ABSTRACT: Soft fruits are appreciated for their taste qualities and for being a source of health-promoting compounds. However, their postharvest is affected by their high respiratory rates and susceptibility to fungal decay. Our aim here is to provide a perspective on the application of short-term high-CO\textsubscript{2} treatments at a low temperature to maintain the postharvest quality of soft fruits. This work also suggests using a multi-omics approach to better understand the role of the cell wall and phenolic compounds in maintaining quality. Finally, the contribution of high-throughput transcriptomic technologies to understand the mechanisms modulated by the short-term gaseous treatments is also highlighted.

KEYWORDS: fruit quality, gaseous treatments, omics technologies, postharvest, soft fruit berries

INTRODUCTION

The development of new methods to reduce food loss and waste as part of the effort to improve food security and reduce global hunger has become one of the major challenges of this century. Furthermore, given the increasing concern about issues related to sustainable development and the environment, consumers are demanding that the use of chemical products is reduced significantly. Therefore, incorporating non-contaminant postharvest technologies to reduce the use of agro-chemical compounds is vital to maintain the quality and avoid the loss of fruits and vegetables during postharvest storage.

Fresh soft fruit berries, such as blueberries (Vaccinium spp.) and raspberries (Rubus idaeus L.), are gaining popularity because of their nutritional and health benefits, and their economic value is increasing accordingly. Despite the coronavirus pandemic, declining revenues, and complicated logistics, trade in soft fruit berries flourished in 2020. In this regard, blueberries were the most demanded, being the berry whose trade is growing most rapidly (around 16–18\% in 2020 and exceeded $ 4.5 billion). This means that the volume of world trade in fresh blueberries is already at least $1.2 billion higher than the volume of fresh strawberries.\textsuperscript{3}

The shelf life of soft fruit berries at room temperature varies considerably among cultivars, but in general, it is limited as a result of their high respiration rates, fragile structures, and high susceptibility to fungal decay.\textsuperscript{4} To overcome these disadvantages, it is recommended to store fruits at a temperature near 0 °C to extend their postharvest storage. However, cold storage triggers total decay and softening and, in the case of blueberry, pedicel pitting as well as pericarp and pulp adhesion.\textsuperscript{3} Moreover, the absence of a protective skin in raspberries and strawberries favors the induction of water and weight losses, reducing their postharvest life even at a low temperature. As a result, low-temperature storage under air conditions is not able to extend the storage life of soft fruit berries more than 20 days, with this period lasting only about 7 days in the case of raspberries.\textsuperscript{4} Therefore, for longer storage periods, combining storage at low temperatures with other technologies is necessary. Physical treatments that modify the storage atmosphere, commonly lowering O\textsubscript{2} or/and increasing high CO\textsubscript{2} in combination with low-temperature storage, such as controlled atmosphere (CA) and modified atmosphere packaging (MAP), have been used to extend the postharvest life of blueberries, raspberries, and strawberries.\textsuperscript{4} However, prolonged exposure to very low O\textsubscript{2} concentrations and very high CO\textsubscript{2} levels can result in off-flavors and off-odors as a result of anaerobic respiration and fermentative metabolism.\textsuperscript{5} Hence, applying gaseous treatments at low temperatures for short periods (1–3 days) could create optimal conditions for maintaining berry quality during postharvest and avoiding the adverse effects mentioned above. Moreover, an important aspect to consider is that the application of these short-term gaseous treatments could reduce costs compared to traditional CA or MAP systems because the time of exposure to non-atmospheric conditions is reduced. If a literature review were undertaken with the aim of learning about the effect of short-term gaseous treatments on soft fruit, it would be seen that most of the research has been performed on strawberries,\textsuperscript{6,7} and thus, blueberries and raspberries are an area worth exploring. Consequently, the aim of this study is to offer a new
perspective on blueberry and raspberry postharvest through the application of short-term gaseous treatments at a low temperature, with a particular focus on the aspects that need to be considered to carry out a full evaluation of their efficacy.

