



Research Article

Volume 28 Issue 4 - July 2024

DOI: 10.19080/ARTOAJ.2024.28.556422

Agri Res & Tech: Open Access J

Copyright © All rights are reserved by Ji-Young Kim

Cultivar Differentiation and Quality Changes Monitoring of Strawberry during Storage using Electronic Nose

Andri Jaya Laksana¹, Jong-Hoon Kim², Seung-Eel Oh² and Ji-Young Kim^{2*}

¹Department of Biosystems Machinery Engineering, Chungnam National University, Daejeon, Korea

²Food Safety and Distribution Research Group, Korea Food Research Institute (KFRI), Wanju, Korea

Submission: July 09, 2024; **Published:** July 18, 2024

***Corresponding author:** Ji-Young Kim, Food Safety and Distribution Research Group, Korea Food Research Institute (KFRI), Wanju, Korea

Abstract

Strawberry, *Fragaria x ananassa* Duchesne, is a popular fruit with unique aromas and a sour-to-sweet taste. Aroma is an important aspect of identifying the quality of Strawberry during storage after harvesting. In this study, an electronic nose was used to identify the characteristics of volatile organic compounds produced in the Strawberry during storage and compare differences in characteristics of volatile organic compounds according to the cultivar of Strawberry. The results indicate no difference between quality indexes in Strawberry except for the weight loss (WL) and volatile organic compounds (VOCs) production during storage. The WL of Seolhyang (ST1) and Geumsil (ST2) increased from 0 to 10 d. VOCs in ST1 correlated to 1-Propanol, 2-methyl-, methyl hexanoate, propyl nonanoate, methyl formate, (Z)-3-Hexen-1-ol, and (E)-2-hexenal during the storage period at 5 °C. VOCs in ST2 were identified as 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone, 2-ethyl-3-methylpyrazine, methyl butanoate, (Z)-3-Hexen-1-ol, and methyl hexanoate. These VOCs can be used as biomarkers in the early detection of undesirable flavor production in the food industry and crucial factors in the shelf-life determination of Strawberry during storage.

Keywords: Cold temperature; Freshness; Fruit; Physicochemical; Volatile organic compounds

Abbreviations: ST1: Strawberry 'Seolhyang'; ST2: Strawberry 'Geumsil'; PCA: Principal Component Analysis; ANOVA: Analysis of Variance; VOCs: Volatile organic compounds; WL: Weight Loss; TA: Titratable Acidity; YM: Total Yeast and Mold; TVC: Total Viable Count; TSSs: Total Soluble Solids

Introduction

Strawberry, known as *Fragaria x ananassa* Duchesne, is a popular fruit with unique aroma that has sour to sweet taste and provides in many places in the world. The fruit contains many beneficial substances for human body such as bioactive compounds, vitamins, fiber, and minerals [1]. Flavonoids and Polyphenols known as antimutagenic, anticarcinogenic, and antioxidant also contain in high rates in strawberry [2]. This nutrition composition can be various based on the purposes of commercial cultivation and breeding programs and the studies which are focused on the fruit quality concept [3]. In modern breeding programs, characteristic of cultivar, such as genotypes, has influence to physical-chemical, nutritional composition, and the sensorial in strawberry [4-6]. Sensory, such as fruit odor, sweet flavor, and flavor aftertaste, can impact to human consumption behavior [7]. Therefore, aroma is one of the crucial aspect for enhancing consumer preferences and commercialization in the market.

Many studies has been conducted to investigate the change of aroma in the strawberry based on different focuses such as freezing process [8], cultivation conditions [9], and maturity stage at harvest [10]. Identified 122 volatile organic compounds (VOCs) categorized as esters, terpenes, lactones, and alcohols with 46.5% ester constituent have been found in Korean cultivars [11]. The VOCs commonly identify using Gas Chromatography-Mass Spectrometry (GC-MS) with solid-phase micro-extraction (SPME) [12-15], Atmospheric Pressure Chemical Ionization-Mass Spectrometry (APCI-MS) with GC-MS [16], multi-dimensional gas chromatography (GC × GC) with SPME method [17], and Headspace (HS) with the combination of SPME-GC-MS in strawberry [18-20].

Olfactory organ naturally has capability to discriminate the aroma by using the combination of (1) cross-sensitive olfactory receptor arrays, (2) olfactory codes, and (3) the recognition system by brain [21]. Electronic nose (e-nose) is an instrument

that comprise similar artificial components of olfactory receptors and composed of a gas sensor array that responds to volatile compounds in a digital fingerprint [22]. The gas sensor array is the combination of several different sensors with a microfabrication process which can contain SnO_2 , CuO , In_2O_3 , and ZnO [23,24]. Metal oxide semiconductor (MOS) is one of sensor array which can detect odors in different sample such as liquors [25], banana [26], essential oils [27], fresh and rotten egg [28,29]. In this study, an electronic nose was used to identify the characteristic of volatile organic compounds produced in the strawberry after harvesting, during storage, and compare the characteristics differences of volatile organic compounds according to cultivar of strawberry.

Materials and Methods

Samples and Materials Preparation

Strawberry 'Seolhyang' (ST1) and 'Geumsil' (ST2), twenty kilograms of each species, were obtained from strawberry farm, packed in 1 kg Styrofoam box, and distributed to the Korea Food Research Institute (KFRI), Wanju-gun, Republic of Korea. After receiving the strawberry at the institute, each samples were stored at $5 \pm 1^\circ\text{C}$ for 10 days and determined their quality indexes every day until the final day of experiment.

Weight Loss, Moisture Content, and Total Soluble Solids

Three boxes of sample were measured the weight using electronic balance (CUX4299HX, CAS Co., Ltd., Yangju-si, Republic of Korea) and calculated the weight loss on a percentage using the following equation [30]:

$$\text{Weight loss (WL)} = \frac{W_o - W_p}{W_o} \times 100 \quad (1)$$

Details:

W_o : initial weight of strawberry before storage (g)

W_p : the weight of strawberry after storage (g)

The moisture content of strawberries (200 gr) was determined using an oven-drying method which previously mixed by kitchen blender (HMF600, Hanil Global Tech Co., Ltd., Sejong-si, Republic of Korea) and 2 grams of mixed samples, on an aluminum container, were dried using a dry oven (HK-D0134F, Hankuk S&I Co., Ltd., Hwaseong-si, Republic of Korea) at 135°C for 3 hours. The moisture content were evaluated using the following equation [31]:

$$\text{Moisture Content (wb)} (\%) = \frac{M_i - M_d}{M_i} \times 100 \quad (2)$$

Details:

M_i : initial/fresh sample weight (g)

M_d : dried sample weight (g)

The blended sample (0.5 mL) from previous preparation were used to determine the total soluble solids (TSSs) using refractometer (PAL-1, Atago Co., Ltd., Tokyo, Japan) [32] and the TSSs result from three replications of analysis were performed as

the percentage (%).

Titrateable Acidity and pH

The pH value of 20 mL mixed strawberry, placed in a 50 mL beaker glass, were examined using a digital pH meter (TA-70, DKK-TOA Corp., Tokyo, Japan) and determined their percentage of titrateable acidity (TA) by adding 0.1 N NaOH to the sample until reached pH 8.2. The NaOH volume that consumed during the titration was converted as citric acid and used to determine the TA according to the equation (3) [33].

$$\text{Titrateable Acidity (TA)} (\%) = \frac{V_{\text{NaOH}} \times 192 \times N_{\text{NaOH}}}{V_s \times 100} \times 100 \quad (3)$$

Details:

V_{NaOH} : Volume of NaOH used in the sample until reach pH 8.2 (mL)

N_{NaOH} : NaOH Normality (0.1 N)

V_s : Volume of Sample

Microbial Growth

Total yeast and mold (YM) and total viable count (TVC) in strawberry were evaluated using the microbial count plates (Yeast & Mold Count Plates 3M Petrifilm, 3MTM, St. Paul, MN, USA) and (Aerobic Count Plates 3M Petrifilm, 3MTM, St. Paul, MN, USA) [34]. In sterile condition, Ten grams of strawberry were obtained and diluted in a filter bag with 90 mL of 0.85% saline solution. The diluted sample was homogenized using a stomacher (Bag Mixer 400 CC, Interscience Intl., Saint-Nom-la-Br  t  che, France) for one minute. After that, one milliliter of sample solution was transferred and diluted by 0.85% saline solution until 10 mL. The series dilution of sample was placed in count plate and incubated for 48 hours at 35°C (TVC) and for 5 days at 25°C (YM).

