Check for updates

Received: 23 June 2021 | Revised: 28 January 2022 | Accepted: 2 February 2022

DOI: 10.1111/jfpp.16464

Journal of Food Processing and Preservation | Institute of Food Science + Technology | WILEY

ORIGINAL ARTICLE

Volatile compositions of strawberry fruit during shelf life using pre and postharvest hexanal treatment

Ayşe Tülin Öz[1] | Ebru Kafkas[2]

[1]Department of Food Engineering, Faculty of Engineering, Osmaniye Korkut Ata University, Osmaniye, Turkey

[2]Department of Horticulture, Faculty of Agriculture, Çukurova University, Adana, Turkey

Correspondence
Ayşe Tülin Öz, Department of Food Engineering, Faculty of Engineering, Osmaniye Korkut Ata University, Osmaniye, Turkey.
Email: aysetulinoz@osmaniye.edu.tr

Funding information
Scientific and Technological Research Council of Turkey (TÜBİTAK)

Abstract

Changes in volatile compositions were determined in Rubygem strawberry variety related to pre and postharvest hexanal application during shelf life. For this concern, Rubygem variety was treated with hexanal vapor and spray applications which were, doses (0%, 0.01%, 0.02%) pre and postharvest after hexanal applications strawberry fruits were stored at 2°C and RH 90% conditions. Effects of hexanal spray and vapor applications of strawberry fruit volatile profiles were analyzed with HS-SPME/GC–MS techniques. Differences among treatments were identified in volatile compositions at 3 days intervals during 15 days of shelf life. The results showed that, hexanal application type and concentration effected the percentage of volatile composition of esters, ketones, terpens, alcohols, acids, aldehydes, and others during shelf life. The hexanal application form and concentration were effected the amount and composition of volatiles of Rubygem strawberry fruit. As a result, hexanal spray application has important effects on ester percentage, however, hexanal vapor treatment increased the alcohols percentage of strawberries at the end of shelf life.

Practical applications

Application of organic substances of hexanal pre and postharvest season has been successfully used due to their environmentally friendly effects. Hexanal is volatile gases, organic aldehydes which are the source of plant extract and used as food additives. There are many research on hexanal application to prevent microbial growth after harvest. In the present study, hexanal spray and vapor applications were used to determined the volatiles profile strawberries fruit during shelf life.

1 | INTRODUCTION

Strawberry (*Fragaria* × *ananassa*) is well-known nonclimacteric fruit and appearance, chemical composition, and flavor profile are important quality parameters of fruit. More than 350 volatiles are responsible for aroma and taste of strawberries (Van de Poel et al., 2014). Even trace amount of volatiles affects the flavor and taste of fruits (Zhoa et al., 2020). It has a sweet, fruity, floral, green, buttery, and sour taste (Samykanno et al., 2013). Generally, different percentages of volatile compounds and the existence of trace part define aroma profiles that strawberry aromas are mainly the composition of esters, aldehydes, alcohols, and sulfur compounds (Ayala-Zavala et al., 2004). Among the volatile compounds managing the aroma of berries, a subset of around 20 compounds influence smell (Mazzoni et al., 2020).The aroma composition of strawberry fruits effects from varieties and growing conditions and agronomical breeding or treatments (Oz et al., 2016). Pre and postharvest application effects fruit and vegetables' visual appearance and chemical composition of produce. Because of the perishable and susceptible nature of strawberry fruit to prevent quality losses during postharvest storage, especially antimicrobial treatments inhibited decay and maintain taste and flavor quality (Li et al., 2020). Thus, to maintain fruit postharvest quality and extent the shelf life, pre, and postharvest treatments are required. Different chemicals, storage techniques have been used to prevent the fungal deterioration of

 © 2022 Wiley Periodicals LLC.

strawberries. Hexanal is organic aldehydes that is one of volatile generated from human and plant substance by-products (Wang et al., 2020). The hexanal is used to prevent microbials such as *B. cinerea*, *M. fructicola*, *S. sclerotiorum*, *A. alternate*, and *C. Gloeosporioides* in fruits and vegetables during pre and postharvest (Zhang et al., 2021). Aroma is the important quality parameter of fruit and vegetables and has an important effect on consumer preference, the volatile compounds of strawberry aroma composition show the variation that depends on cultivar, harvest maturity stage and storage conditions, and also sample preparation and extraction techniques (Vendel et al., 2019). The aroma composition of strawberry fruit has been studied in many research, nevertheless, the effect of preharvest spray and postharvest hexanal vapor treatments on the composition of strawberry fruit aroma has not been studied during shelf life. The understanding of the effects of hexanal spray and vapor applications on volatile compositions of stored Rubygem strawberry fruit was evaluated by using HS/SPME/GC/MS.

2 | MATERIALS AND METHODS

Rubygem strawberry variety is widely cultivated and favorite variety in Turkey. Rubygem strawberry variety was used as experimental