- **SHORT-TERM HIGH-CO$_2$ TREATMENTS TO MAINTAIN BLUEBERRY AND RASPBERRY FRUIT QUALITY DURING POSTHARVEST**

It is known that CO$_2$ gas concentrations ranging between 15 and 20% reduce fungal attack, respiration, water loss, and softening of fruit berries, thereby extending their postharvest life. In reference to short-term treatments, currently, only one recently published study has proven that a short-term treatment with 15% CO$_2$ for 3 days, followed by air storage at 1 °C for 11 days, was effective in maintaining color parameters and firmness in raspberries. The first aspect to consider is the duration of the treatment and the concentration of CO$_2$ used because, although these are short treatments, these two parameters (time and dose) are known to affect the response of the fruit. For example, off-flavors develop when CO$_2$ concentrations exceed the tolerance threshold during a 3-day short-term gas treatment to maintain strawberry quality. Thus, while the application of a 3-day treatment with 20% CO$_2$ is effective in maintaining strawberry quality, higher concentrations (40%) administered for the same time lead to the accumulation of fermentative products generating off-flavor.

In the case of blueberries and raspberries, as a first step, both the time of exposure and CO$_2$ dose conditions should be optimized to improve their storability. Moreover, to obtain a real understanding of the effect of short-term gaseous treatments, it would be necessary to clarify whether they are cultivar-dependent or not. Although it is well-known that short-term treatments are effective in maintaining the postharvest quality of different cultivars of grape berries, the molecular responses and metabolites elicited were cultivar-specific.

Another important aspect to consider when designing short-term gaseous treatments for raspberries and blueberries is that the signals that trigger their ripening have, up until now, been poorly understood, and in fact, there is some controversy as to whether these fruits should be classified as climacteric or non-climacteric. Although raspberries have been classified as non-climacteric, the pattern of ethylene production in these fruit shows a constant increase during ripening, quite different from other non-climacteric fruits, such as strawberries and grapes. On the other hand, even though blueberries have been classified as climacteric fruits, there are certain discrepancies in the literature. Unlike many climacteric fruits, which can be harvested at a pre-climacteric stage of development and ripened closer to the market in a controlled manner, blueberries depend upon the plant for assimilates and should be harvested as near to commercial maturity as possible because their organoleptic attributes do not improve after harvesting, particularly sweetness, because they lack starch reserves. Thus, all of these variables must be taken into account to perform short-term gaseous treatments in raspberries and blueberries.

- **ELUCIDATION OF THE MECHANISMS THROUGH A MULTI-OMIC APPROACH**

**Importance of the Cell Wall: A Proteomic Approach.** Fruit softening and postharvest decay are two main problems causing deterioration in the quality and appearance of soft fruit and contribute significantly to their loss. It is believed that disassembly of cell wall polymers and the dissolution of the middle lamella, as a result of the coordinated expression of several gene families encoding cell-wall-modifying enzymes, are mainly responsible for softening and could contribute to pathogen attack by reducing the strength of the cell wall, the main barrier against tissue colonization. Thus, it is imperative to investigate how the cell wall structure and composition relate to properties of blueberries and raspberries and how these are modified in response to the postharvest conditions in these fruits. Different studies have addressed the firmness trait of blueberries, focusing on physiological and molecular changes at the onset of ripening as well as individual differences. However, to improve soft fruit postharvest quality, we need to further explore cell-wall-modifying genes and proteins in response to postharvest treatments to be able to identify all molecular markers linked to maintaining firmness through the use of short-term gaseous treatments.