Texture

The texture of 15 Strawberry was measured using a texture analyzer (TA.XT2, Stable Micro Systems Ltd., Vienna Court, UK) as Newton (N). The texture profile analysis was performed based on the puncture and cutting systems using a cylinder 5-mm probe and a single blade set (HDP/BS Probe, Stable Micro Systems Ltd., Vienna Court, UK). In detail, modified parameters were defined as pre-test speed 5.0 mm s^{-1} , test speed 5.0 mm s^{-1} , post-test speed 5.0 mm s^{-1} , distance 45 mm, and trigger force 0.098 N [35,36].

Color Changes

Color changes in strawberry was captured using an automatic colorimeter (CR-400, Konica Minolta Inc., Osaka, Japan) with 10 sample with two replications. The color value was performed as CIELAB color parameters L^* , a^* , and b^* which represents lightness from black to white, green to red, and yellow to blue, respectively [37]. For color differences or ΔE , the value was calculated according to the following formula (4):

$$\Delta E^* = \sqrt{(L_{\text{initial}}^* - L_{\text{stored}}^*)^2 + (a_{\text{initial}}^* - a_{\text{stored}}^*)^2 + (b_{\text{initial}}^* - b_{\text{stored}}^*)^2} \quad (4)$$

Volatile Organic Compounds Analysis

Volatile organic compounds (VOCs) in the strawberry was obtained using GC-FID Heracles II (Alpha M.O.S. Corp., Toulouse, France). The sample (500 grams) was mixed by kitchen blender (HMF600, Hanil Global Tech Co., Ltd., Sejong-si, Republic of Korea) and 2 mL of strawberry juice was placed in 20 mL vial and injected into the instrument in six repeats. Before the injection, the method was set based on the following parameters: injector temperature was set at 200 °C with injection volume of 1000 µL of 125 µL/s of speed, the sample incubation and trapping temperature were performed at 40 °C with 500 rpm agitation for 20 minutes. Furthermore, the thermal profile in the GC was programmed initially started from 50 °C to endpoint at 250 °C with the heating rate from 1 to 3 °C/s with detectors' temperature at 260 °C. Besides, hydrogen gas flow was set at 30 mL/min to obtain the acquisition duration of 110s and acquisition period of 0.01 s. The results were recorded as chromatograph and treated raw data for further analysis. The VOCs identification was conducted using Kovats indices with retention time of C6-C16 and processed through Alpha-Soft software and AroChembae library. The confirmed VOCs were described in chemical compounds name, chemical formula, and odor description.

Statistical Analysis

Analysis of variance (ANOVA) was performed by SPSS statistics 24.0 software (SPSS Inc., Chicago, IL, USA) with a post hoc test of Tukey-HSD with significance level at 5%. The variables correlation (Pearson Correlation) and principal component analysis (PCA) of sample were conducted using R programming version 4.3.0 and RStudio Desktop 2023.12.1-402.

Results and Discussion

Quality indexes

Quality indexes of strawberry during storage for 10 days had been performed. There were moisture content, total soluble solids, weight loss, pH, titratable acidity, total viable count, total yeast and mold, hardness, color changes, and volatile organic compounds. The percentage of moisture content of ST1 and ST2 was similar from day 0 until the final experiment (Figure 1(A)) and no significant differences among samples at $p > 0.05$. In Figure 1(B), it shows the TSSs of sample ST1 and ST2. Generally, the ST1 had higher value in TSSs compared to ST2. TSSs content increase during strawberry ripening and decreases in mature fruit due to respiration [38]. Soluble solids content will decrease $\pm 1.8\%$ as average in line with the increase of temperature from 14.5 to 19.5 °C [39]. It can be expected that changes in TSSs of strawberry was slowed during storage at 5 °C due to low in respiration rate. The WL of ST1 in the early experiment was lower than ST2. However, the WL of ST1 increased on day 8 (1.02 kg) and more drastically increased in 10 days (1.33 kg). Weight loss in strawberry mainly occurs due to fruit respiration and water loss from fruit to atmosphere during transpiration [40,41]. Strawberries is easily

to dry out due to thin and delicate skin and make them to rapid water loss [42].

pH and Titratable acidity (TA) in strawberry was performed as citric acid and observed from day 0 to day 10 (Figure 2). Change in pH is an indicator metabolism process that utilizes sugar and organic acids [43]. Besides, TA is attributable to the metabolic consumption of organic acids and possibly impact to fruit senescence in high rate of consumption [44]. The pH value of ST1 and ST2 was similar from initial day until the final day of experiment around 3.81-3.89. The TA in sample ST1 and ST2 described similar results at 1.68-2.10% stored for 10 days at 5 °C. It shows that pH and TA of strawberries were maintained from their initial conditions during storage at 5 °C.

Total viable microbe (TVC) in ST1 initially were lower at 4.77 log CFU/g than ST2 at 6.63 log CFU/g (Figure 3 (A)). Besides, total yeast and mold (YM) in ST1 and ST2 relatively similar at 5.33 and 5.95 log CFU/g. The detected microbes can be linked to postharvest procedures through rinse water, human hand contamination, transportation, and storage condition [45]. Isolated bacterial found on the surface of strawberry can be Bacillaceae, Pseudomonadaceae, and Microbacteriaceae. Besides, isolated fungal are *A. flavus*, *A. pluriseptata*, *C. albidus*, and *U. maydis* [46]. The growth of TVC fluctuate compared to YM whether in ST1 or ST2. The final population of TVC in ST1 and ST2 on day 10 were 5.00 and 6.83 log CFU/g; YM in ST1 and ST2 on day 10 were 6.40 and 5.93 log CFU/g (Figure 4).

The different qualities of strawberry (pH, TA, and texture), stored at cool temperature, are clearly influenced by the cultivar [47]. The texture of strawberry especially hardness in ST2 during storage at 5 °C relatively increased from day 0 to day 10. Meanwhile, ST1 no difference hardness at $p > 0.05$ from the first day until the final day of experiment in puncture and cutting method. These results are similar to the previous study [46]. Texture softening can be caused by microbial growth, physiological changes, moisture loss, enzymatic disruption of pectins, and high temperature condition during storage or ripening [5,42,48]. The hardness-puncture of ST1 were 4.04 N (day 0) and 4.49 N (day 10). Hardness-puncture of ST2 were 5.03 N (day 0) and 5.28 N (day 10). Furthermore, hardness-cutting of ST1 and ST2 on day 0 were 10.38 N and 10.30 N, respectively. On day 10, the hardness-cutting of ST1 and ST2 were 11.78 N and 13.91 N.

The color value of strawberry during storage was described in Figure 5. Oxidative browning reactions impact to less red and darkening color in ripe strawberries and this condition can be slowed at 0 °C [5,49]. It can be seen that for 10 days of storage of strawberry the color parameters such as L^* , a^* , b^* , and ΔE in ST1 and ST2 were no significant changes at $p > 0.05$. The color values from initial to final experiment in 10 days were relatively similar each other and maintained. In general, all quality indexes except weight loss was no significant difference at $p > 0.05$. This condition was maintained due to low temperature of storage (at 5 °C).

