimeter (for more details, see section "Fruit colour measurements"). Around 250 g of fruits were randomly divided into plastic punnets which were immediately flow packed with an automated flow packaging machine provided by SAES Getters S.p.A. Two distinct materials were used, a conventional macro perforated plastic film (control) and an innovative, highly selective active packaging system, characterized by a good transparency and an enriched with anti-fog additives and including an integrated ethylene absorber in the form of a coating (1-2 µm) (2DAF) (International Patent Application n° PCT/IB2016/050401, in the name of SAES Getters S.p.A.).

Punnets were then divided into two groups and placed in storage rooms (72 ± 2 RH%) maintained at 10 ± 2°C (optimal storage conditions) and 22 ± 2°C (sub-optimal storage conditions) for up to 13 days. Three punnets for each temperature/film were used. Sampling was performed after 1, 3, 6, 8, 10 and 13 days of storage.

Analysis of gas composition

At each timepoint gas composition within the punnets was performed by using the F-950 Three Gas Analyzer (Felix Instruments, Settle, USA). This instrument allowed measuring the concentration of oxygen (% O_2), carbon dioxide (% CO_2) as well as the pool of volatile organic compounds (ppm VOCs) including ethylene, esters and alcohols. Moreover, this instrument provides the value of relative humidity of the atmosphere analysed. Each punnet was transferred to 20°C for 30 minutes to equilibrate, before the analysis.

Weight loss estimation and sampling

At each time point, the fruit net weight within each punnet was measured with a laboratory scale (FZ500i digital milligram balance, A&D Company, Ltd., Japan).

Fruit colour measurement

At each time point, lightness (L*), hue angle (H=arctan(b*/a*) and chroma (C*= sqrt (a*²+b*²)) values were measured with a Minolta Chroma meter (CR-300 with an 8-mm aperture) calibrated against a standard white tile. Each record was reported as average of six measurements taken from six fruit.

Titratable acidity and total soluble solids content

Titratable acidity (TA) and total soluble solids (TSS) were measured from the juice squeezed from four fruits. TA was determined by titration of 5 g of juice with 0.1 N sodium hydroxide to a pH end point of 8.1, results are expressed as % citric acid. Titration was performed using a Titrator Compact G10S (Mettler, Toledo, USA). TSS were estimated using a portable digital (model 53011, Turoni, Italy) and results were expressed as °Brix.

β-carotene and lycopene determination

Tomato (four fruits) fruits were ground and juices were analysed for lycopene content using the spectrophotometric method adapted from Anthon and Barrett (2007). The lipophilic fraction of the juice was extracted and separated with a solution of hexane ethanol and acetone (2:1:1 v/v), the phases were separated, and the hexane phase was read at 503 nm. Pigments concentrations were expressed in mg Kg^{-1} on fresh weight (FW) basis.

Statistical analysis

All data were subjected to a one-way ANOVA followed by Sidak's multiple comparisons test. Statistics were performed using GraphPad Prism version 6 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com.

3. Results

Weight losses and gas composition inside the packages

In general, the tomato berries did not show much variations in weight during storage under the tested conditions. Only few changes were observed in 2DAF-storaged fruits, which showed higher weights compared to control fruits after 8 days at 10°C and after 13 days at 22°C (Fig. 1A, 1B).

Gas composition inside the packages was primarily affected by temperature and then by the material used. In fact, even if samples stored in the 2DAF film accumulated higher concentrations of CO_2 and consumed more O_2 compared to control samples, at 10°C these differences were not significant (Fig. 2A, 2C). At 22°C instead a strong decrement in O_2 and a progressive accumulation of CO_2, were observed. The minimum O_2 levels was reached after 8 days of storage, while the maximum peak of CO_2 was recorded after 10 days at 22°C (Fig. 2B, 2D).

