ABSTRACT
Aroma components from the ripe fruit of Prunus salicina L. cv. Friar and their changes during cold storage were analyzed in this study. Fifty-one volatiles were identified by dichloromethane direct extraction method using gas chromatography–mass spectrophotometry (GC-MS). Their total content was 50.4 μg/g, including alcohols, aldehydes, esters, lactones, acids, ketones, phenols, and small amounts of hydrocarbons and heterocyclic compounds. Nine compounds were determined as the would-be impact odorants of Prunus salicina L. cv. Friar, accounting for 24.7% of contents of total aroma components. According to the size of the aroma indices, their contribution to the aroma was list: (E)-2-hexenal, γ-dodecalactone, hexyl acetate, butane-2,3-diol, 3-methyl-2-butene-1-ol, hexanal, butyl acetate, 1-butanol, and 2-methyl-1-butanol. Compared with the ripe fruit of Prunus salicina L. cv. Friar, types and relative contents of the would-be impact odorants declined during cold storage at 0°C and the shelf-life period at 20°C after harvest. This result showed that low temperature inhibited the synthesis of aroma components to a certain extent. The lack of acetates and lactones, which contributed to fruit aroma largely, was the main reason for fading of fruit flavor after cold storage.

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Introduction
Volatile aroma components determine the special flavor of fruits and are closely related to human health and nutrition. With the increased inquiry of fruit quality, advanced analysis techniques such as gas chromatography–mass spectrophotometry (GC-MS) was used in analyzing of the fruit flavor. Compared with other fruits, such as apricots,1,2 nectarines,3,4 and peaches,5-7 few studies have focused on the volatile aroma compounds of plums, and some have shown that plums are very rich in volatile compounds, and more than 100 compounds had been identified.6-11 The volatiles of plums include primarily esters, aldehydes, terpenoids, acids, alcohols, alkanes, ketones, lactones, and phenols, among which esters form the most abundant group.12-15

Prunus salicina L. cv. Friar has good adaptability to drought and barren land, originated in China with a history of cultivation for more than 3000 years. They are distributed widely in the provinces of Shandong, Liaoning, Hebei, and Shanxi in China.16 Because of the large size and high yield, the fruit is loved by both growers and consumers. However, it matures at the end of August or early September, which is a hot and rainy season, resulting in a poor resistance to cold. Chilling injury,
such as fading of flavor or even loss of flavor can easily occur during cold storage of the fruit.\textsuperscript{17} To understand the reason for chilling injury and find a way to prevent it, we must study the volatile aroma components when fruits encounter chilling injury. It has been reported that during the low-temperature storage period of peach (cv. Bayuecui), the contents of hexenal and benzaldehyde were obviously inhibited.\textsuperscript{18} By studying the volatile compounds of three commercial Japanese plum cultivars (‘Pioneer’, ‘Laetitia’, and ‘Angeleno’), Louw and Theron found that for all the cultivars, the cold-stored plums had volatile profiles distinctly different from those of the immature, harvested, and tree-ripened fruit.\textsuperscript{19} However, changes of aroma components from \textit{Prunus salicina} L. cv. Friar during cold storage have not been studied.

The aim of this study was to examine the volatile composition in the ripe fruit of \textit{Prunus salicina} L. cv. Friar and estimate the contribution of the volatile compounds to the aroma, by identifying the would-be impact odorants present in the extracts of dichloromethane. Based on the above-mentioned research, we also investigated the changes in the would-be impact odorants during cold storage at 0°C.

\section*{Materials and methods}

\subsection*{Plant materials}

The fruits of 8-year \textit{Prunus salicina} L. cv. Friar were harvested at the commercial stage on September 1, 2013. The trees were planted 2 m apart within rows and 4 m apart between rows in the Xiwenzhuang orchard, located in Xiaodian area, the city of Taiyuan, Shanxi Province. The conventional management techniques, such as irrigation, fertilization, soil management, pruning, and disease control, were used in the orchard.