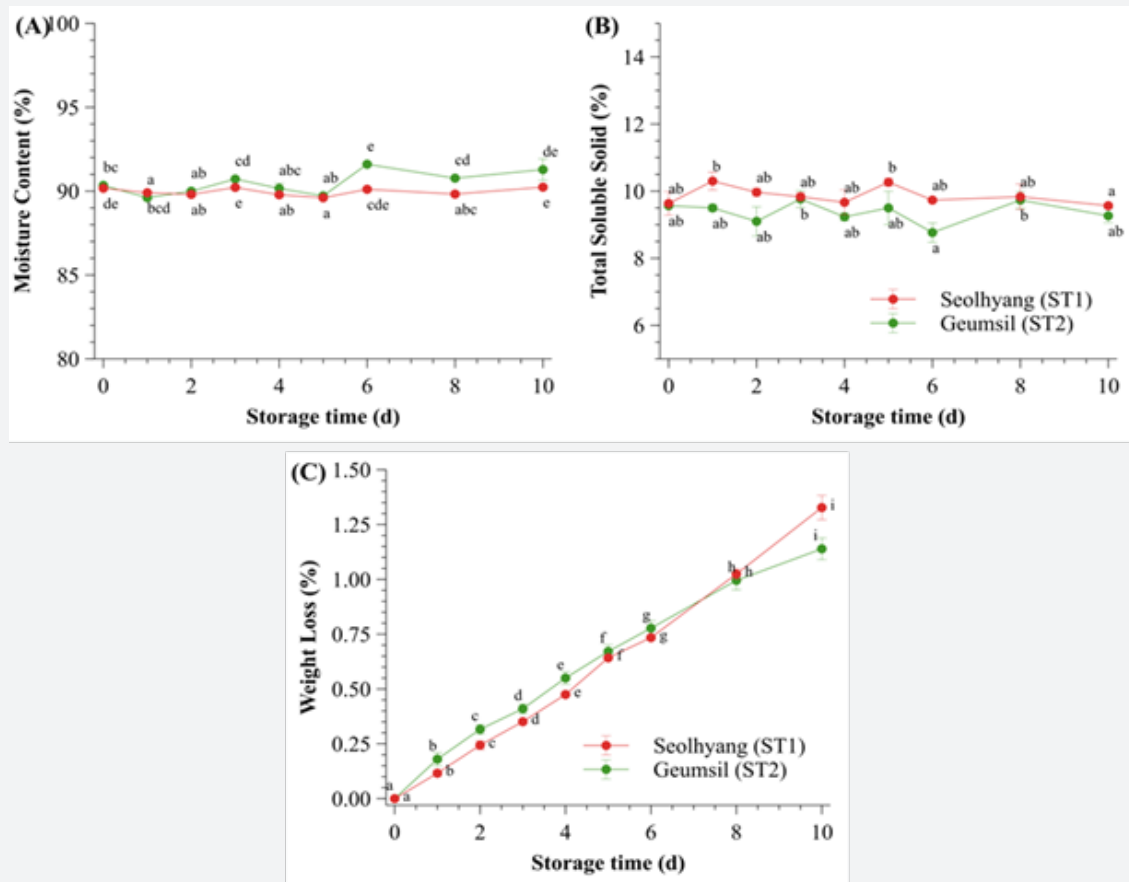


Figure 1: (A) Moisture content is expressed on a fresh weight basis, (B) total soluble solid, and (C) weight loss of Strawberry during storage for ten days at 5 °C. The data are expressed as mean $\pm$ SD, $n = 3$; the different letters (a-i) considering the same conditions represent significant differences at $p < 0.05$.

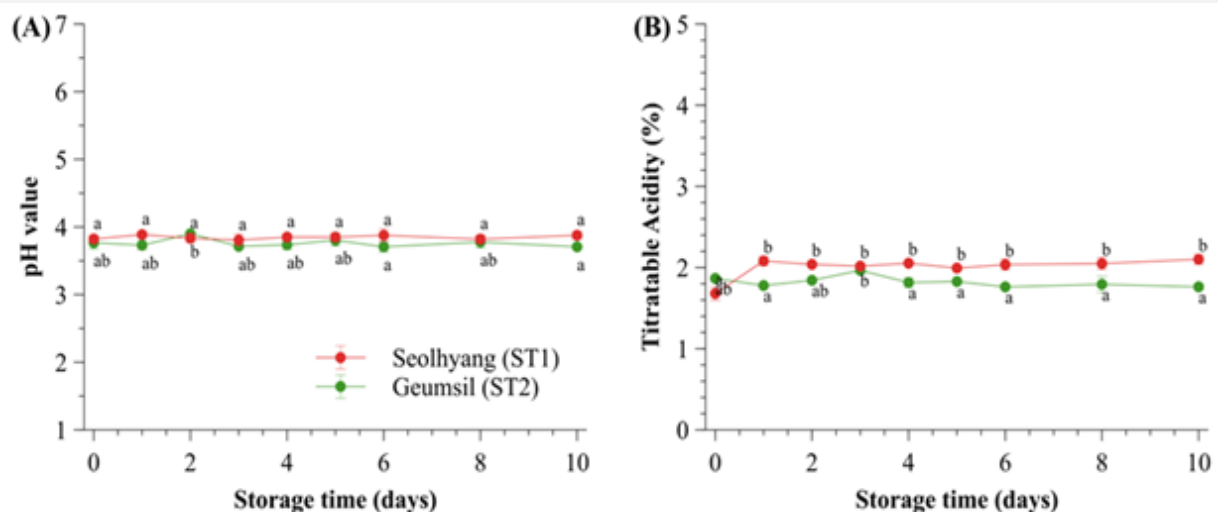


Figure 2: (A) pH and (B) titratable acidity of Strawberry during storage at 5 °C for ten days. The data are expressed as mean $\pm$ SD, $n = 3$; the different letters (a-e) considering the same conditions represent significant differences at $p < 0.05$.

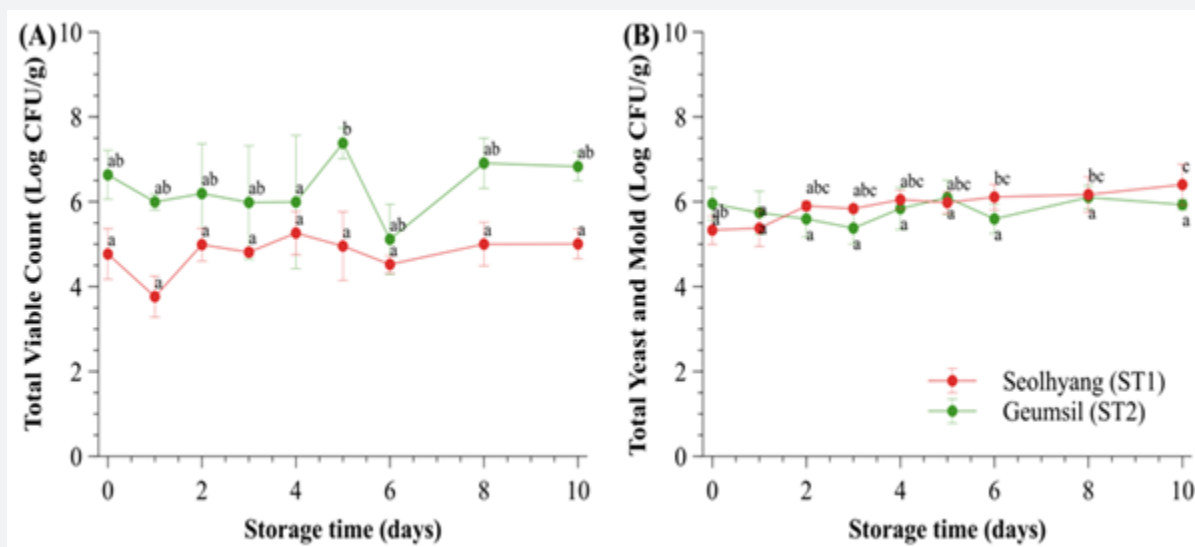


Figure 3: Microbial changes of (A) total viable count and (B) total yeast and mold in Strawberry during storage at 5 °C for 10 days. The data are expressed as mean $\pm$ SD, n = 3; the different letters (a-e) considering at the same conditions represents significant differences at $p < 0.05$.