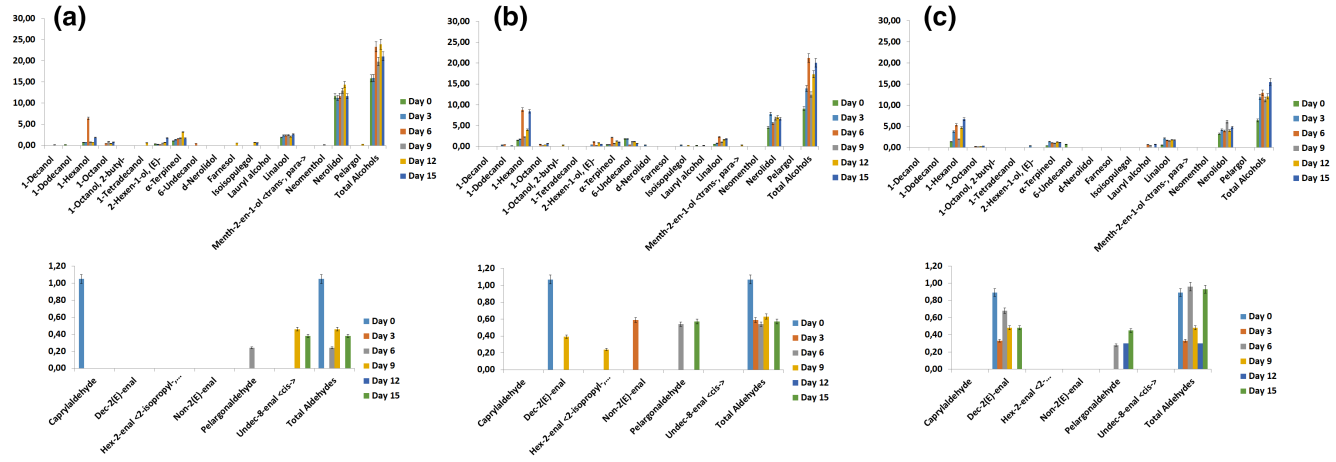


FIGURE 1 Effects of hexanal vapour application on alcohol and aldehyde profiles of Rubygem strawberry variety, (a) control, (b) hexanal-I, (c) hexanal-II

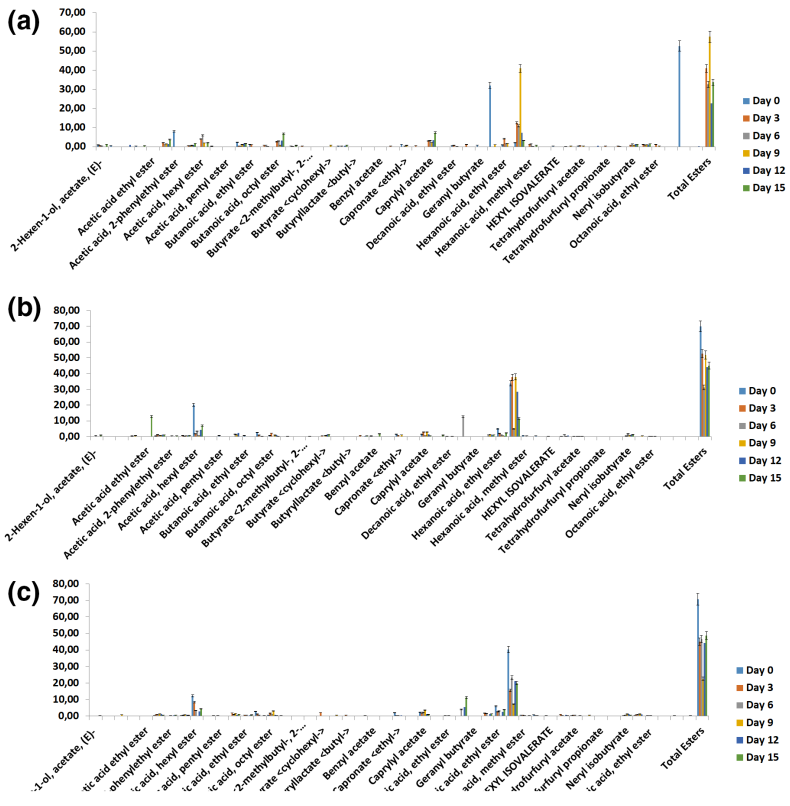


FIGURE 2 Effects of hexanal vapour application on ester profiles of Rubygem strawberry variety, (a) control, (b) hexanal-I, (c) hexanal-II