Different cell wall models have emphasized the relevance of non-covalent interactions between polymers, which may respond dynamically to developmental and environmental conditions. In this context, it has been shown that structural O-glycoproteins, extensins, and arabinoxylans proteins form complexes with pectin and xylans by ionic interaction and covalent cross-links. Expansins induce non-enzymatic cell wall loosening by disrupting non-covalent interactions between cellulose microfibrils and the hemicellulose polymers that coat them in the wall. In this sense, the macromolecular structure–function relationships of cell wall polymer–protein networks as well as the mechanisms for their assembly and subsequent remodeling remain an active area of research. Current and emerging immunocytochemical and immunohistochemical techniques, using novel and well-designed specific probes, are being employed for monitoring the dynamics and precise localization of cell wall structural polysaccharides and in situ proteins within complex tissues. It is well-known that strawberries exposed to 20% CO$_2$ are firmer than those stored in air at a low temperature because cell-to-cell adhesion and the integrity of the middle lamella are maintained as a result of the treatment with high CO$_2$ levels and a downregulation of pectin methylsterase proteins occurs. Additionally, the presence of major enzymes and genes involved in the degradation of pectin, the main component of middle lamella during blueberry postharvest, has been reported. However, the effect of high levels of CO$_2$ on structural proteins has not yet been characterized, and there is little information about the spatial and temporal localization of these structural cell wall proteins. Hence, their precise localization within the cell wall would require further investigations at the cytological and histological levels. Furthermore, the role of expansins in blueberries and raspberries during ripening has been studied, but how they are distributed spatially in soft fruit berries is relatively unknown, a factor that could help better explain the function of this family of proteins. Thus, further studies on polymer–protein assembly are required to advance our knowledge of the effect of high levels of CO$_2$ at low temperatures on the maintenance of soft berry textures, which is a research area that also needs to be deepened.

The cuticle plays a significant role in the softening process, in reducing water loss, and in protecting fruits from pathogen invasion. Postharvest changes in the fruit cuticle have not received much interest until recently, and while not abundant,
the majority of the published reports indicate that fruit cuticles continue to evolve after harvest and that a common pattern of change cannot be expected for different species or even cultivars. Softening of Duke and Brigitta blueberry fruits stored at 0 °C has been shown to be highly correlated to cuticle composition, indicating its relevance on this attribute. Also, despite the important implications for postharvest fruit quality, little effort has been devoted to the study of cuticle formation, especially from a biochemical and molecular perspective. Therefore, in our view, it is essential to investigate whether high CO\textsubscript{2} levels alter cuticle composition during storage at a low temperature and whether these changes are related to the reduced water loss associated with short-term high-CO\textsubscript{2} treatments.

Importance of Phenolic Compounds: Transcriptomic and Metabolomic Approaches. Another essential quality factor to be maintained in soft berries during postharvest is their functional properties. In fact, these fruits are especially appreciated because of their high content in antioxidants. The most common antioxidants in soft fruit berries are vitamin C and polyphenols, such as phenolic acids, flavonoids (anthocyanins, flavanols, and flavonols), and tannins. These compounds can be easily altered by many factors, including certain postharvest storage conditions. Despite the amount of studies on the regulation of phenylpropanoid metabolism, specifically anthocyanins and other flavonoids in many plant species, little is known in soft berries. With regard to these fruits, most studies have been performed during their stages of development and ripening, but information related to the effect of postharvest conditions is very limited. At this point, it is important to note that genes required for the biosynthesis of flavonoids are controlled predominantly at the transcriptional level. Different protein superfamily members mediate the transcriptional regulation of the flavonoid biosynthetic pathway, such as the MYB and basic helix−loop−helix (bHLH) transcription factors and the conserved WD40 repeat (WDR) proteins. However, nothing is known about the effect of short-term gaseous treatments on transcription factors and proteins mediating the transcriptional regulation of flavonoids. Thus, new perspectives on soft berries postharvest should include not only the study of flavonoid accumulation but also their transcriptional regulation.