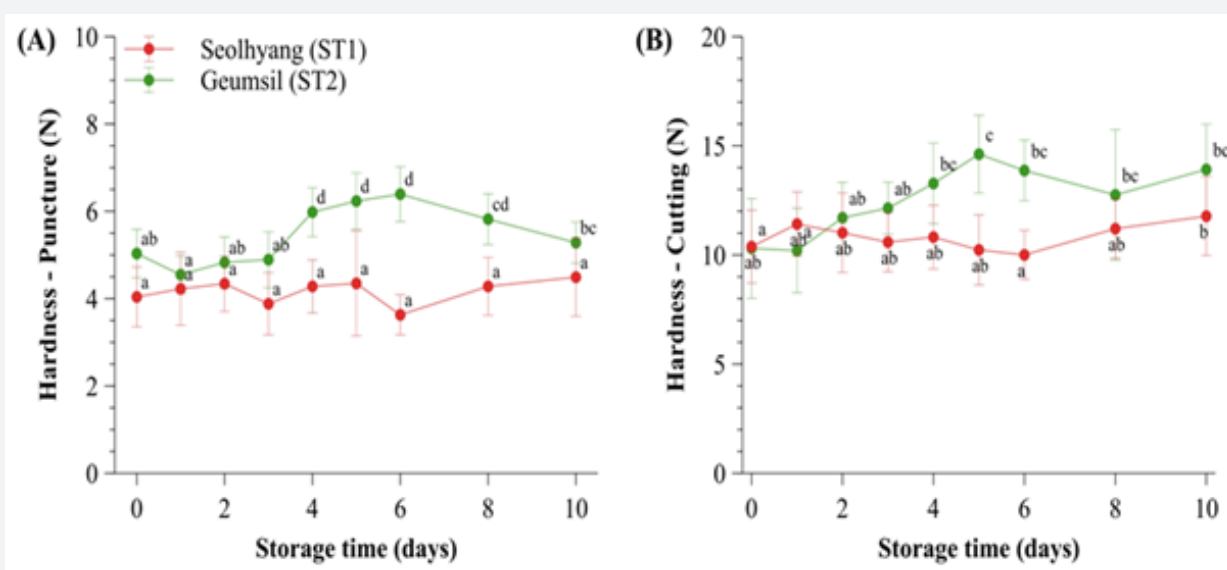


Figure 4: Firmness of Strawberry during storage at 5 °C for 10 days with different methods (A) puncture and (B) cutting. The data are expressed as mean $\pm$ SD, n = 15; the different letters (a-e) considering at the same conditions represents significant differences at $p < 0.05$.

Volatile Organic Compounds Analysis

Volatile organic compounds are organic chemical compounds that evaporate easily at room temperature [50]. The composition of aroma in strawberry mostly influenced by cultivar, maturity, and postharvest environment such as storage temperature and period [51]. The production of aroma during storage at 5 °C is higher than that stored at 0 °C such as methyl hexanoate while

decrease during storage [52]. VOCs were identified using electronic nose in ST1 and ST2 stored at 5 °C from day 0 to day 10. Table 1 shows the chemical compounds and odor description of VOCs in strawberry. In ST1, the VOCs were identified methyl formate; 1-propanol; 1-propanol, 2-methyl-; methyl butanoate; ethyl butyrate; ethyl 2-methylbutyrate; (Z)-3-hexen-1-ol; (E)-2-hexenal; 3-heptanone; methyl hexanoate; ethyl hexanoate; 2-ethyl-

6-methylpyrazine; 4-hydroxy-2,5-dimethyl-3(2H)-furanone; linalool; 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone; methyl eugenol; butyl butanoate; 6-decenal; ()-carvone; and propyl nonanoate. Besides, the VOCs in ST2 were 1-propanol; 1-propanol, 2-methyl-; methyl butanoate; ethyl butyrate; butanoic acid; (Z)-3-hexen-1-ol; (E)-2-hexenal; 2-heptanone; methyl hexanoate; 2-ethyl-6-methylpyrazine; 4-hydroxy-2,5-dimethyl-3(2H)-furanone; linalool; 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone; methyl eugenol; hexanal; E-2-hexen-1-ol; butyl butanoate; 2-ethyl-3-methylpyrazine; triethyl phosphate; ()-carvone; and 2-dodecanone. In Figure 6, it shows the chromatogram of VOCs in ST1 on day 0, day 4, and day 10. The chromatograms of VOCs changes in ST2 can be seen in Figure 7 with various intensity in different columns (MXT-5 and MXT-1701).

Table 1: Identified volatile organic compounds in ST1 and ST2 during storage at 5 °C.

RT-Column	Formula	Chemical Compound	Odor Description*
18.51-1	C ₂ H ₄ O ₂	Methyl formate	Fruity, plum, estery
26.30-1	C ₃ H ₈ O	1-Propanol	Alcoholic, fermented, musty
31.21-1	C ₄ H ₁₀ O	1-Propanol, 2-methyl-	Ethereal, winery, cortex
38.84-1	C ₅ H ₁₀ O ₂	Methyl butanoate	Fruity, apple, sweet, banana, pineapple
49.76-1	C ₆ H ₁₂ O ₂	Ethyl butyrate	Fruity, pineapple, banana, caramelized, sweet strawberry
51.51-1	C ₄ H ₈ O ₂	Butanoic acid**	Sharp acetic, cheese, butter, fruit
54.84-1	C ₇ H ₁₄ O ₂	Ethyl 2-methylbutyrate	Sharp. Sweet, green, apple, blackberry, strawberry
55.61-1	C ₆ H ₁₂ O	(Z)-3-hexen-1-ol	Green, leafy, floral, petal, oily, earthy
56.51-1	C ₆ H ₁₀ O	(E)-2-hexenal	Green, banana, almond, apple, cherry, herbaceous, leafy, strawberry
58.41-1	C ₇ H ₁₄ O	2-Heptanone**	Fruity, spicy, sweet, herbal, coconut, woody
58.80-1	C ₇ H ₁₄ O	3-Heptanone	Green, fatty, fruity
63.52-1	C ₇ H ₁₄ O ₂	Methyl hexanoate	Ethereal, fruity, pineapple, apricot, strawberry, tropical, fruit, banana
69.64-1	C ₈ H ₁₆ O ₂	Ethyl hexanoate	Sweet, pineapple, green, banana, anise, apple, wine, gum, strawberry
70.82-1	C ₇ H ₁₀ N ₂	2-Ethyl-6-methylpyrazine	Roasted potato
73.17-1	C ₆ H ₈ O ₃	4-hydroxy-2,5-dimethyl-3(2H)-furanone	Sweet, cotton, candy, caramelized, sugar, strawberry
77.06-1	C ₁₀ H ₁₈ O	Linalool	Citrus, floral, sweet, woody, green, blueberry
82.67-1	C ₇ H ₁₀ O ₃	5-Ethyl-3-hydroxy-4-methyl-2(5H)-furanone	Sweet, fruity, maple, brown sugar, nutty, chicory
92.47-1	C ₁₁ H ₁₄ O ₂	Methyl eugenol	Sweet, fresh, warm, clove, carnation, cinnamon
57.39-2	C ₆ H ₁₂ O	Hexanal**	Fresh, green, fatty, aldehydic, leafy, fruity, sweaty
65.51-2	C ₆ H ₁₂ O	E-2-Hexen-1-ol**	Fresh, green, leafy, fruity, unripe, banana
72.49-2	C ₈ H ₁₆ O ₂	Butyl butanoate	Fruity, banana, pineapple, green, cherry, tropical fruit, ripe fruit, juicy fruit
74.17-2	C ₇ H ₁₀ N ₂	2-Ethyl-3-methylpyrazine**	Nutty, peanut, musty, corn, raw, earthy, bread
85.05-2	C ₁₀ H ₁₈ O	6-Decenal	Tallow, green, cucumber
86.00-2	C ₆ H ₁₅ O ₄ P	Triethyl phosphate**	Mild cider
91.51-2	C ₁₀ H ₁₄ O	()-Carvone	sweet spearmint, herbal minty
93.94-2	C ₁₂ H ₂₄ O ₂	Propyl nonanoate	Yeast, melon
95.69-2	C ₁₂ H ₂₄ O	2-Dodecanone**	Fruity, citrus, floral, orange

*Odor descriptions were confirmed through Aro Chem Base library (Alpha M.O.S. Corp., Toulouse, France).