As observed for respiratory gases, the relative

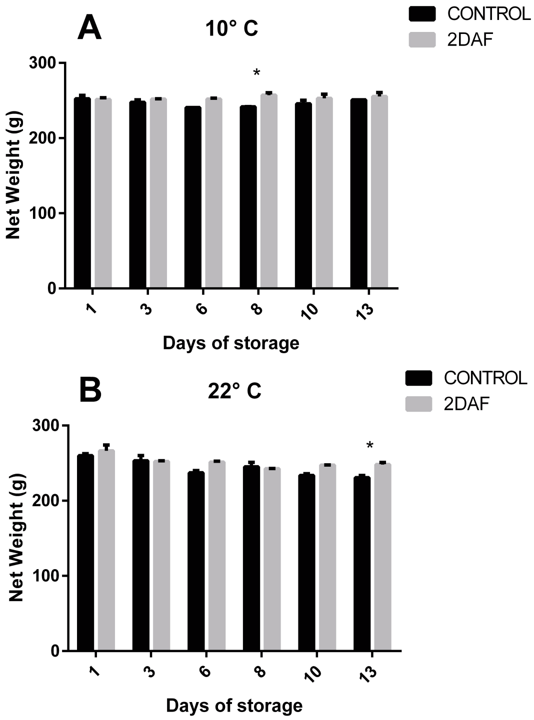

Fig. 1 - Tomato berries weight as affected by packaging material during storage at 10°C (A) and 22°C (B). Asterisks indicate significant differences between 2DAF and control *P<0.05; **P<0.01; ***P<0.001; ***P<0.0001; n=3.

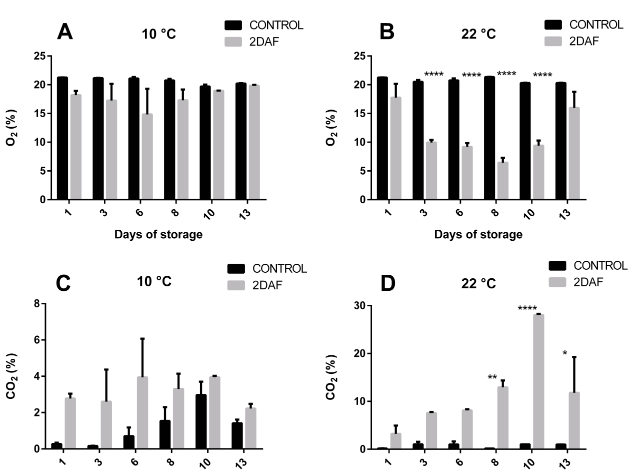

Fig. 2 - Changes in oxygen (A, B) and carbon dioxide (C, D) concentrations inside the packages, as affected by packaging material and storage temperature. Asterisks indicate significant differences between 2DAF and control *P<0.05; **P<0.01; ***P<0.001; ***P<0.0001; n=3.

humidity was affected by temperature. At 10°C no changes were observed between the two films (Fig. 3A), while at 22°C control packages accumulated a higher humidity in the inner atmosphere. These changes in comparison to 2DAF, were highly significant after 1 day of storage and significant (*P<0.05*) after 10 days (Fig. 3 B).

The accumulation of volatile organic compounds (VOCs) in control packages was limited and tent to fade during storage at both temperatures. On the other hand, the use of 2DAF allowed a more marked rise in VOCs concentration inside the headspace. VOCs maximum concentration was observed after 6 days at 10°C and after 8 days at 22°C. The highest concentration of VOCs was almost 7-fold higher at 22°C compared to the maximum concentration at 10°C (Fig. 3 C, 3D).

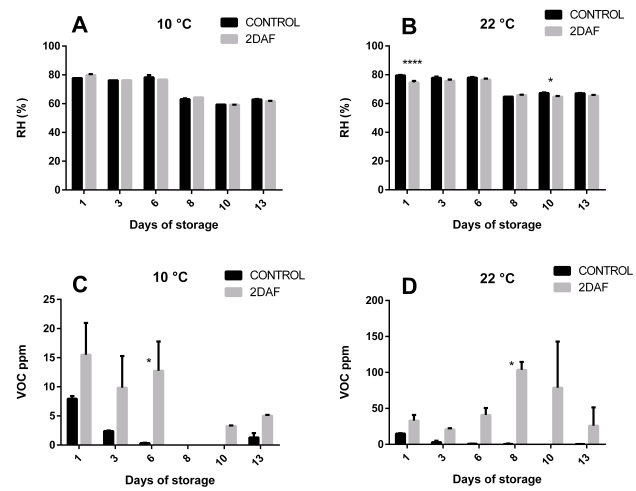

Fig. 3 - Changes in relative humidity (A, B) and volatile organic compounds (C, D) concentrations inside the packages, as affected by packaging material and storage temperature. Asterisks indicate significant differences between 2DAF and control *P<0.05; **P<0.01; ***P<0.001; ***P<0.0001; n=3.