Different works have analyzed the content of polyphenols as well as the antioxidant capacity of soft berries cultivated in different locations and during ripening. Results obtained by various researchers on the impact of different postharvest treatments on the antioxidant capacity of polyphenols in soft fruit berries were contradictory. In this sense, it should be noted that most studies on the total antioxidant capacity of fruit samples have been carried out by individually determining the antioxidant compounds or by monitoring the reaction between them and certain test reagents. These methods measure a method-characteristic capacity but do not provide direct mechanistic information. Lately, electrochemistry has begun to play a significant role in the study of the antioxidant capacity of fruit and the characterization of fruit cultivars according to the postharvest storage conditions, both of which require further investigation. In recent years, an electrochemical methodology using solid-state voltammetry has been developed. This methodology has also permitted the reactivity of phenolic compounds with reactive oxygen species to be monitored after their \textit{in situ} electrochemical generation.
Moreover, it allows table grape samples to be differentiated depending upon the storage atmosphere (air or short-term gaseous treatments). The fact that this voltammetric method exploits the electroactive character of polyphenolic compounds abundant in raspberries and blueberries opens a new perspective in studying how the application of postharvest treatments might affect their antioxidant capacity.

**Contribution of High-Throughput Transcriptomic Technologies to Soft Fruit Postharvest.** High-throughput omics techniques using transcriptomic approaches have become a viable option to support traditional postharvest research. Recent advances in sequencing and computational technologies have greatly facilitated the generation of a large amount of sequence data in a relatively fast and cheap manner. Moreover, transcriptome sequencing (RNA-seq) has opened many doors for high-throughput discovery of genes and genetic markers and quantifying gene expression in non-model species, such as *Rubus* and *Vaccinium* genus, which lack reference genome information. Most RNA-seq studies concerning soft fruit berries have been performed to characterize developmental and ripening processes. With regard to postharvest, recently, a *de novo* RNA-seq analysis was performed on blueberries with the purpose of characterizing the response of these fruits to cold storage. The study highlighted the relevance of genes involved in cell wall metabolism, synthesis of wax compounds, and abiotic and biotic stress. However, no studies on the effect of gaseous treatments have been conducted until now. Consequently, comparative RNA-seq analyses could be useful as a means to undertake an in-depth study of the molecular mechanisms modulated by low-temperature gas treatments used to maintain the quality of soft fruit berries during postharvest. (Figure 1). Currently, attention is being paid to the role of epigenetic regulation of gene expression as a modulating mechanism of genome activity and its impact on fruit quality. To date, almost all studies on epigenetics in the postharvest field have focused on the modulation of pathways involved in fruit development, including ripening and senescence, but to our knowledge, no studies have been conducted on blueberries and raspberries. A new perspective would involve a holistic analysis of epigenetic modification sites that could be relevant to gene expression profiles and fruit quality during postharvest. Therefore, to translate all of this information into a potential application for soft fruit postharvest, future research in this field should aim to develop a more comprehensive experimental design that considers multiple regulatory levels, including transcriptional networks, post-transcriptional regulation, and epigenetics. This will require data mining, high-throughput approaches, and the development of user-friendly tools to implement multi-omics strategies.