**the VOCs were observed in ST2.

Multivariate analysis

Pearson correlation coefficient measures the linear relationship between pairs of variables [53]. Correlation coefficients are scaled from -1 to +1, where 0 indicates that

there is no association or relationship in the data [54]. Pearson correlation was conducted to determine the relationship between VOCs and storage time from day 0 to day 10. In Figure 8(A), it can be seen that during the storage period VOCs in ST1 had a positive correlation with 1-Propanol, 2-methyl- (0.75) which

represented ethereal and winy aroma, methyl hexanoate (0.72), and propyl nonanoate (0.74) which had yeast aroma. In the other hand, VOCs in ST1 had negative correlation with methyl formate (-0.96), (Z)-3-Hexen-1-ol (-0.82), and (E)-2-hexenal (-0.92) which described fresh strawberry aroma. In Figure 8(B), The VOCs in ST2 had positive correlation during storage period were 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone (0.74) and 2-ethyl-3-methylpyrazine (0.82) which describe fruity, unripen and raw aroma. Meanwhile, methyl butanoate, (Z)-3-Hexen-1-ol, and methyl hexanoate had negative correlation at 0.76, -0.63, and -0.63 that represented ethereal, leafy, and fruity aroma. Methyl hexanoate in ST2 had negative correlation with storage period at -0.63. The ST2 also had unique VOCs compared to ST1 that were represented by butanoic acid and hexanal with butter, sweaty and fatty aroma. Six compounds (Z)-3-hexenal (green), 4-hydroxy-2,5-dimethyl-3(2H)-furanone (caramel-like, sweet), methyl butanoate (fruity), ethyl butanoate (fruity), methyl 2-methylpropanoate (fruity), and 2,3-butanedione (buttery) identified as key flavor in the strawberry-like odor [55]. 2,5-dimethyl-4-hydroxy-2H-furan-3-one, (sweet), γ -dodecalactone (sweet), γ -decalactone (sweet), δ -decalactone (sweet), hexanoic acid (sour), 2-methylbutanoic

acid (sour), cis-3-hexenal (green), trans-3-hexenol (green), cis-2-nonenal (green), trans-nerolidol (sweaty), δ -dodecalactone (sweet), vanillin (sweet), linalool (floral and citrus-like), ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, and ethyl hexanoate are considered as main contributors to the aroma of strawberry [56].

Principal component analysis (PCA) was used to interpret datasets by reducing their dimensionality in a treatable way by preserving most of the information from the original data [57]. PCA of ST1 was defined by PC1 49.6% and PC2 19.5% and ST2 by PC1 37% and PC2 23.7%. Variables contribution in PCA of ST1 were methyl butanoate, ethyl 2-methylbutyrate, linalool, 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone, and methyl hexanoate; PCA of ST2 were ethyl butyrate, (Z)-3-hexen-1-ol, 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone, and triethyl phosphate (Figure 9(A), (B), (C) and (D)). In Figure 10(A), It shows the radar graph of VOCs intensity changes in ST1 during storage which ethyl butyrate and (E)-2-hexenal were the highest among other identified VOCs in the sample. E-2-hexen-1-ol, (E)-2-hexenal, and ethyl butyrate were the three highest VOCs identified in ST2 during storage (Figure 10(B)).

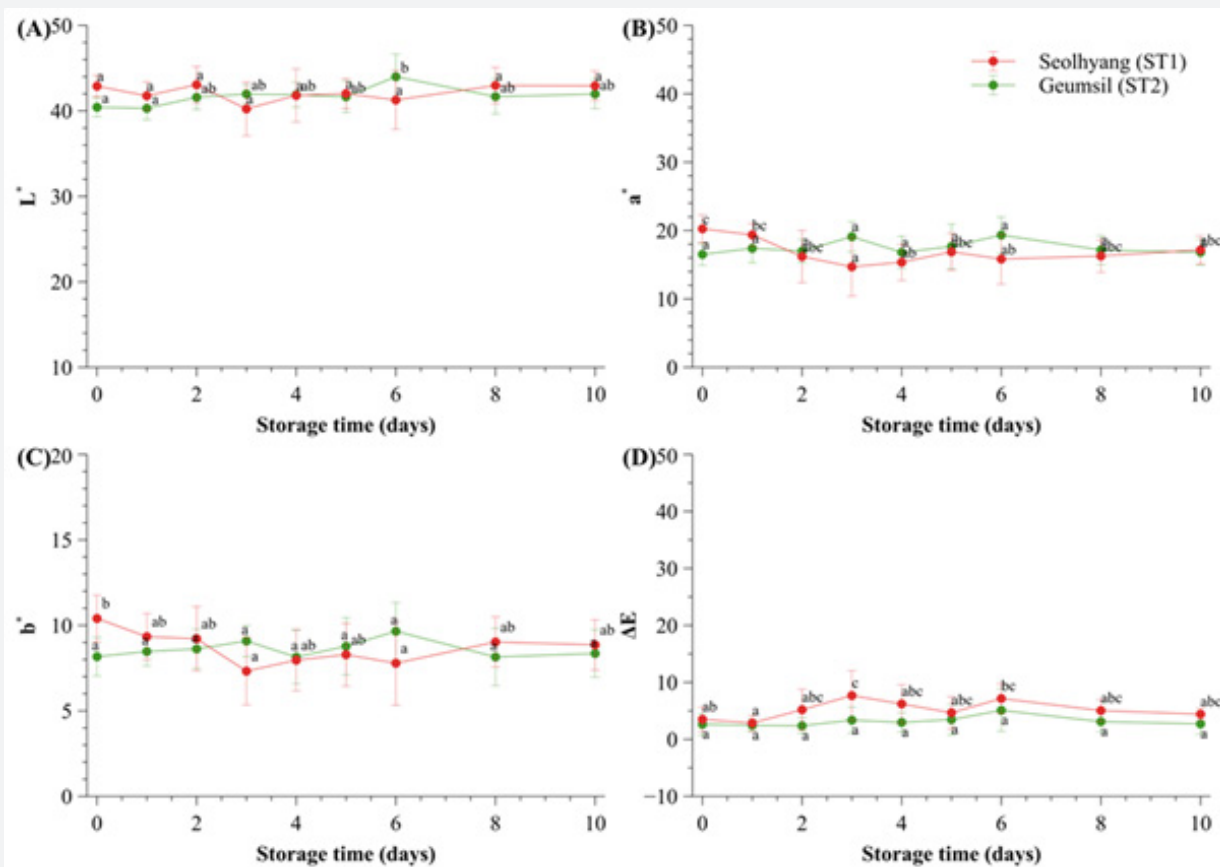


Figure 5: Color values (A) L*, (B) a*, (C) b*, and (D) ΔE of Strawberry during storage at 5 °C for 10 days. The data are expressed as mean $\pm$ SD, n = 10; the different letters (a-e) considering at the same conditions represents significant differences at p < 0.05.