Titratable acidity, total soluble solids, and fruit colour

Quality attributes of tomato berries were slightly affected by storage and packaging material. Titratable acidity was higher in control berries after 3 days of storage at 10°C, while at the other time points as well as at 22°C, no significant changes were observed between control and 2DAF-stored fruits (Fig. 4 A , 4 B).

Sugar concentration of tomatoes showed only few changes in fruits stored at 10°C, which, after 3 and 8 days showed higher °Brix values when packed in the 2DAF film (Fig. 4C, 4D).

No marked changes in colour were observed, with only two exceptions regarding 2DAF-stored berries, which showed significantly higher lightness and hue angle values after 10 days at 22°C (Fig. 5 A-F).

Fruit carotenoid concentrations

Both β-carotene and lycopene levels were quite stable during storage, however, it seems that the dif-

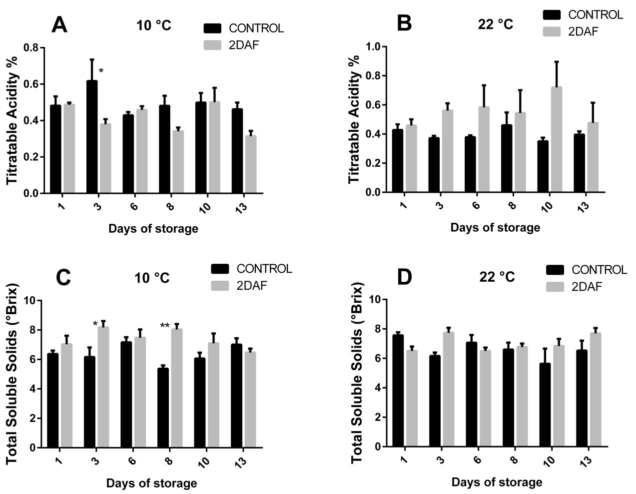

Fig. 4 - Changes in titratable acidity (A, B) and total soluble solids content (C, D) in tomato berries, as affected by packaging material and storage temperature. Asterisks indicate significant differences between 2DAF and control *P<0.05; **P<0.01; ***P<0.001; ***P<0.0001; n=4.

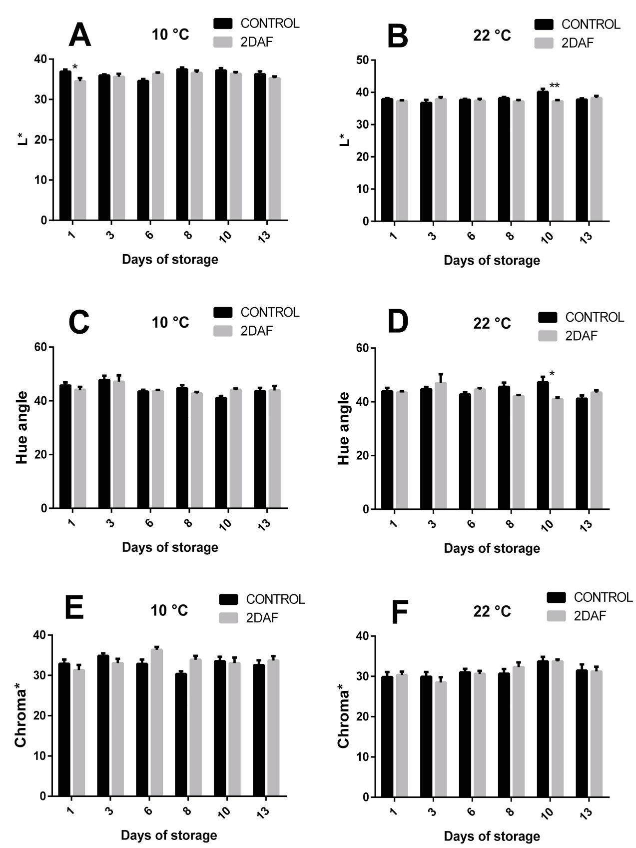

Fig. 5 - Changes in colour coordinate: lightness (A, B), hue angle (C, D) and chroma (E, F) measured on tomato berry skin, as affected by packaging material and storage temperature. Asterisks indicate significant differences between 2DAF and control *P<0.05; **P<0.01; ***P<0.001; ***P<0.0001; n=6.

ferent packaging used affected the accumulation these pigments, which were generally higher in 2DAF-stored samples. β-carotene concentration was significantly higher in 2DAF-stored samples after 8 days at both 10°C and 22°C (Fig. 6 A, 6B), while lycopene was significantly higher in the same packaging conditions, after 3 and 8 days at 10 °C and at the end of storage at 22°C (Fig. 6 C, 6D).