\subsection*{Treatments}

After harvest, the fruits were immediately transported to the laboratory. A total of 40 fruits were randomly selected and stored at room temperature for 15 days to be sufficiently developed with the strong and rich aroma. These selected fruits were used for extraction and analysis of the volatile composition to identify the would-be impact odorants. The remaining fruits were precooled at 0°C for 24 h, followed by selecting the healthy ones with hard and brittle texture, without pests and mechanical injury. These fruits were stored at 0−1°C in polyethylene bags of 20 μm thickness with six holes, the size of cigarette butts. In total, 10 kg of fruits was regarded as one replication and three such replications were conducted. Extraction and analysis of aroma components were conducted on the harvest day and day 49 and day 87 of cold storage, as well as day 7 of shelf life at 20°C.

\subsection*{Volatile extraction and concentration}

Total of 20 fruits were cut along the ventral suture, the stone was removed, and quartering sampled. Then, 250 g of the samples mixed with 200 mL of distilled water was homogenized and transferred to a separatory funnel of 1000 mL capacity. After adding the internal standard of 0.5 mL pentanoic acid, the concentration for 1.28 mg/mL, the volatile aroma components were extracted with 150, 100, and 50 mL of dichloromethane three times. The overall organic phase above was dried with anhydrous sodium, rotating evaporated, and concentrated to 1 mL for GC-MS. The internal standard of pentanoic acid was not added to cold storage samples.

\subsection*{GC-MS analysis}

The dichloromethane extracts were separated and analyzed on an Agilent (Palo Alto, CA) 5975C mass selective detector connected to an Agilent 7890A gas chromatograph, equipped with a
30 m × 0.25 mm × 0.25 μm HP-5 MS capillary column. Injection port temperature was 250°C with a split ratio of 10:1. The injection volume was 0.4 μL. Helium was used as the carrier gas at a linear velocity of 1.06 ml/min. The oven temperature was programmed from 40°C for 5 min, increasing at 5°C/min to 240°C, held for 5 min, and then increasing at 8°C/min to 300°C for 40 min. The transfer line was heated at 280°C. The operating conditions of the mass detector were as follows: the quadrupole temperature 150°C, source temperature 230°C, and electronic impact mode of 70 eV over the mass range m/z 30–350 amu in a full scan mode.

The identification of volatile compounds was achieved by comparing the mass spectra with the data system library (NIST, 2005) and combined with manual spectral analysis at the same time. The content of each volatile compound of ripe fruit was obtained as pentanoic acid equivalent to the GC peak area, and the relative content of aroma compounds during cold storage was obtained by the area normalization of GC results.

**Determination of fruit quality parameters**

Fruit quality parameters [firmness, total soluble solids (TSS), total acid content, rotted rate, and chilling injury index] were determined using the conventional detective methods. Eight fruits were randomly selected for determining firmness, TSS, and total acid content. Flesh firmness was measured in kilograms on two opposite pared sides of the fruit with an electronic penetrometer (Fruit Pressure Tester FT 327, Forli, Italy) fitted with a 5.0 mM tip. To determine the TSS, the fruits were destoned and ground. A drop of the mixed juice was dripped onto a digital refractometer (Pocket Refractometer PAL-1 ATAGO, Tokyo, Japan), which measured the TSS levels in %Brix. Total acid was expressed as the average equivalent (%) of malic acid, citric acid, and tartaric acid by titrating 10 g aliquot of the mixed plum juice with 0.1 M NaOH. The rotted rate was the percentage of the rotting fruit number taking up the total number of fruits. The chilling injury index was calculated as follows: the fruit was cut along the suture and the chilling pulp with water-soaked, transparent spots and having a clear dividing line with other health sites. The fruits were graded according to the size of chilling spot—no chilling injury was 0. Slight chilling injury and the chilling spot’s area less than 1/10 of the fruit was 1. Chilling spot area greater than 1/10 and less than 1/2 of the fruit was defined as level 2. Level 3 was the chilling spots occupying more than 1/2 of the fruit. The chilling injury index was expressed as: Σ (the fruit number × the chilling level)/(the total number of fruit × the highest level). Total fruit number for the rotted rate and the chilling injury index was more than 60.