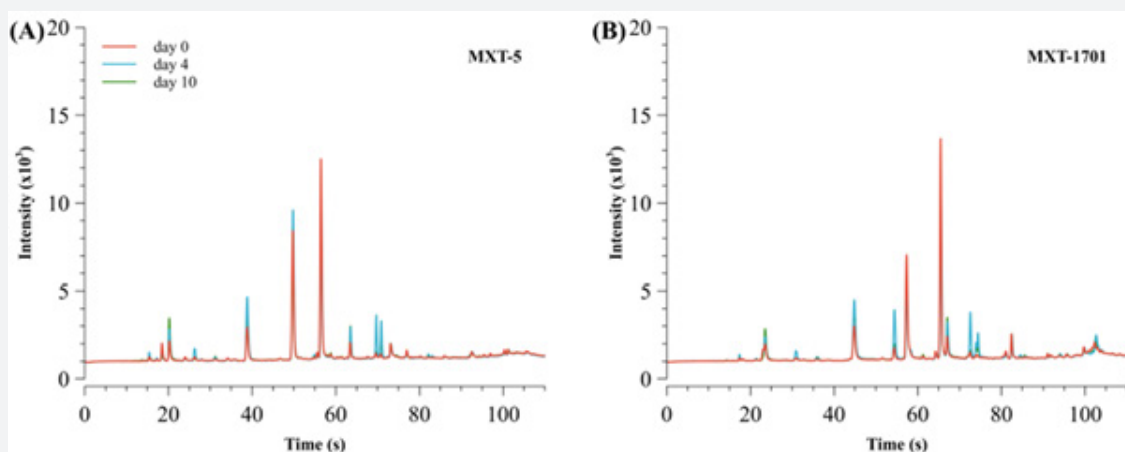


Figure 6: Chromatograms of ST1 during storage during storage at 5 °C on day 0, day 4, and day 10.

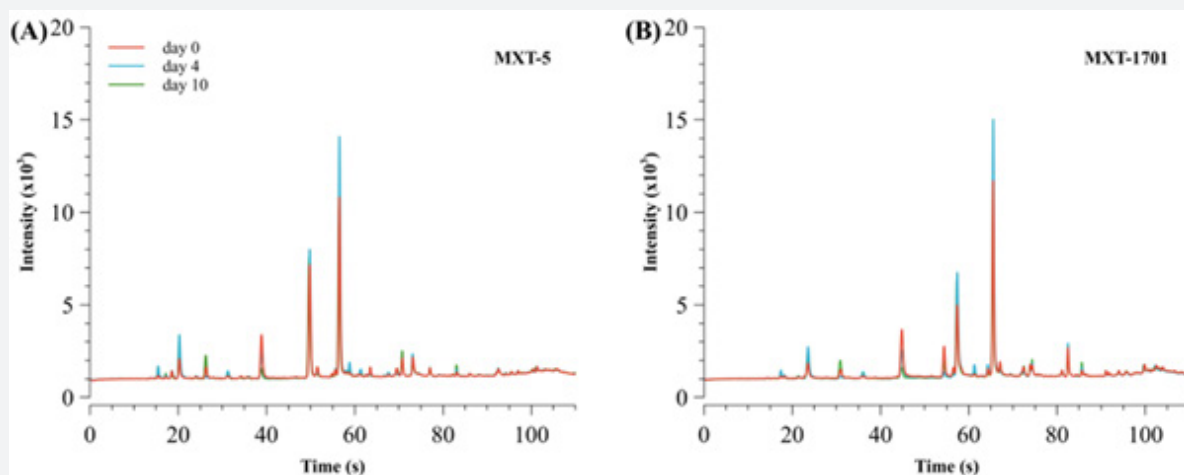


Figure 7: Chromatograms of ST2 during storage during storage at 5 °C on day 0, day 4, and day 10.

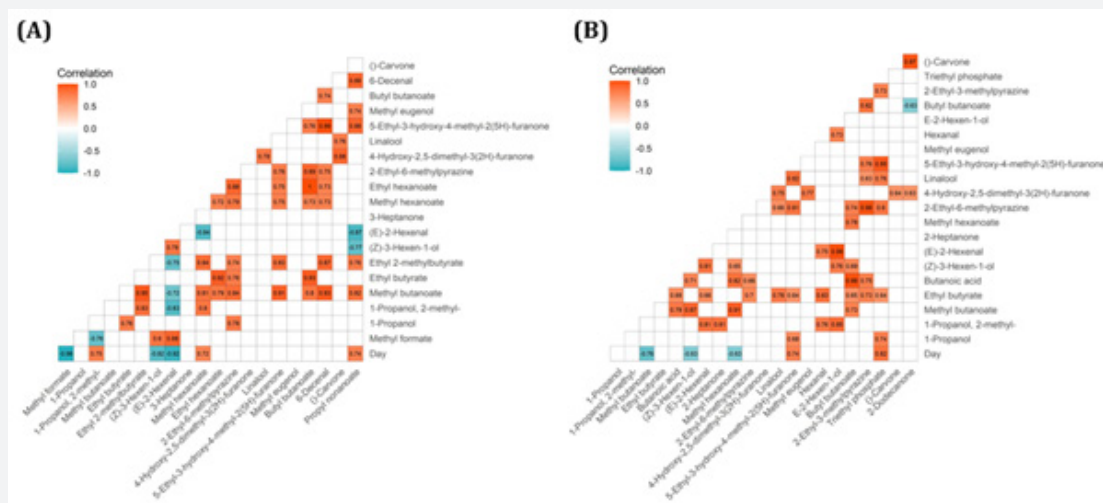


Figure 8: Pearson correlation between VOCs in strawberry (A) ST1 and (B) ST2 during storage for 10 days at 5 °C. The displayed values indicate significant Pearson correlation at $p < 0.05$.

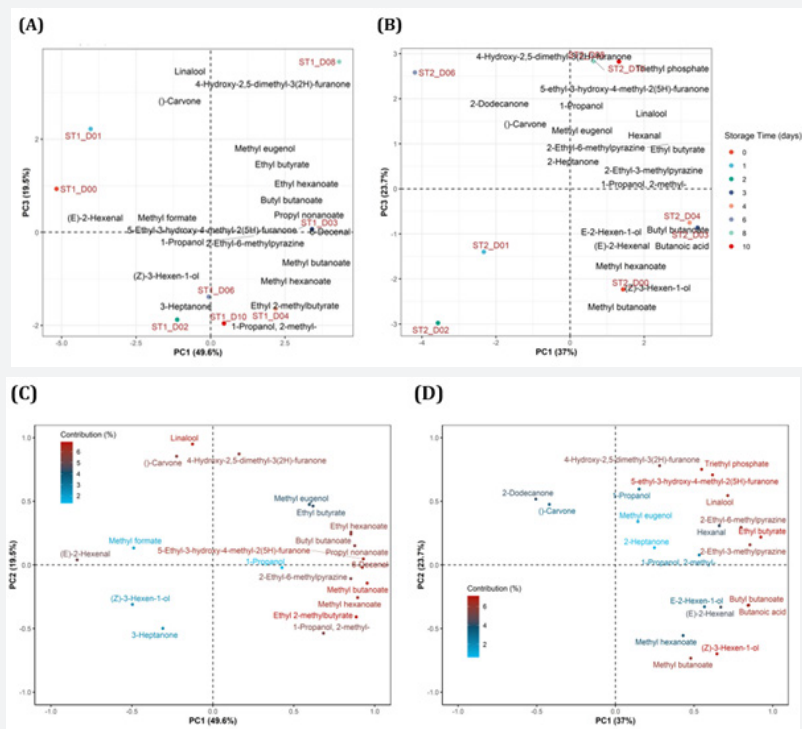


Figure 9: PCA-Biplot of identified VOCs (A) ST1 and (B) ST2 and Variables contribution in PCA of (C) ST1 and (D) ST2 in strawberry during storage at 5 °C for 10 days.