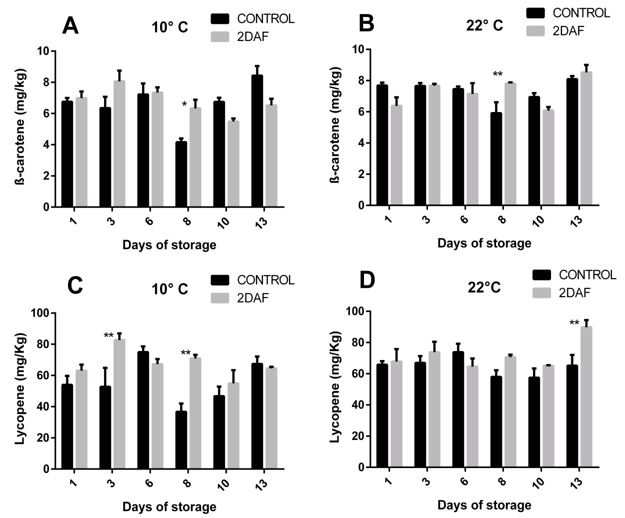

Fig. 6 - Changes β-carotene (A, B) and lycopene (C, D) concentration in tomato berries, as affected by packaging material and storage temperature. Asterisks indicate significant differences between 2DAF and control *P<0.05; **P<0.01; ***P<0.001; ***P<0.0001; n=4.

4. Discussion and Conclusions

The use of MAP has led to a significant improvement of storage management of various horticultural products in the last years (Arah *et al.*, 2016). Tomato is highly appreciated worldwide for its characteristic sensorial properties and for its nutraceutical value, mainly due to the presence of carotenoid pigments including β-carotene and lycopene as the most representative (Frusciante *et al.*, 2007). The experiment described in this paper helped in elucidating the effect of an innovative packaging solution in comparison to a traditionally adopted microperforated plastic film during storage at two temperatures. It is also important to consider that tomato is chilling sensitive and low temperature can induce injury and reduce the quality. The identification of adequate film gas permeability can extend the storability of tomato and preserving the fruit quality (Fagundes *et al.*, 2015).

As first consideration it is important to notice that none of the considered storage conditions determined a marked weight loss, thus it is possible to assume that there were no marked changes in the water content of berries. This last aspect has been considered when evaluating all the parameters which have been assayed on fresh weight bases. Different storage conditions, together with genetic variability can affect the respiration of the produce during storage and shelf life (Colelli and Elia, 2009). Among the possible factors affecting the accumulation of O_2 and CO_2 inside the punnets, temperature was the most effective. It is possible that the lowest storage temperature (10°C) determined a decrease in the fruit metabolism and thus no significant changes were observed. On the other hand, the higher storage temperature (22°C) can be considered as optimal for several metabolic activities (Maul *et al.*, 2000). In this context, the effect of the different packaging was evident, with a more pronounced O_2 decrement accompanied to a progressive accumulation of CO_2 into the headspace, due to the respiratory activity of fruits. It is also to be considered that the control reference film was macro-perforated, thus it was expected to have a very/no low barrier effect toward gases. Nevertheless, it is interesting to notice that punnets wrapped in the control film accumulated higher humidity compared to those packed with the 2DAF film. High relative humidity is not recommendable because even though it can help in preventing the water loss, it could facilitate fungal development (Paull, 1999).