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

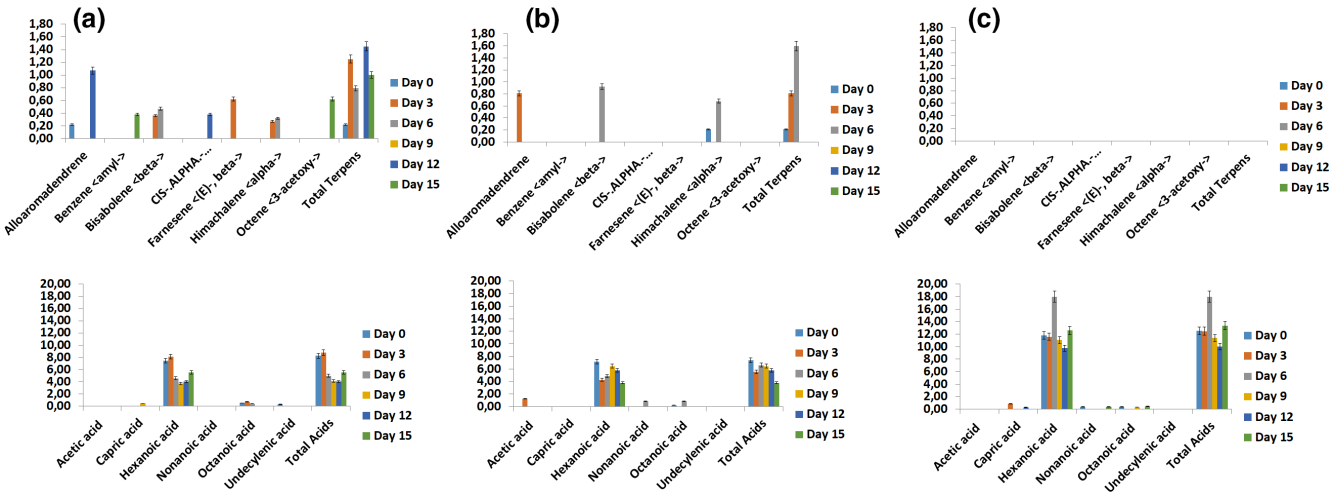
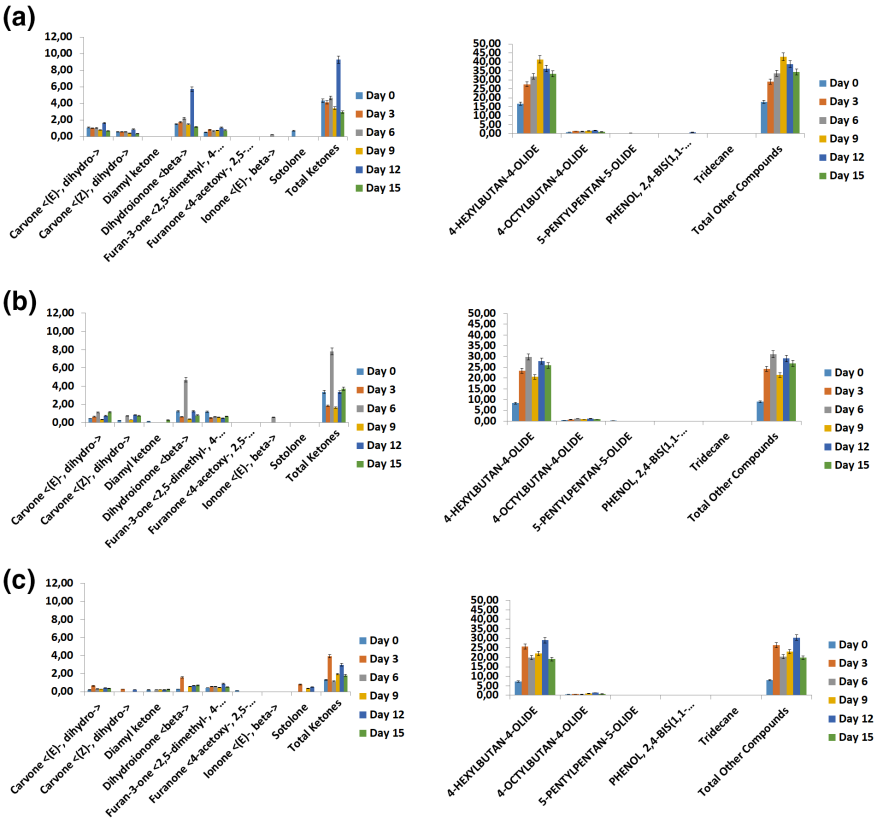


FIGURE 3 Effects of hexanal spray application on alcohol, aldehyde, terpene, and acid profiles of Rubygem strawberry fruit (a) control, (b) hexanal-I (c) hexanal-II

FIGURE 4 Effects of hexanal vapour application on ketone and other compound profiles of Rubygem strawberry variety, (a) control, (b) hexanal-I, (c) hexanal-II Hexanal-II



plant material in this study. The plants were cultivated in black polythene mulch and under the plastic tunnel at Osmaniye Korkut Ata University strawberry plantation area during the 2020 growing season. Rubygem strawberry plants were irrigated with drip irrigation and strawberry fruits were harvested by hand at the commercial ripe stage. The fruits were sorted on the basis of uniformity in size, and color (90% red), appearance, ripeness, and free from physical damage.

2.1 | Pre and postharvest spray and steam application

The fruits of Rubygem strawberry variety were treated with hexanal spray (preharvest season) two times at prior to 7 and 15 days before harvest and postharvest season which were treated for both seasons in three different doses (0%, 0.01%, 0.02%). After harvest, fruits were also treated with hexanal vapor with three different doses (0%,

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

0.01%, 0.02%). All the data obtained from the research were carried out in three replications and 10 fruits were used for each replication and a total of 30 fruits were used for chemical analysis. After spray and vapor applications, strawberry samples were divided into three groups; the control groups (0% hexanal), 0.01% hexanal (Hexanal-I), and hexanal 0.02% (Hexanal-II) for each treatment group. The treatment doses for hexanal were assessed based on the results of the previous report. Treatment doses are assigned according to the results of Paliyath et al. (2003), Paliyath and Murr (2007), Cheema et al. (2014), Jincy et al. (2017), Kumar et al. (2018). Hexanal sprayed and vapor treated Rubygem strawberry fruits were kept in MAP obtained from a commercial strawberry company. The strawberries were stored at +2°C and 90–95% relative humidity cold storage conditions for 15 days.

Rubygem strawberry fruit samples were analyzed in 3 days intervals throughout 15 days of storage period and evaluated based on their fruit volatile profile using Headspace Solid Phase Micro Extraction combined with Gas Chromatography–Mass Spectrometry (HS-SPME-GC–MS). HS/SPME/GC/MS technique for aroma extraction. The fruits were homogenized using a fruit blender and 1 ml $CaCl_2$ was added with 1 g homogenate. Afterward, the samples were transferred in a water bath at 40°C for 30 min. SPME fiber PDMS (Polydimethylsiloxane; red, 1 cm) were used. Volatile compounds were analyzed by using an Shimadzu GC-2010 Plus Gas Chromatography Mass Spectrometry (GC / MS) with an HP-Innowax Agilent column (30 m × 0.25 mm inner diameter, 0.25 um thickness) Helium as carrier gas. The GC oven temperature was maintained at 40°C and programmed to 260°C at a rate of 5°C/min and then held constant at 260°C for 40 min. The injector temperature was 250°C. MS was taken at 70 eV. The mass range was m/z 30–400. A library search was performed using the Wiley (W9 N11, Nist (NIST 11), and Flavor (FFNSC 1.2) GC–MS Libraries. Mass spectra were also compared with those of reference compounds and validated with the aid of retention indices from published sources. The relative percentage amounts of the separated compounds were calculated from the total ion chromatograms in the computer environment.