### References

1. EastFruit. *Berry Business of 2020: Summary and Forecasts for 2021*. EastFruit: Kyiv, Ukraine, 2021; https://east-fruit.com/en/news/berry-business-2020-main-events-and-forecasts-for-2021/.
2. Horvitz, S. Postharvest Handling of Berries. In *Postharvest Handling*; Kahramanoglu, I., Ed.; IntechOpen, Ltd.: London, U.K., 2017; DOI: 10.5772/intechopen.69073.
3. Zhou, Q.; Zhang, C.; Cheng, S.; Wei, B.; Liu, X.; Ji, S. Changes in energy metabolism accompanying pitting in blueberries stored at low temperature. *Food Chem.* 2014, 164, 493–501.
4. Huynh, N. K.; Willos, M. D.; Eyles, A.; Stanley, R. A. Recent advances in postharvest technologies to extend the shelf life of blueberries (*Vaccinium Sp*.), raspberries (*Rubus idaeus* L.) and blackberries (*Rubus Sp*.). *J. Berry Res.* 2019, 9, 687–707.
5. Mattheis, J.; Fellman, J. K. Impacts of modified atmosphere packaging and controlled atmospheres on aroma, flavor, and quality of horticultural commodities. *HortTechnology* 2000, 10, 507–510.
6. Blanch, M.; Alvarez, I.; Sanchez-Ballesta, M. T.; Escribano, M. I.; Merodio, C. Increasing catechin and procyanidin accumulation in high-CO₂-treated *Fragaria vesca* strawberries. *J. Agric. Food Chem.* 2012, 60, 7489–7496.
7. Eum, H. L.; Han, S. H.; Lee, E. J. High-CO₂ treatment prolongs the postharvest shelf life of strawberry fruits by reducing decay and cell wall degradation. *Foods* 2021, 10, 1649.
8. Romero, I.; Vazquez-Hernandez, M.; Maestro-Gaitan, I.; Escribano, M. I.; Merodio, C.; Sanchez-Ballesta, M. T. Table grapes during postharvest storage: A review of the mechanisms implicated in the beneficial effects of treatments applied for quality retention. *Int. J. Mol. Sci.* 2020, 21, 9320.
9. Gonzalez-Orozco, B. D.; Mercado-Silva, E. M.; Castrano-Tostado, E.; Vazquez-Barrios, M. E.; Rivera-Pastrana, D. M. Effect of short-term controlled atmospheres on the postharvest quality and sensory shelf life of red raspberry (*Rubus idaeus* L.). *CyTA-J. Food Sci.* 2020, 18, 352–358.
10. Blanch, M.; Rosales, R.; Mateos, R.; Perez-Gago, M. B.; Sanchez-Ballesta, M. T.; Escribano, M. I.; Merodio, C. Effects of high CO₂ levels on fermentation, peroxidation, and cellular water stress in *Fragaria vesca* stored at low temperature in conditions of unlimited O₂. *J. Agric. Food Chem.* 2015, 63, 761–768.
11. Fuentes, L.; Figueora, C. R.; Valdenebro, M. Regulation and cross-talk during non-climacteric fruit development and ripening. *Horticulturae* 2019, 5, 45.
12. Posé, S.; Paniagua, C.; Matas, A. J.; Gunning, A. P.; Morris, V. J.; Quesada, M. A.; Mercado, J. A. A nanostructural view of the cell wall disassembly process during fruit ripening and postharvest storage by atomic force microscopy. *Trends Food Sci. Technol.* 2019, 87, 47–58.

### Corresponding Author

**M. Teresa Sanchez-Ballesta** – Department of Characterization, Quality and Safety, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), E-28040 Madrid, Spain; orcid.org/0000-0001-7993-9077; Email: mballesta@ictan.csic.es

**Authors**

Irene Romero – Department of Characterization, Quality and Safety, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), E-28040 Madrid, Spain; orcid.org/0000-0003-0083-485X

**M. Isabel Escribano** – Department of Characterization, Quality and Safety, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), E-28040 Madrid, Spain

**Carmen Merodio** – Department of Characterization, Quality and Safety, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), E-28040 Madrid, Spain

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jafc.2c01305

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### Notes

The authors declare no competing financial interest.