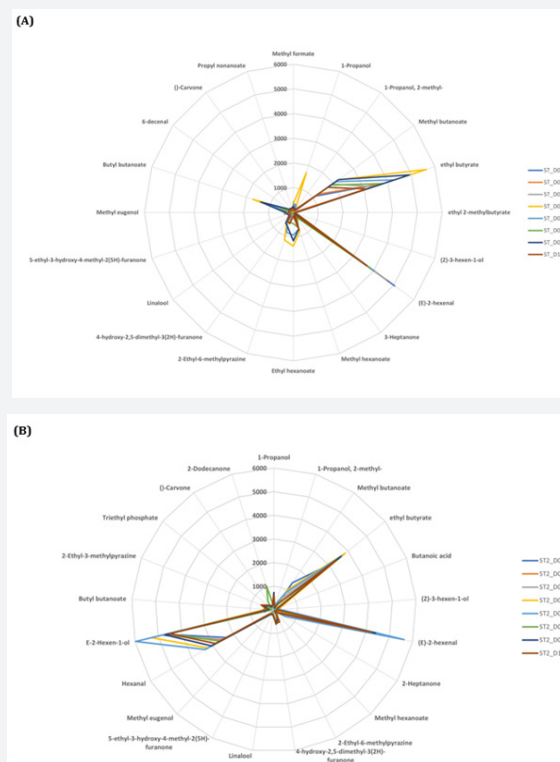


Figure 10: Radar graphs of identified VOCs in strawberry (A) ST1 and (B) ST2 during storage for 10 days at 5 °C.

Conclusion

This study generally discussed the changes in quality indexes such as moisture content, TSS, WL, pH, TA, TVC, YM, hardness, L^* , a^* , b^* , ΔE , and VOCs in Strawberry with different cultivars. The results indicate that during storage at 5 °C for 10 d. There is no difference between quality indexes in Strawberry except the WL and VOCs production during storage. The WL of ST1 and ST2 significantly increased from 0 to 10 d ($p < 0.05$). Besides, the VOCs in ST1 increased during storage, such as 1-Propanol, 2-methyl-, methyl hexanoate, and propyl nonanoate. On the other hand, VOCs in ST1 decreased during storage, such as methyl formate, (Z)-3-Hexen-1-ol, and (E)-2-hexenal. The VOCs in ST2 increased 5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone and 2-ethyl-3-methylpyrazine. Meanwhile, methyl butanoate, (Z)-3-Hexen-1-ol, and methyl hexanoate decreased during storage. This study provided not only the essential information for freshness identification but also critical points in the shelf-life determination of Strawberry during storage. Besides, these VOCs can be used as biomarkers in the early detection of undesirable flavor production during the storage of Strawberry in the food industry.

Acknowledgment

This work was supported by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET) through "Development of Smart Agricultural Products Distribution Storage Technology" Project. This research was funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA) (Grant number: 322049-3).

References

- Giampieri F, Tulipani S, Alvarez-Suarez JM, José LQ, Bruno M, et al. (2012) The strawberry: Composition, nutritional quality, and impact on human health. *Nutrition* 28: 9-19.
- Tulipani S, Mezzetti B, Battino M (2009) Impact of strawberries on human health: Insight into marginally discussed bioactive compounds for the Mediterranean diet. *Public Health Nutr* 12(9): 1656-1662.
- Gündüz K (2016) Strawberry. In: *Nutritional Composition of Fruit Cultivars*. Elsevier, pp. 733-752.
- Cao X, Wang Y, Liao X, Hu X (2018) Characterization of physico-chemical and bio-chemical compositions of selected four strawberry cultivars. *J Appl Botany & Food Qual* 19.
- Nunes G, Teixeira F, Schwarz K, Cristiano KC, Juliano Tadeu VR, et al. (2020) Influence of genetic variability on the quality of strawberry cultivars: sensorial, physical-chemical and nutritional characterization. *Acta Sci Agron* 43: e46862.
- Ruan J, Lee YH, Hong SJ, Yeoung YR (2013) Sugar and organic acid contents of day-neutral and ever-bearing strawberry cultivars in high-elevation for summer and autumn fruit production in Korea. *Hortic Environ Biotechnol* 54: 214-222.
- Gunness P, Kravchuk O, Nottingham SM, Bruce RD, Michael JG (2009) Sensory analysis of individual strawberry fruit and comparison with instrumental analysis. *Postharvest Biol Technol* 52(2): 164-172.
- Larsen M, Poll L (1995) Changes in the composition of aromatic compounds and other quality parameters of strawberries during freezing and thawing. *Z Lebensm Unters Forch* 201: 275-277.
- Li Y, Zhang Y, Liu X, Yuwei X, Zuying Z (2021) Cultivation Conditions Change Aroma Volatiles of Strawberry Fruit. *Horticulturae* 7: 81.
- Aubert C, Bruaut M, Chalot G, Cottet V (2021) Impact of maturity stage at harvest on the main physicochemical characteristics, the levels of vitamin C, polyphenols and volatiles and the sensory quality of Gariguette strawberry. *Eur Food Res Technol* 247: 37-49.
- Jee E, Do E, Gil CS, Seolah K, Sun Yi Lee, et al. (2024) Analysis of volatile organic compounds in Korean-bred strawberries: insights for improving fruit flavor. *Front Plant Sci* 15: 1360050.
- Abouelenen D, Mustafa AM, Angeloni S, Germana B, Sauro V, et al. (2021) Influence of Freezing and Different Drying Methods on Volatile Profiles of Strawberry and Analysis of Volatile Compounds of Strawberry Commercial Jams. *Molecules* 26(14): 4153.
- Kafkas E, Cabaroglu T, Selli S, Bozdoğan M, Kırkcıoğlu, SP, et al. (2006) Identification of volatile aroma compounds of strawberry wine using solid-phase microextraction techniques coupled with gas chromatography-mass spectrometry. *Flavor Fragr J* 21(1): 68-71.
- Li H, Brouwer B, Oud N, Julian CV, Yury T, et al. (2021) Sensory, GC-MS and PTR-ToF-MS profiling of strawberries varying in maturity at harvest with subsequent cold storage. *Postharvest Biology and Technology* 182: 111719.
- Wang C, Zhang L, Qiao Y, Liao Li, Defang S, et al. (2022) Effects of ultrasound and ultra-high pressure pretreatments on volatile and taste compounds of vacuum-freeze dried strawberry slice. *LWT* 160: 113232.
- Modise DM, Wright CJ, Watson R, Linforth R, Taylor AJ (2004) Flavor volatile compound analysis in strawberry (*Fragaria x ananassa* Duch.) fruits: comparison of two mass spectrometer techniques for identifying volatile compounds. *South Afr J Botany* 70: 306-309.
- Williams A, Ryan D, Olartegasca A, Philip M, Eddie P (2005) Analysis of strawberry volatiles using comprehensive two-dimensional gas chromatography with headspace solid-phase microextraction. *J Chromatogr B* 817: 97-107.
- De Boisherebert V, Giraudel J-L, Montury M (2006) Characterization of strawberry varieties by SPME-GC-MS and Kohonen self-organizing map. *Chemometrics and Intelligent Laboratory Systems* 80(1): 13-23.
- Průchová K, Grégrová A, Helísková H, Vojtěch Kružík, Helena Čížková, et al. (2022) Enantioselective HS-SPME-GC-MS for Authentication of Natural and Synthetic Strawberry Flavour in Syrups. *Pol J Food Nutr Sci* 72: 305-317.
- Zheng S, Cai J, Huang P, Yuki W, Zhenbiao Y, et al. (2023) Determination of volatile profiles of woodland strawberry (*Fragaria vesca*) during fruit maturation by HS-SPME GC-MS. *J Sci Food Agric* 103(15): 7455-7468.
- Hayasaka T, Lin A, Copa VC, Lorenzo PL, Regine AL, et al. (2020) An electronic nose using a single graphene FET and machine learning for water, methanol, and ethanol. *Microsyst Nanoeng* 6: 50.
- Tan J, Xu J (2020) Applications of electronic nose (e-nose) and electronic tongue (e-tongue) in food quality-related properties determination: A review. *Artificial Intelligence in Agriculture* 4: 104-115.
- Chen H, Huo D, Zhang J (2022) Gas Recognition in E-Nose System: A Review. *IEEE Trans Biomed Circuits Syst* 16: 169-184.
- Zang C, Zhou H, Ma K, Yasuo Y, Shuwei L, et al. (2023) Electronic nose based on multiple electrospinning nanofibers sensor array and application in gas classification. *Front Sens* 4: 1170280.
- Liu H, Wu R, Guo Q, Zhongqiu Hua, Yi Wu (2021) Electronic Nose Based on Temperature Modulation of MOS Sensors for Recognition of Excessive Methanol in Liqueurs. *ACS Omega* 6(45): 30598-30606.
- Sanaeifar A, Mohtasebi SS, Ghasemi-Varnamkhasti M, Ahmadi H (2016)