3 | RESULTS AND DISCUSSION

To evaluate the effects of preharvest hexanal spray and postharvest hexanal vapour applications on Rubygem strawberry fruit variety aroma compositions were measured every 3 days intervals during shelf life. The results of aroma profiles of Rubygem strawberry variety are shown in Figures (Figures 1-8). The volatile profiles of hexanal vapor treatment Rubygem strawberry variety were different based on their aroma profiles. Seven terpenes, six aldehydes, 18 alcohols, 48 esters, six acids, eight ketones, and five other compounds were detected in srawberry fruits treated with hexanal vapour during shelf life (Figures 1a–c and 2a–c; 3a–cand 4a–c). Four terpenes, three aldehydes, 15 alcohols, 50 esters, five acids, seven ketones, and seven other compounds were also detected in hexanal sprayed strawberry fruits during shelf life (Figures 5a–c; 6a–c; 7a–c and 8a–c). As seen in Figure 1a–c total alcohols were in vapor application of control group 15.87%, 9.06% in hexanal I, and 6.42% in hexanal II, respectively, at the initial time of storage. However, total alcohols were 25.97% in spray application of hexanal II (Figure 5c) and 27.69% in hexanal I (Figure 5b), whereas the lowest in the control group with 17.86% (Figure 5a) at the initial time of storage. In case of hexanal spray treatment, total alcohols were decreased to 10.73% in control (Figure 5a), 5.48% in hexanal I (Figure 5b) , and 4.60% in hexanal II (Figure 5c) at the end of storage. On the contrary, at the end of storage the total alcohols were increased to 21.07% in control (Figure 1a), 20.07% in hexanal I (Figure 1b), and 15.52% hexanal II (Figure 1c) with hexanal vapor treatment. Rubygem strawberry fruit had the highest alcohol percentage in the control group among hexanal applications in both treatments and hexanal vapor treated fruit also had a higher alcohol percentage compared to spray-treated strawberry fruit toward storage. Total alcohol was accounted for

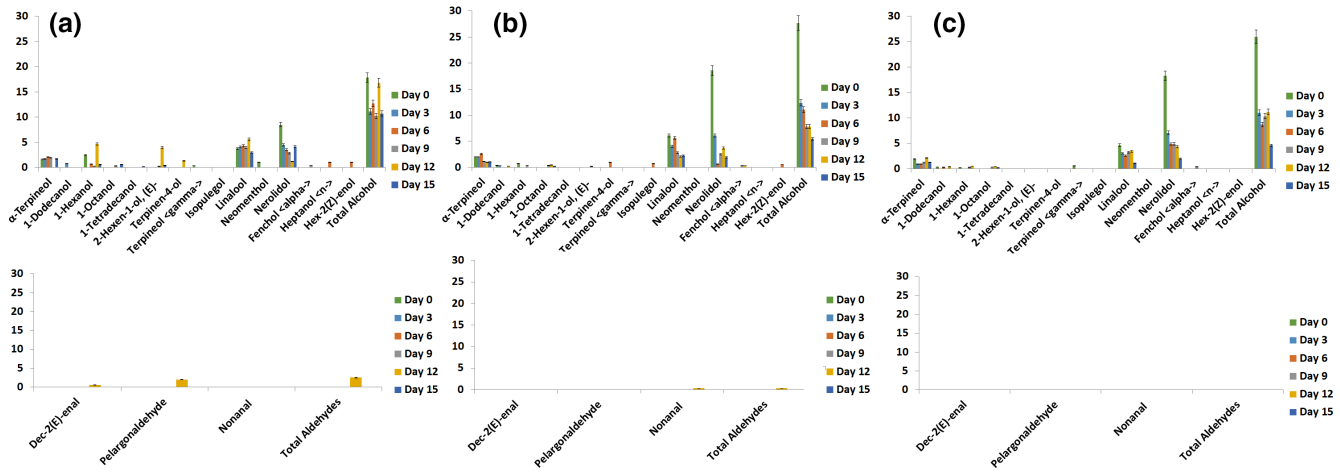


FIGURE 5 Effects of hexanal spray application on alcohol and aldehyde profiles of Rubygem strawberry variety, (a) control, (b) hexanal-I, (c) hexanal-II