### References

(1) EastFruit. *Berry Business of 2020: Summary and Forecasts for 2021*. EastFruit: Kyiv, Ukraine, 2021; https://east-fruit.com/en/news/berry-business-2020-main-events-and-forecasts-for-2021/.
(2) Horvitz, S. Postharvest Handling of Berries. In *Postharvest Handling*; Kahramanoglu, I., Ed.; IntechOpen, Ltd.: London, U.K., 2017; DOI: 10.5772/intechopen.69073.
(3) Zhou, Q.; Zhang, C.; Cheng, S.; Wei, B.; Liu, X.; Ji, S. Changes in energy metabolism accompanying pitting in blueberries stored at low temperature. *Food Chem.* 2014, 164, 493–501.
(4) Huynh, N. K.; Willos, M. D.; Eyles, A.; Stanley, R. A. Recent advances in postharvest technologies to extend the shelf life of blueberries (*Vaccinium Sp*.), raspberries (*Rubus idaeus* L.) and blackberries (*Rubus Sp*.). *J. Berry Res.* 2019, 9, 687–707.
(5) Mattheis, J.; Fellman, J. K. Impacts of modified atmosphere packaging and controlled atmospheres on aroma, flavor, and quality of horticultural commodities. *HortTechnology* 2000, 10, 507–510.
(6) Blanch, M.; Alvarez, I.; Sanchez-Ballesta, M. T.; Escribano, M. I.; Merodio, C. Increasing catechin and procyanidin accumulation in high-CO₂-treated *Fragaria vesca* strawberries. *J. Agric. Food Chem.* 2012, 60, 7489–7496.
(7) Eum, H. L.; Han, S. H.; Lee, E. J. High-CO₂ treatment prolongs the postharvest shelf life of strawberry fruits by reducing decay and cell wall degradation. *Foods* 2021, 10, 1649.
(8) Romero, I.; Vazquez-Hernandez, M.; Maestro-Gaitan, I.; Escribano, M. I.; Merodio, C.; Sanchez-Ballesta, M. T. Table grapes during postharvest storage: A review of the mechanisms implicated in the beneficial effects of treatments applied for quality retention. *Int. J. Mol. Sci.* 2020, 21, 9320.
(9) Gonzalez-Orozco, B. D.; Mercado-Silva, E. M.; Castrano-Tostado, E.; Vazquez-Barrios, M. E.; Rivera-Pastrana, D. M. Effect of short-term controlled atmospheres on the postharvest quality and sensory shelf life of red raspberry (*Rubus idaeus* L.). *CyTA-J. Food Sci.* 2020, 18, 352–358.
(10) Blanch, M.; Rosales, R.; Mateos, R.; Perez-Gago, M. B.; Sanchez-Ballesta, M. T.; Escribano, M. I.; Merodio, C. Effects of high CO₂ levels on fermentation, peroxidation, and cellular water stress in *Fragaria vesca* stored at low temperature in conditions of unlimited O₂. *J. Agric. Food Chem.* 2015, 63, 761–768.
(11) Fuentes, L.; Figueora, C. R.; Valdenebro, M. Regulation and cross-talk during non-climacteric fruit development and ripening. *Horticulturae* 2019, 5, 45.
(12) Posé, S.; Paniagua, C.; Matas, A. J.; Gunning, A. P.; Morris, V. J.; Quesada, M. A.; Mercado, J. A. A nanostructural view of the cell wall disassembly process during fruit ripening and postharvest storage by atomic force microscopy. *Trends Food Sci. Technol.* 2019, 87, 47–58.
(13) Cappai, F.; Benevento, J.; Ferrão, L. F. V.; Munoz, P. Molecular and genetic bases of fruit firmness variation in Blueberry—a review. *Agronomy* 2018, 8, 174.

(14) Sasidharan, R.; Voesenek, L. A. C. J.; Pierik, R. Cell wall modifying proteins mediate plant acclimatization to biotic and abiotic stresses. *Crit. Rev. Plant Sci.* 2011, 30, 548−562.

(15) Ngouema-Ona, E.; Vicré-Gibounin, M.; Gotté, M.; Plancot, B.; Lerouge, P.; Bardor, M.; Driouich, A. Cell wall O-glycoproteins and N-glycoproteins: Aspects of biosynthesis and function. *Front. Plant Sci.* 2014, 5, 499.

(16) Cosgrove, D. J.; Li, L. C.; Cho, H. T.; Hoffmann-Benning, S.; Moore, R. C.; Blecker, D. The growing world of expansins. *Plant Cell Physiol.* 2002, 43, 1436−1444.

(17) Harker, F. R.; Elgar, H. J.; Watkins, C. B.; Jackson, P. J.; Hallett, I. C. Physical and mechanical changes in strawberry fruit after high carbon dioxide treatments. *Postharvest Biol. Technol.* 2000, 19, 139−146.

(18) Bang, J.; Lim, S.; Yi, G.; Lee, J. G.; Lee, E. J. Integrated transcriptomic-metabolomic analysis reveals cellular responses of harvested strawberry fruit subjected to short-term exposure to high levels of carbon dioxide. *Postharvest Biol. Technol.* 2019, 148, 120−131.