**Results and discussion**

**Identification of volatile compounds of ripe fruit**

The total ion chromatogram of the ripe fruit and the retention time of the main components are shown in Figure 1. This methodology allowed tentatively identifying 51 compounds, representing a total content of 50.4 μg/g of the pulp (Table 1). Alcohols, accounting for 9.1 μg/g of the pulp, represented the major group of compounds with 18.0% of the total content. Among the 11 alcohols, the content of 22,23-dihydro-stigmasterol was the most abundant (4.27 μg/g of the pulp). Its structure was similar to that of cholesterol, and it could reduce total blood cholesterol and low-density lipoprotein levels in vivo and prevent cardiovascular disease to some extent. 22,23-Dihydro-stigmasterol was not tentatively identified in the fruit of plums earlier.\[^11–13,15\] The contents of 4-methoxybenzenemethanol, (Z)-3-hexen-1-ol, 1-butanol, and 2,6-dimethyl-2,7-octadiene-1,6-diol were 0.93, 0.81, 0.71, and 0.56 μg/g, respectively. The content of the remaining six alcohols was less than 0.50 μg/g. 1-Butanol, 2-methyl-1-butanol, 3-methyl-2-butene-1-ol, and butane-2,3-diol were above their sensory perception limits (SPLs) of 500, 250, 3, and 3 ng/g, respectively.\[^13,19\] The content of 1-hexanol was 0.49 ng/g, slightly lower than its SPL of 500 ng/g. The origin of C\(_6\) alcohols, such as 1-
hexanol, reported as an important contributor to the aroma of fresh plums, are related to the lipoxygenase activity.\textsuperscript{[11,12]} This enzyme occurring in plants and, namely, in fruits, catalyzes the oxidation of unsaturated fatty acids, as a first step, to produce short-chain alcohols.\textsuperscript{[20–23]} The C\textsubscript{6} alcohols contribute to the green and herbaceous odor.

A total of 10 ketones were identified, accounting for 21.0\% of the total content, which was 10.6 \(\mu\)g/g of ripe fruit. They mainly included 3-hydroxy-2-butanone, furanones, and pyranones. The content of five furanones was 6.47 \(\mu\)g/g, which accounts for 60.8\% of the total ketones, they were, respectively, 5-Ethylidihydro-2(3H)-furanone, Dihydro-5-propyl-2(3H)-furanone, 5-Hexylidihydro-2 (3H)-furanone, 5-[1-Hydroxyhexyl]-tetrahydrofuran-2-one and 5-Butylidihydro-2(3H)-furanone. Furan compounds were also detected in some plums.\textsuperscript{[12]}

Four aldehydes, including hexanal, (E)-2-hexenal, benzaldehyde, and benzeneacetaldehyde, represented 9.7 \(\mu\)g/g of the pulp, accounting for 19.3\% of the total content. Hexanal and (E)-2-hexenal (4.4 and 5.0 \(\mu\)g/g, respectively) were the most abundant, above their SPL (64 and 17 ng/g, respectively).\textsuperscript{[20,24]} The same results were observed with C\textsubscript{6} alcohols, these C\textsubscript{6} aldehydes were also produced from the metabolizing process of unsaturated fatty acids and mainly contributed to the green odor of fruit.\textsuperscript{[18,21,23,25]} Benzaldehyde with an almond flavor had been described as a contributor to the aroma of the fresh plums.\textsuperscript{[10,11]} However, in this study, its content was lower than its SPL (350 ng/g).

The content of acids was low (1.4 \(\mu\)g/g), representing only 2.8\% of the total content. Of the four acids, hexadecanoic acid was the most abundant (1.1 \(\mu\)g/g), but its content was lower than its SPL (10 \(\mu\)g/g). Hexadecanoic acid has already been identified in candied plum, and it has been described to have grassy and heavy odor descriptors.\textsuperscript{[12]}

Esters are considered to be the most important aroma constituents of fruits, contributing to fruity and floral notes.\textsuperscript{[11,12,20]} The total of nine esters, accounting for 7.5 \(\mu\)g/g, represented 14.8\% of the total content. Hexyl acetate (0.2 \(\mu\)g/g) was highly above its SPL (2 ng/g).\textsuperscript{[24]} The content of butyl acetate was 0.3 \(\mu\)g/g, which was also above its SPL (66 ng/g).\textsuperscript{[19]} Although the esters are important aroma constituents of fruits, contributing to the fruity aroma notes, the processing and storage promote their hydrolysis and decrease their content.\textsuperscript{[8,12]}