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

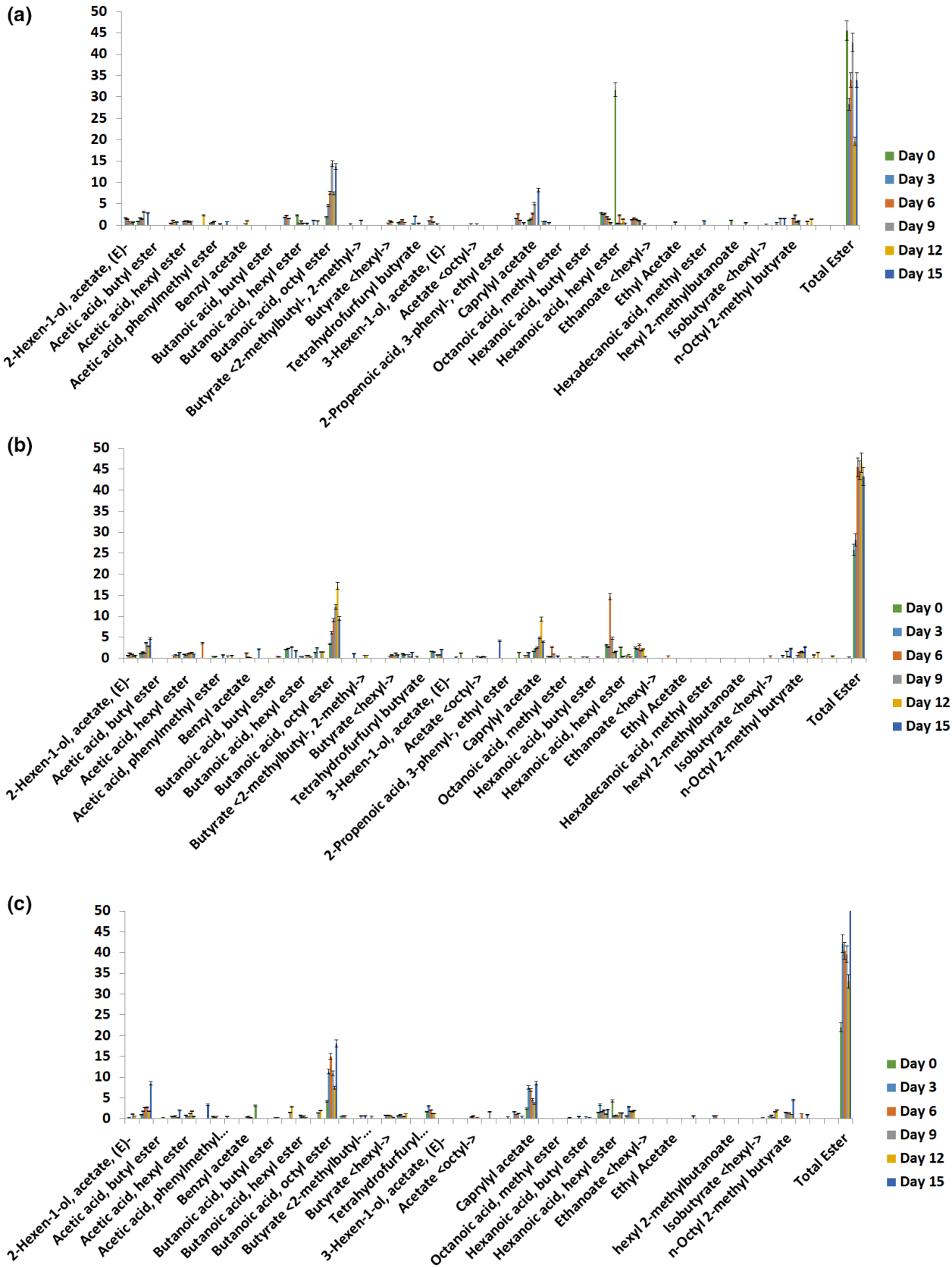


FIGURE 6 Effects of hexanal spray application on ester profiles of Rubygem strawberry variety, (a) control, (b) hexanal-I, (c) hexanal-II

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

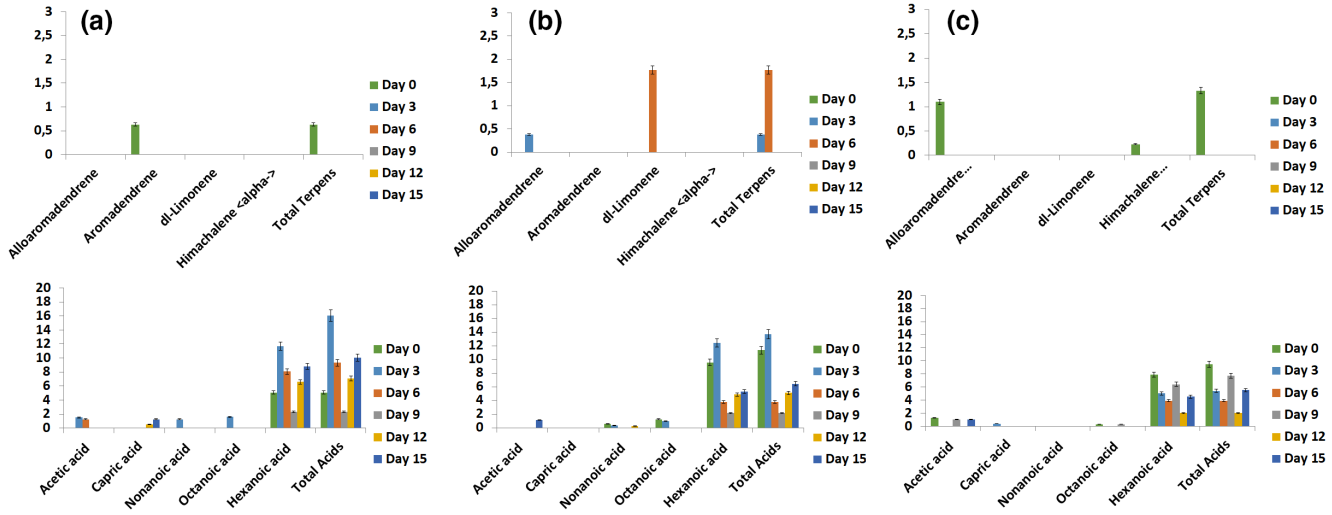


FIGURE 7 Effects of hexanal spray application on terpene and acid profiles of Rubygem strawberry variety (a) control, (b) hexanal-I, (c) hexanal-II