As for gases and relative humidity, the production and accumulation of VOCs was first influenced by storage temperature and then by the packaging film. Tomato aroma and flavour are characterized by a complex pool of volatile organic compounds (Krumbein and Auerswald, 1998). The approach adopted in this trial allowed us estimating the total concentration of volatiles in a simple, non-invasive and rapid way. As a drawback, it did not permit the identification of the single classes of molecules which could include, ethylene, esters and alcohols, among others. However, it is interesting to notice that punnets packed in the 2DAF film accumulated significantly higher amounts of VOCs, especially at the highest temperature of storage. It is well known that at low temperature the volatiles release from tomato fruits is limited due to the reduced metabolic activity and volatility of the molecules (Spadafora *et al.*, 2019). Also, the alteration of the gas composition in the atmosphere surrounding the product can induce the production of specific volatile metabolites (Rowan, 2011). This finding suggests the possibility to modulate the sensory properties of tomato in the postharvest phase, by selecting proper packaging strategies which allow accumulating/maintaining higher concentrations of quality-related volatiles. The sensory properties of tomato fruits are generally evaluated in terms of soluble solids content and acidity (Beckles, 2012). These two parameters (and the balance between them) are important determinants of tomato quality and consumers acceptance. Apparently, the conditions adopted in this trial were not effective in altering the acidity in a significant manner, although it was higher in cold stored control sample after 3 days. Majidi and colleagues (2014) reported that tomato fruit stored in MAP had significantly higher total soluble solids than those stored at the same temperature (13°C) without MAP. Similarly, in the present study, the combination of low temperature (10°C) and passive MAP, determined an increment in total soluble solids in the central phase of the storage period.

Even if few differences were found, the colour-related indexes did not change markedly in response to the packaging conditions. This was expected, because the tomatoes used in this trial were fully ripe, so the skin colouration was completely developed and uniform at the beginning of the storage. Also, the storage lasted up to 13 days, and in this time frame it is not common to observe marked colour alterations of tomato skin (Rosati *et al.*, 2000; Heredia *et al.*, 2009). On the other hand, significant changes involved the pigments composition of berries. It has been shown that berries lycopene and β-carotene content is not always well correlated with colour indexes, especially during storage (Pék *et al.*, 2010). Some connection can be hypothesized instead, between carotenoids and VOCs. In fact, some low molecular weight organic compounds derive from carotenoids catabolism (Perveen *et al.*, 2015), thus the use of the active packaging could have determined a change in the carotenoid metabolism leading to the coordinate increment of carotenoids and VOCs between 6 and 8 days of storage, as suggested by the results obtained. It has been previously observed that during postharvest, tomato fruits showed an increment in the levels of some important volatile compounds such as heptane and hexanal, and this increment was in line with highest β-carotene and lycopene concentrations in berries. The connection between carotenoids and VOCs was also observed since 6-methyl 5-hepten-2-one, a carotenoid-derived volatile compound, increased in fruits during storage (Franzoni *et al.*, 2018). This aspect worth to be further investigated as involves both the sensory and nutraceutical properties of fruits.

Considering the results obtained, it can be concluded that the use of this innovative material can represent an effective tool for improving the postharvest management of tomato berries.

References

AGUDELO-RODRÍGUEZ G., MONCAYO-MARTÍNEZ D., CASTELLANOS D.A., 2020 - *Evaluation of a predictive model to configure an active packaging with moisture adsorption for fresh tomato.* - Food Packag. Shelf Life, 23: *100458.*

ÁLVAREZ-HERNÁNDEZ M.H., ARTÉS-HERNÁNDEZ F., ÁVALOS-BELMONTES F., CASTILLO-CAMPOHERMOSO M.A., CONTRERAS-ESQUIVEL J.C., VENTURA-SOBREVILLA J.M., MARTÍNEZ-HERNÁNDEZ G.B., 2018 - *Current scenario of adsorbent materials used in ethylene scavenging systems to extend fruit and vegetable postharvest life.* - Food Bioproc. Tech., 11(3): 511-525.

ANTHON G., BARRETT D.M., 2007 - *Standardization of a rapid spectrophotometric method for lycopene analysis*. - Acta Horticulturae, 758: 111-128.

ARAH I.K., AHORBO G.K., ANKU E.K., KUMAH E.K., AMAGLO H., 2016 - *Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review.* - Adv. Agric., 2016: 1-8.

BECKLES D.M., 2012 - *Factors affecting the postharvest soluble solids and sugar content of tomato* (Solanum lycopersicum L.) *fruit*. - Postharvest Biol. Technol., 63(1), 129-140.

CAVAIUOLO M., COCETTA G., SPADAFORA N.D., MÜLLER C.T., ROGERS H.J., FERRANTE A., 2017 - *Gene expression analysis of rocket salad under pre-harvest and postharvest stresses: A transcriptomic resource for* Diplotaxis tenuifolia. - PloS one, 12(5): e0178119.

COLELLI G., ELIA A., 2009 - *Physiological and technological aspects of fresh-cut horticultural products.* - Italus Hortus, 16(1): 55-78.