Two lactones, butyrolactone and \(\gamma\)-dodecalactone, were detected in this study. Their contents were 0.3 and 1.2 \(\mu\)g/g, respectively. \(\gamma\)-Dodecalactone was above its SPL (7 ng/g).\textsuperscript{[12]} Lactones are formed from the corresponding hydroxy acids. These compounds, particularly \(\gamma\)-lactones, are important compounds in terms of their contribution to the aroma and pleasant fruity odor descriptors generally.\textsuperscript{[11,21]}
Table 1. Volatiles contents (μg/g FW equivalent of pentanoic acid) of ‘friar’ plum in ripe fruit.

| Retention time | Compound                          | Molecular weight | Content (μg/g) |
|----------------|-----------------------------------|------------------|---------------|
| 4.16           | 1-Butanol                         | 74.1             | 0.71 ± 0.22   |
| 6.09           | 2-Methyl-1-butanol                | 88.1             | 0.31 ± 0.13   |
| 7.29           | 3-Methyl-2-butene-1-ol            | 86.1             | 0.23 ± 0.05   |
| 7.52           | Butane-2,3-diol                   | 90.1             | 0.24 ± 0.06   |
| 10.30          | (Z)-3-Hexen-1-ol                  | 100.1            | 0.81 ± 0.05   |
| 10.81          | 1-Hexanol                         | 102.1            | 0.49 ± 0.03   |
| 16.70          | Benzyl alcohol                    | 108.1            | 0.17 ± 0.07   |
| 24.27          | 4-Methoxy-benzenemethanol         | 138.1            | 0.93 ± 0.06   |
| 26.36          | 2,6-Dimethyl-2,7-octadiene-1,6-diol| 170.1          | 0.56 ± 0.02   |
| 33.64          | 3,4,5-Trimethoxy-benzenemethanol  | 198.1            | 0.37 ± 0.03   |
| 62.91          | 22,23-Dihydro-stigmasterol        | 414.4            | 4.27 ± 0.11   |
| 5.18           | 3-Hydroxy-2-butanone              | 88.1             | 1.72 ± 0.08   |
| 17.37          | 5-Ethylidihydro-2(3H)-furanone    | 114.1            | 0.80 ± 0.22   |
| 23.60          | Dihydro-5-propyl-2(3H)-furanone   | 128.1            | 0.13 ± 0.04   |
| 24.38          | Tetrahydro-6-propyl-2H-pyran-2-one| 142.1            | 0.25 ± 0.05   |
| 29.13          | 5-Hexylidihydro-2(3H)-furanone    | 170.1            | 2.65 ± 0.02   |
| 29.84          | Tetrahydro-6-pentyl-2H-pyran-2-one| 170.1            | 1.50 ± 0.03   |
| 32.28          | 5-[1-Hydroxyhexyl]-tetrahydrofuran-2-one | 186.1     | 0.22 ± 0.08   |
| 33.78          | 6-Isopropenyl-9-methyl-1-oxaspiro[4,5]decan-2-one | 208.2 | 0.58 ± 0.09   |
| 34.19          | 5-Butylidihydro-2(3H)-furanone    | 100.0            | 2.67 ± 0.01   |
| 34.43          | Tetrahydro-4-hydroxy-6-pentyl-2H-pyran-2-one | 186.1 | 0.12 ± 0.13   |
| 8.16           | Hexanal                           | 100.1            | 4.42 ± 0.05   |
| 10.16          | (E)-2-hexenal                     | 98.1             | 4.97 ± 0.09   |
| 14.14          | Benzaldehyde                      | 106.0            | 0.26 ± 0.07   |
| 17.04          | Benzenecoaceteldehyde             | 120.1            | 0.06 ± 0.03   |
| 8.79           | Butyl acetate                     | 116.1            | 0.26 ± 0.06   |
| 15.79          | (Z)-3-Hexen-1-ol acetate          | 142.1            | 0.09 ± 0.02   |
| 16.01          | Hexyl acetate                     | 144.1            | 0.17 ± 0.06   |
| 37.99          | Isobutyl octyl phthalate          | 334.2            | 3.72 ± 0.12   |
| 39.84          | Diisobutyl phthalate              | 278.2            | 1.16 ± 0.07   |
| 44.40          | Isobutyl cyclohexyl methyl phthalate| 318.2     | 0.72 ± 0.02   |
| 45.21          | Butyl 2-ethylhexyl 1,2-benzenedicarboxylate | 334.2 | 0.43 ± 0.03   |
| 45.77          | 2-Propyl dodecyl sulfate          | 306.2            | 0.50 ± 0.04   |
| 53.93          | E-8-Methyl-9-tetradecen-1-ol acetate| 268.2   | 0.40 ± 0.07   |
| 12.41          | Butyroxyacetone                   | 86.0             | 0.26 ± 0.09   |
| 34.04          | y-Dodecalactone                   | 198.2            | 1.16 ± 0.13   |
| 23.7           | Nonanoic acid                     | 158.1            | 0.10 ± 0.02   |
| 29.60          | Maleamic acid                     | 115.0            | 0.19 ± 0.03   |
| 39.67          | n-Hexadecanoic acid               | 256.2            | 1.06 ± 0.15   |
| 45.11          | Nonahexacontanoic acid            | 999.1            | 0.08 ± 0.03   |
| 30.13          | 2,4-Bis(1,1-dimethylethyl)-phenol  | 206.2            | 0.03 ± 0.02   |
| 30.25          | Butylated hydroxytoluene          | 220.2            | 4.74 ± 0.18   |
| 21.48          | Naphthalene                       | 128.1            | 0.08 ± 0.02   |
| 21.85          | Dodecane                          | 170.2            | 1.15 ± 0.06   |
| 24.67          | Tridecane                         | 184.2            | 0.80 ± 0.09   |
| 32.14          | Nonadecane                        | 268.3            | 0.27 ± 0.12   |
| 34.37          | Heptadecane                       | 240.3            | 0.45 ± 0.08   |
| 36.49          | Octadecane                        | 254.3            | 0.39 ± 0.22   |
| 41.38          | 1,8-Naphthalic anhydride          | 198.0            | 0.29 ± 0.11   |
| 50.25          | Tetratriacontane                  | 478.6            | 1.30 ± 0.06   |
| 56.87          | Eicosane                          | 282.3            | 1.18 ± 0.09   |