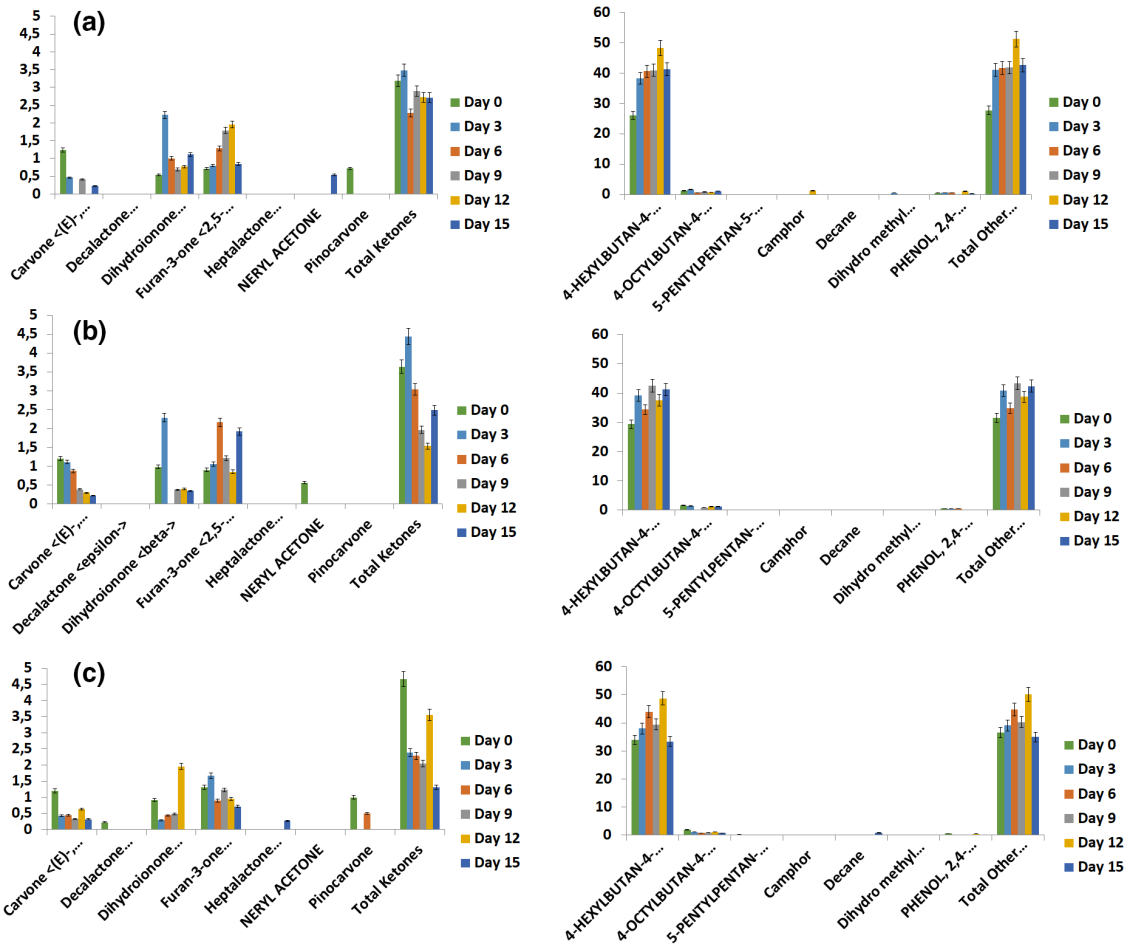


FIGURE 8 Effects of hexanal spray application on ketone and other compounds profiles of Rubygem strawberry variety, (a) control, (b) hexanal-I, (c) hexanal-II

around 10–24% of the volatiles in the control group. Nerolidol and linalool were the most abundant compounds among the detected alcohols in hexanal-treated group particularly hexanal spray-treated group at the initial time of storage but at the end of storage in hexanal vapor-treated group. However, nerolidol and 1-hexanol were found highest in hexanal vapor treatment of Rubygem strawberry variety