EXAMA A., ARUL J., LENCKI R., LI, Z., 1992 - *Suitability of various plastic films for modified atmosphere packaging of fruits and vegetables: gas transfer properties and effect of temperature fluctuation*. - Acta Horticulturae, 343: 175-180.

EXAMA A., ARUL J., LENCKI R.W., LEE L.Z., TOUPIN C., 1993 - *Suitability of plastic films for modified atmosphere packaging of fruits and vegetables.* - J. Food Sci., 58(6): 1365-1370.

FAGUNDES C., MORAES K., PÉREZ-GAGO M.B., PALOU L., MARASCHIN M., MONTEIRO A.R., 2015 - *Effect of active modified atmosphere and cold storage on the postharvest quality of cherry tomatoes.* - Postharvest Biol. Technol., 109: 73-81.

FRANZONI G., COCETTA G., TRIVELLINI A., ANGELI S., FERRANTE A., 2018 - *Abscisic acid and carotenoids metabolism in tomato during postharvest*. - Acta Horticulturae, 1194: 381-388.

FRUSCIANTE L., CARLI P., ERCOLANO M.R., PERNICE R., DI MATTEO A., FOGLIANO V., PELLEGRINI N., 2007 - *Antioxidant nutritional quality of tomato.* - Mol. Nutr. Food Res., 51(5): 609-617.

HEREDIA A., PEINADO I., BARRERA C., GRAU A.A., 2009 - *Influence of process variables on colour changes, carotenoids retention and cellular tissue alteration of cherry tomato during osmotic dehydration.* - J. Food Compos. Anal., 22(4): 285-294.

KRUMBEIN A., AUERSWALD H., 1998 - *Characterization of aroma volatiles in tomatoes by sensory analyses.* - Food, 42(06): 395-399.

MAJIDI H., MINAEI S., ALMASSI M., MOSTOFI Y., 2014 - *Tomato quality in controlled atmosphere storage, modified atmosphere packaging and cold storage.* - J. Food Sci. Technol., 51(9): 2155-2161.

MANGARAJ S., GOSWAMI T.K., MAHAJAN P.V., 2009 - *Applications of plastic films for modified atmosphere packaging of fruits and vegetables: a review.* - Food Eng. Rev., 1(2): 133.

MAUL F., SARGENT S.A., SIMS C.A., BALDWIN E.A., BALABAN M.O., HUBER D.J., 2000 - *Tomato flavor and aroma quality as affected by storage temperature.* - J. Food Sci., 65(7): 1228-1237.

PAULL R., 1999 - *Effect of temperature and relative humidity on fresh commodity quality*. Postharvest Biol. Technol., 15(3): 263-277.

PÉK Z., HELYES L., LUGASI A., 2010 - *Color changes and antioxidant content of vine and postharvest-ripened tomato fruits.* - HortScience, 45(3), 466-468.

PERVEEN R., SULERIA H.A.R., ANJUM F.M., BUTT M.S., PASHA I., AHMAD S., 2015 - *Tomato (*Solanum lycopersicum*) carotenoids and lycopenes chemistry; metabolism, absorption, nutrition, and allied health claims. A comprehensive review.* - Crit. Rev. Food Sci. Nutr., 55(7): 919-929.

ROSATI C., AQUILANI R., DHARMAPURI S., PALLARA P., MARUSIC C., TAVAZZA R., BOUVIER F., CAMARA B, GIULIANO G., 2000 - *Metabolic engineering of beta-carotene and lycopene content in tomato fruit.* - Plant J., 24(3), 413-420.

ROWAN D.D., 2011 - *Volatile metabolites.* - Metabolites, 1(1): 41-63.

SHARMA R.R., REDDY S.V.R., JHALEGAR M.J., 2014 - *Preharvest fruit bagging: a useful approach for plant protection and improved post-harvest fruit quality. A review.* - J. Hortic. Sci. Biotech., 89(2): 101-113.

SPADAFORA N.D., COCETTA G., CAVAIUOLO M., BULGARI R., DHORAJIWALA R., FERRANTE A., ROGERS H., MÜLLER C.T., 2019 - *A complex interaction between pre-harvest and post-harvest factors determines fresh-cut melon quality and aroma.* - Sci. Rep., 9(1): 1-15.

TYAGI S., SAHAY S., IMRAN M., RASHMI K., MAHESH S. S., 2017 - *Pre-harvest factors influencing the postharvest quality of fruits: A review.* - CJAST, 1-12.