Note: The content of all compounds identified were expressed as the average of three cultivars.
Phenols and hydrocarbons accounted for 4.8 and 5.9 μg/g of the pulp, representing 9.5% and 11.7% of the total content, respectively. Within these groups of compounds, butylated hydroxytoluene (4.7 μg/g) was the most abundant. Naphthalene and its derivatives were detected in fresh plum (Prunus domestica L.) and its various products. Dodecane was also identified in 'Methley' plum.

**Searching and identification of the would-be impact odorants of the ripe fruit**

Any kind of ripe fruit has its special flavor; however, all the volatiles are not necessarily equally important. Only those aroma compounds with higher content and lower threshold constitute the would-be impact odorants of the fruit. In order to evaluate the contribution of the compounds to the aroma of Prunus salicina L. cv. Friar, the aroma indices (I) were calculated.

\[ I = \frac{c}{s} \]

where \( c \) is the content found in the pulp of ripe fruit by dichloromethane extraction and \( s \) is the SPL for the compound reported in the literature. The SPLs vary depending on the sample matrix, pH, the sample temperature, and the methodologies of sensory analysis used. In this study, SPL in water was used for all the available compounds. Compounds that exhibit \( I > 1 \) are considered to have a potential individual contribution to the aroma. In the ripe fruit of ‘Friar’ plum, the following nine compounds were identified as having an \( I > 1 \): (E)-2-hexenal, α-dodecalactone, hexyl acetate, butane-2,3-diol, 3-methyl-2-buten-1-ol, hexanal, butyl acetate, 1-butanol, and 2-methyl-1-butanol (Table 2). They are the would-be impact odorants of Prunus salicina L. cv. Friar, which are associated with sweet, cooked, and fruity odors. Their content was 12.5 μg/g, representing 24.7% of the total content.