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

especially at the end of storage. Trans-nerolidol and beta-linalool are the primary volatile of strawberry fruit and the amount of trans-nerolidol increased during postharvest ripening (Fu et al., 2017). Nerolidol and linalool increased in hexanal vapor application, however, in hexanal spray treatment, amount of nerolidol and linalool percentage decreased at the end of shelf life. Percentage of alcohols present as much as 35% of the volatiles, but only a small amount take part of strawberry fruit aroma (Larsen & Watkins, 1995). Alcohols are form floral, fruity, or fermented flavors depending on their molecular weight (Morales et al., 2005). External application of hexanal volatile aldehyde, hexanal in the form of formulation is reported to they are also important precursors for the formation of 6 carbon alcohols and 6 carbon esters which are among the most abundant volatile compounds in many fruits like strawberry and contribute to typical fruity odors (Ashitha et al., 2020; Paillard, 1986). Aldehydes are similar to acids and alcohols that react easily with this group of flavor compounds even small amounts of these compounds have a potential flavor substances. The highest aldehyde percentage was detected at the initial of storage of hexanal vapor application as 1.05% in control (Figure 1a), 1.07% in hexanal-I (Figure 1b), and 0.89% in hexanal-II (Figure 1c), whereas the lowest aldehydes detected in hexanal spray applications (Figure 5a–c). Terpens are detected only trace amount of Rubygem strawberry fruit at the initial of storage but terpen compounds were not detected in spray application (Figures 1a–c and 7a–c). Acids affects aroma volatiles immediately but affects also off-flavor (Zabetakis & Holden, 1997). Hexanoic acid was detected higher amount compared to other acids both in vapor and spray application during storage (Figures 3a–c and 7a–c). Esters are important volatile for strawberry fruit aroma (Perez et al., 1992). Esters especially rich in ripe fruits which provide fruity and floral notes that between 25 and 90% in ripe fruit (Forney et al., 2000). Ester formation generally consists of mature fruit but the esterase activity is only at mature stage (Yamashita et al., 1977). Similarly, the percentage of hexanal sprayed of strawberry fruit esters approximately doubled at the end of the compared initial time of storage (Figure 6a–c) but vapor applications of hexanal on strawberry fruit esters decreased at the end of storage compared to the beginning of storage (Figure 2a–c). Esters are composed of amino acids, sugars, and lipids (Zhang et al., 2009). Ester formation is connected with alcohol production especially butanol and hexanol were a significant effect on flavor improvement (Bood & Zabetakis, 2002). The results showed that the amount of esters both quantitatively and qualitatively were the most abundant compounds. As a result, the esters were the most abundant volatile both spray and vapor application at the initial of storage (Figures 2a–c and 6a–c) toward storage also and around fifty different esters were detected in hexanal spray (Figure 6a–c) treated samples. Ester content increased at the end of storage and hexanoic acid, hexyl ester were maximum in control fruit samples at the initial time (Figure 6a). Fu et al. (2017) reported that volatile esters increased during the postharvest ripening. Ketones were also found to be a chemical group in strawberry fruit and total ketones percentage were decreased at the end of storage compared with the initial time both vapor and spray treated strawberry (Figures 4a–c and 8a–c). The second detected most abundant volatile was alcohols with fifteen different compounds identified both hexanal applications and predominant alcohol was nerolidol especially at the beginning of storage of hexanal spray treatment (Figure 5a–c). Keton was the third most abundant compound after alcohols and other volatiles at the initial time of storage but tended to decrease at the end. Amino acids, sugar, and lipids are precursors of aroma components of ester (Zhang et al., 2009). Esters provide fruity and floral notes and they comprise from 25% to 90% of the total volatiles in fresh ripe fruit (Forney et al., 2000). The formation of esters is only found in the mature stage because the esterase activity is absent at the immature stage (Yamashita et al., 1977).The result indicates that esters counted both quantitatively and qualitatively the most abundant class of these compounds. Predominant among the esters were Hexanoic acid, ethyl ester, 2-Hexen-1-ol, acetate, Butanoic acid, hexyl ester, 4-Ethylbenzoic acid, 2-butyl ester, Hexanoic acid, methyl ester, Propionic acid ethyl ester. 21.07 in control, 20.07% in hexanal I, and 15.52% in hexanal II. The highest aldehyde percentage and numbers were detected at the initial of storage in hexanal-I with 1.07% whereas lowered aldehyde was detected in hexanal spray application. Hexanal vapor treatment of Rubygem strawberry aroma composition showed decreasing trend except for total alcohol while hexanal spray treated strawberry fruit aroma composition showed decreasing trend except for total esters during shelf life.

4 | CONCLUSION

Flavor is the important main sensorial component which is determinative in the choice, reception, and consumption of food. The postharvest hexanal vapor application effect positively amount, aldehydes and alcohols but spray application positively effect only in total ester compared initial time of storage. Changes in volatile compositions were determined in Rubygem strawberry variety related to pre and postharvest hexanal applications during shelf life. Results showed that hexanal application type and concentration effected in the amount of volatile and composition of total alcohols, total aldehydes, total terpens, total acids, total esters, total ketones during shelf life. The hexanal application form and concentrations were effected on volatiles composition profiles and their percentages of Rubygem strawberry variety. For this reason, hexanal application has important effects on volatiles of strawberries during shelf life. The hexanal using form protects the strawberry quality and quantity losses and the determination of fruit aroma compounds often has a profound effect on the results obtained in the volatile profile determination. The volatiles vary between treatments, and this may influence the results from the treatment type and doses were used. As a result, hexanal spray application effected positively on total ester percentage compared to vapor treatment at the end of storage. However, alcohol percentage was higher in hexanal vapor treated strawberry fruit than spray treatment especially at the end of storage.

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

ACKNOWLEDGMENTS

This study was supported financially by The Scientific and Technological Research Council of Turkey (TUBITAK) Scientific Research Projects Unit (Project No:120O183). The authors thank the Yaltir Agricultural Products Inc. and Aypek Packaging Company for donating the packaging materials.

AUTHOR CONTRIBUTIONS

Ayse Tulin Oz: Formal analysis; investigation; methodology; software; supervision; writing – original draft; writing – review and editing. **nesibe ebru Kafkas:** Formal analysis; methodology; validation; writing – review and editing.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Ayşe Tülin Öz https://orcid.org/0000-0002-6179-062X

REFERENCES

Ashitha, G. N., Sunny, A. C., & Nisha, R. (2020). Effect of pre-harvest and postharvest hexanal treatments on fruits and vegetables: A Review. *Agricultural Reviews*, *41*, 124–131.

Ayala-Zavala, J. F., Wang, S. Y., Wang, C. Y., & Gonzalez-Aguilar, G. A. (2004). Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. *LWT-Food Science and Technology*, *37*, 687–695.

Bood, K. G., & Zabetakis, I. (2002). The biosynthesis of strawberry flavor (II): Biosynthetic and molecular biology studies. *Journal of Food Science*, *67*(1), 2–8.

Cheema, A., Padmanabhan, P., Subramanian, J., Blom, T., & Paliyath, G. (2014). Improving quality of greenhouse tomato (*Solanum lycopersicum*: L) by pre- and postharvest applications of hexanal containing formulations. *Postharvest Biology and Technology*, *95*, 13–19.

Forney, C. F., Kalt, W., & Jordan, M. A. (2000). The composition of strawberry aroma is influenced by cultivar, maturity, and storage. *HortScience*, *35*, 1022–1026.

Fu, X., Cheng, S., Zhang, Y., Du, B., Feng, C., Zhou, Y., Mei, X., Jiang, Y., Duan, X., & Yang, Z. (2017). Differential responses of four biosynthetic pathways of aroma compounds in postharvest strawberry (*Fragaria ananassa* Duch.) under interaction of light and temperature. *Food Chemistry*, *221*, 356–364.