- Application of MOS based electronic nose for the prediction of banana quality properties. *Measurement* 82: 105-114.
27. Rasekh M, Karami H, Wilson AD, Gancarz M (2021) Performance Analysis of MAU-9 Electronic-Nose MOS Sensor Array Components and ANN Classification Methods for Discrimination of Herb and Fruit Essential Oils. *Chemosensors* 9: 243.
28. Yimenu SM, Kim JY, Kim BS (2017) Prediction of egg freshness during storage using electronic nose. *Poultry Science* 96(10): 3733-3746.
29. Yongwei W, Wang J, Zhou B, Lu Q (2009) Monitoring storage time and quality attribute of egg based on electronic nose. *Anal Chim Acta* 650(2): 183-188.
30. Amiri A, Mortazavi SMH, Ramezani A, Mahmoodi SM, Mottaghipisheh J, et al. (2021) Prevention of decay and maintenance of bioactive compounds in strawberry by application of UV-C and essential oils. *Food Measure* 15: 5310-5317.
31. Raj R, Cosgun A, Kulić D (2022) Strawberry Water Content Estimation and Ripeness Classification Using Hyperspectral Sensing. *Agronomy* 12: 425.
32. Patel H, Taghavi T, Samtani JB (2023) Fruit Quality of Several Strawberry Cultivars during the Harvest Season under High Tunnel and Open Field Environments. *Horticulturae* 9: 1084.
33. Laksana AJ, Choi YM, Kim JH, Byeong-Sam K, Ji-Young K (2022) Real-Time Monitoring the Effects of Storage Conditions on Volatile Compounds and Quality Indexes of Halal-Certified Kimchi during Distribution Using Electronic Nose. *Foods* 11(15): 2323.
34. Laksana AJ, Kim JH, Ahn JH, Kim JY (2024) Volatile Compounds and Quality Characteristics of Fresh-Cut Apples and Mixed Fruits Coated with Ascorbic Acid during Cold Storage. *Agriculture* 14: 474.
35. Akter N, Reza MdSA, Esrafil Md, Alamin Md, Soniya A, et al. (2023) Nutritional, Textural, Sensory Properties and Storage Stability Evaluation of Newly Formulated Strawberry Bar. *FNS* 14(4): 287-299.
36. Feldmann MJ, Pincot DDA, Cole GS, Knapp SJ (2024) Genetic gains underpinning a little-known strawberry Green Revolution. *Nat Commun* 15(1): 2468.
37. Li M, Yang Z, Zhai X, Zhihua Li, Xiaowei H, et al. (2024) Incorporation of *Lactococcus lactis* and Chia Mucilage for Improving the Physical and Biological Properties of Gelatin-Based Coating: Application for Strawberry Preservation. *Foods* 13(7): 1102.
38. Hernández-Muñoz P, Almenar E, Valle VD, Dinoraz V, Rafael G (2008) Effect of chitosan coating combined with postharvest calcium treatment on strawberry (*Fragaria*×*ananassa*) quality during refrigerated storage. *Food Chemistry* 110(2): 428-435.
39. Menzel CM (2022) Effect of Temperature on Soluble Solids Content in Strawberry in Queensland, Australia. *Horticulturae* 8: 367.
40. Bose SK, Howlader P, Jia X, Wenxia W, Heng Yin (2019) Alginate oligosaccharide postharvest treatment preserve fruit quality and increase storage life via Absciscic acid signaling in strawberry. *Food Chem* 283: 665-674.
41. Nourozi F, Sayyari M (2020) Enrichment of Aloe vera gel with basil seed mucilage preserve bioactive compounds and postharvest quality of apricot fruits. *Scientia Horticulturae* 262: 109041.
42. Muley AB, Singhal RS (2020) Extension of postharvest shelf life of strawberries (*Fragaria ananassa*) using a coating of chitosan-whey protein isolate conjugate. *Food Chem* 329: 127213.
43. Lan W, Zhang R, Ahmed S, Wen Q, Yaowen L (2019) Effects of various antimicrobial polyvinyl alcohol/tea polyphenol composite films on the shelf life of packaged strawberries. *LWT* 113: 108297.
44. Khalifa I, Barakat H, El-Mansy HA, Soliman SA (2016) Improving the shelf-life stability of apple and strawberry fruits applying chitosan-incorporated olive oil processing residues coating. *Food Packaging and Shelf Life* 9: 10-19.
45. Tenea GN, Reyes P (2024) Bacterial community changes in strawberry fruits (*Fragaria* × *ananassa* variety “Monterey”) from farm field to retail market stands, an indicator of postharvest contamination. *Front Microbiol* 15: 1348316.
46. Satitmunnaithum J, Kitazawa H, Arofathullah NA, Ani Widiastuti, Agung DK, et al. (2022) Microbial population size and strawberry fruit firmness after drop shock-induced mechanical damage. *Postharvest Biol Technol* 192: 112008.
47. Pelayo C, Ebeler SE, Kader AA (2003) Postharvest life and flavor quality of three strawberry cultivars kept at 5°C in air or air+20 kPa CO₂. *Postharvest Biol Technol* 27(2): 171-183.
48. Panou AA, Karabagias IK, Riganakos KA (2020) Effect of Gamma-Irradiation on Sensory Characteristics, Physicochemical Parameters, and Shelf Life of Strawberries Stored under Refrigeration. *Int J Fruit Sci* 20(2): 191-206.
49. Sacks EJ, Shaw DV (1993) Color Change in Fresh Strawberry Fruit of Seven Genotypes Stored at 0C. *Hort Sci* 28: 209-210.
50. Anand SS, Philip BK, Mehendale HM (2014) Volatile Organic Compounds. In: *Encyclopedia of Toxicology*. Elsevier, pp. 967-970.
51. Forney CF, Kalt W, Jordan MA (2000) The Composition of Strawberry Aroma Is Influenced by Cultivar, Maturity, and Storage. *Hort Sci* 35: 1022-1026.
52. Ayala-Zavala JF, Wang SY, Wang CY, González-Aguilar GA (2004) Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. *LWT - Food Sci Technol* 37(7): 687-695.
53. Chen D, Anderson CJ (2023) Categorical data analysis. In: *International Encyclopedia of Education(Fourth Edition)*. Elsevier, pp. 575-582
54. Schober P, Boer C, Schwarte LA (2018) Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia & Analgesia* 126(5): 1763-1768.
55. Schieberle P, Hofmann T (1997) Evaluation of the Character Impact Odorants in Fresh Strawberry Juice by Quantitative Measurements and Sensory Studies on Model Mixtures. *J Agric Food Chem* 45: 227-232.
56. Fukuhara K, Li X-X, Okamura M, Kazuaki N, Yasuyoshi H (2005) Evaluation of Odorants Contributing to “Toyonaka” Strawberry Aroma in Extracts using an Adsorptive Column and Aroma Dilution Analysis. *J Japan Soc Hort Sci* 74: 300-305.
57. Jolliffe IT, Cadima J (2016) Principal component analysis: a review and recent developments. *Phil Trans R Soc A* 374(2065): 20150202.



This work is licensed under Creative Commons Attribution 4.0 License
DOI: [10.19080/ARTOAJ.2024.28.556422](https://doi.org/10.19080/ARTOAJ.2024.28.556422)

**Your next submission with Juniper Publishers
will reach you the below assets**

- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats
(Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission
<https://juniperpublishers.com/online-submission.php>