(19) Chen, H.; Cao, S.; Fang, X.; Mu, H.; Yang, H.; Wang, X.; Xu, Q.; Gao, H. Changes in fruit firmness, cell wall composition and cell wall degrading enzymes in postharvest blueberries during storage. *Sci. Hortic.* 2015, 188, 44−48.

(20) Zheng, D.; Hrazdina, G. Cloning and characterization of an expansin gene, REXPI, and a 1-aminocyclopropane-1-carboxylic acid synthase gene, RIACS1 in ripening fruit of raspberry (*Rubus idaeus* L.). *Plant Sci.* 2010, 179, 133−139.

(21) Montecchiarini, M. L.; Silva-Sanzana, C.; Valderramo, L.; Alemano, S.; Gollán, A.; Rivadeneira, M. F.; Bello, F.; Vázquez, D.; Blanco-Herrera, F.; Podestá, F. E.; Tripodi, K. E. J. Biochemical differences in the skin of two blueberries (*Vaccinium corymbosum*) varieties with contrasting firmness: Implication of ions, metabolites and cell wall related proteins in two developmental stages. *Plant Physiol. Biochem.* 2021, 162, 483−495.

(22) Lara, I.; Heredia, A.; Domínguez, E. Shelf life potential and the fruit cuticle: The unexpected player. *Front. Plant Sci.* 2019, 10, 770.

(23) Moggia, C.; Graell, J.; Lara, I.; Schmeda-Hirschmann, G.; Thomas-Valdés, S.; Lobos, G. A. Fruit characteristics and cuticle triterpenes as related to postharvest quality of highbush blueberries. *Sci. Hortic.* 2016, 211, 449−457.

(24) Hichri, I.; Barrieu, F.; Bogs, J.; Kappel, C.; Delrot, S.; Lauvergeat, V. Recent advances in the transcriptional regulation of the flavonoid biosynthetic pathway. *J. Exp. Bot.* 2011, 62, 2465−2483.

(25) Connor, A. M.; Luby, J. J.; Hancock, J. F.; Berkheimer, S.; Riley, D. J.; Lesslie, P.; Hansson, E. J. Changes in fruit antioxidant activity among blueberry cultivars during cold-temperature storage. *J. Agric. Food Chem.* 2002, 50 (4), 893−898.

(26) Haffner, K.; Rosenfeld, H. J.; Skrede, G.; Wang, L. Quality of red raspberry *Rubus idaeus* L. cultivars after storage in controlled and normal atmospheres. *Postharvest Biol. Technol.* 2002, 24, 279−289.

(27) Doménech-Carbó, A. Electrochemistry of plants: Basic theoretical research and applications in plant science. *J. Solid State Electrochem.* 2021, 25, 2747−2757.

(28) Doménech-Carbó, A.; Gavara, R.; Hernández-Muñoz, P.; Domínguez, I. Contact probe voltammetry for *in situ* monitoring of the reactivity of phenolic tomato (*Solanum lycopersicum* L.) compounds with ROS. *Talanta* 2015, 144, 1207−1215.

(29) Romero, I.; Domínguez, I.; Doménech-Carbó, A.; Gavara, R.; Escribano, M. I.; Merodio, C.; Sanchez-Ballesta, M. T. Effect of high levels of CO₂ on the electrochemical behavior and the enzymatic and non-enzymatic antioxidant systems in black and white table grapes stored at 0 °C. *J. Sci. Food Agric.* 2019, 99, 6859−6867.

(30) de la Concepcion, M. C.; Sargent, D. J.; Surbanovski, N.; Colgan, R. J.; Moretto, M. De novo sequencing and analysis of the transcriptome of two highbush blueberry (*Vaccinium corymbosum* L.) cultivars ‘Bluecrop’ and ‘Legacy’ at harvest and following postharvest storage. *PLoS One* 2021, 16, No. e0255139.