Jincy, M., Djanaguiramana, M., Jeyakumar, P., Subramanian, K. S., Jayasankar, S., & Paliyath, G. (2017). Inhibition of phospholipase D enzyme activity through hexanal leads to delayed mango (*Mangifera indica* L.) fruit ripening through changesin oxidants and antioxidant enzymes activity. *Scientia Horticulturae*, *218*, 316–325.

Kumar, S. K., El Kayal, W., Sullivan, J. A., Paliyath, G., & Jayasankar, S. (2018). Pre-harvest application of hexanal formulation enhances shelf life and quality of 'fantasia' nectarines by regulating membrane and Cell Wall catabolism-associated genes. *Scientia Horticulturae*, *229*, 117–124.

Larsen, M., & Watkins, C. B. (1995). Firmness and concentrations of acetaldehyde, ethyl acetate and ethanol in strawberries stored in controlled and modified atmospheres. *Postharvest Biology and Technology*, *5*, 39–50.

Li, D., Zhang, X., Qu, H., Li, L., Mao, B., Xu, Y., Lin, X., & Luo, Z. (2020). Delaying the biosynthesis of aromatic secondary metabolites in postharvest strawberry fruit exposed to elevated CO2 atmosphere. *Food Chemistry*, *306*(15), 125611.

Mazzoni, L., Di Vittori, L., Balducci, F., Forbes-Hernández, T. Y., Giampieri, F., Battino, M., Mezzetti, B., & Capocasa, F. (2020). Sensorial and nutritional quality of inter and intra—Specific strawberry genotypes selected in resilient conditions. *Scientia Horticulturae*, *261*, 108945.

Morales, M. T., Luna, G., & Aparicio, R. (2005). Comparative study of virgin olive oil sensory defects. *Food Chemistry*, *91*(293–301), 26–301.

Oz, A. T., Baktemur, G., Paydas Kargi, S., & Kafkas, E. (2016). Volatile compounds of strawberry varieties. *Chemistry of Natural Compounds*, *52*(3), 507–509. https://doi.org/10.1007/s10600-016-1690-8

Paillard, N. M. M. (1986). Evolution of the capacity of aldehyde production by crushed apple tissues, during an extended storage of fruits. In G. Charalambous (Ed.), *The shelf life of foods and beverages* (pp. 368–378). Proc. 4th Intl. Flavor Conf. Amsterdam: Elsevier Science Publishers B.V.

Paliyath, G. & Murr, D.P. (2007). *Compositions for the preservation of fruits and vegetables*. US patent 7,198,811.

Paliyath, G., Murr, D.P., Yada, R.Y., & Pinhero, R.G. (2003). *Inhibition of Phospholipase D*. US patent 6,514,914.

Perez, A. G., Rios, J. J., Sanz, C., & Olias, J. M. (1992). Aroma components and free amino acids in strawberry variety Chandler durin ripening. *Journal of Agricultural and Food Chemistry*, *44*, 3620–3624.

Samykanno, K., Pang, E., & Marriott, P. J. (2013). Genotypic and environmental effects on flavor attributes of 'Albion' and 'Juliette' strawberry fruits. *Scientia Horticulturae*, *164*, 633–642.

Van de Poel, B., Vandendriessche, T., Hertoga, M. L. A. T. M., Nicolai, B. M., & Geeraerd, A. (2014). Detached ripening of non-climacteric strawberry impairs aroma profile and fruit quality. *Postharvest Biology and Technology*, *95*, 70–80.

Vendel, I., Hertog, M., & Nicolaï, B. (2019). Fast analysis of strawberry aroma using SIFT-MS: A new technique in postharvest research. *Postharvest Biology and Technology*, *152*, 127–138.

Wang, L., Wu, Y., Li, G., Xu, H., Gao, J., & Zhang, Q. (2020). Superhydrophobic n-octadecylsiloxane (PODS)-functionalized PDA-PEI film as efficient water-resistant sensor for ppb-level hexanal detection. *Chemical Engineering Journal*, *399*, 125755.

Yamashita, I., Iino, K., Nemoto, Y., & Yoshikawa, S. (1977). Studies on flavor development in strawberries. 4. Biosynthesis of volatile alcohol and esters from aldehyde during ripening. *Journal of Agricultural and Food Chemistry*, *25*, 1165–1168.

Zabetakis, I., & Holden, M. A. (1997). Strawberry flavour: Analysis and biosynthesis. *Journal of the Science of Food and Agriculture*, *74*, 421–434.

Zhang, Y., Wang, G., Dong, J., Zhong, C., Kong, J., Li, T., & Han, Z. (2009). Analysis of volatile components in strawberry cultivar Xingdu 1 and Xingdu 2 and their parents. *Agricultural Science in China*, *8*, 441–446.

Zhang, S., Zheng, M., Zhai, H., Ma, P., Lyu, Y., Hu, Y., & Cai, J. (2021). Effects of hexanal fumigation on fungal spoilage and grain quality of stored wheat. *Grain & Oil Science and Technology*, *4*(2021), 10–17.

Zhao, J., Liu, J., Wang, F., Wang, S., Feng, H., Xie, X., Hao, F., Zhang, L., & Fang, C. (2020). Volatile constituents and ellagic acid formation in strawberry fruits of selected cultivars. *Food Research International*, *138*, 10976.

How to cite this article: Öz, A. T., & Kafkas, E. (2022). Volatile compositions of strawberry fruit during shelf life using pre and postharvest hexanal treatment. *Journal of Food Processing and Preservation*, 46, e16464. https://doi.org/10.1111/jfpp.16464

17454549, 2022, 6, Downloaded from https://ifst.onlinelibrary.wiley.com/doi/10.1111/jfpp.16464 by Cukurova University, Wiley Online Library on [22/07/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License