**Changes of the would-be impact odorants and fruit quality during cold storage and shelf-life period**

Currently, cold storage is often used in commercial production; therefore, this investigation studied the changes of the would-be impact odorants during cold storage at 0°C and shelf-life period (Figure 2 and Table 3). At harvest, four kinds of would-be impact odorants, 2-methyl-1-butanol, hexanal, butyl acetate, and (E)-2-hexenal, were detected representing 20.4% of the relative content of the total aroma compounds, and (E)-2-hexenal was the most abundant (15.4%). At day 47 of cold storage, 2-methyl-1-butanol and butyl acetate were not detected and the relative content of (E)-2-hexenal increased to 16.1% from 15.4% at harvest. The relative content of hexanal declined to some extent compared with that at harvest, so the total relative content declined to 19.8%. Up to day 87 of cold storage, only hexanal and (E)-2-hexenal were detected, whose relative content also declined to 13.5%. At day 7 of shelf-life at 20°C, butane-2,3-diol, hexanal, and (E)-2-hexenal were detected, and

### Table 2. Volatile compounds of 'Friar' plum with aroma index (\( I > 1 \)) and their odor descriptors.

| Compound            | Content (μg/g) | SPL (ng/g) | I     | Odor descriptors     |
|---------------------|---------------|------------|-------|----------------------|
| 1-Butanol           | 0.71 ± 0.22   | 500[^a]    | 1.42  | Fruity, mellow       |
| 2-Methyl-1-butanol  | 0.31 ± 0.13   | 250[^a]    | 1.24  | Mellow, apple, banana|
| 3-Methyl-2-buten-1-ol| 0.23 ± 0.05   | 3[^b]      | 76.7  | Apple                |
| Butane-2,3-diol     | 0.24 ± 0.06   | 3[^b]      | 80.9  | Syruppy              |
| Hexanal             | 4.42 ± 0.05   | 64[^c]     | 69.1  | Green                |
| (E)-2-hexenal       | 4.97 ± 0.09   | 17[^c]     | 292.4 | Green, almonds       |
| Butyl acetate       | 0.26 ± 0.06   | 66[^a]     | 3.9   | Fruity               |
| Hexyl acetate       | 0.17 ± 0.06   | 2[^a]      | 85.0  | Synthetic fruity     |
| γ-Dodecalactone     | 1.16 ± 0.13   | 7[^c]      | 165.7 | Peach, apricot       |

SPL reported by: [^a] Wang et al., 2008; [^b] Nunes et al., 2008; [^c] Tian et al., 2009.  
Note: The content of all compounds identified were expressed as the average of three cultivars.
Figure 2. Total ion chromatograms of volatile compounds during cold storage at 0°C and shelf-life period of ‘friar’ plum.
their relative content was 10.5%. 3-Methyl-2-butene-1-ol and 1-butanol, which are also the would-be impact odorants of *Prunus salicina* L. cv. Friar, were not detected during cold storage and shelf-life period. Wei et al. (2009) also found that the relative content of the volatiles of Royal Gala apples decreased during cold storage at 0°C, in either bagged or non-bagged fruit.

Esters are the most important compounds of the fruit, and they are also the main source of fruit aroma. Based on the above-mentioned findings in this study, it is understood that butyl acetate and hexyl acetate were the would-be impact odorants of *Prunus salicina* L. cv. Friar and primarily contributed to the ester-like flavor of the fruit. However, during cold storage and shelf-life period, butyl acetate was detected only at harvest and hexyl acetate was not detected throughout the period. Lactones, particularly γ-lactones, had an important role in forming the special aroma of drupe fruits such as peach and apricot, and γ-dodecalactone was also the would-be impact odorant of *Prunus salicina* L. cv. Friar. However, it was not found during cold storage and shelf-life period. The lack of acetates and lactones was probably the main reason for fading of fruit flavor after cold storage.

The results of the fruit sensory quality are shown in Table 4. At harvest, the flesh firmness, TSS, and total acid content were 5.7 kg/cm², 18.3%, and 1.14%, respectively. Their contents declined during cold storage, and at day 87 at 0°C storage, their contents decreased to 4.16 kg/cm², 17.6%, and 0.94%, respectively. After cold storage followed by shelf life at 20°C for 7 days, the flesh firmness and total acid content continued to drop to 3.87 kg/cm² and 0.89%,
respectively; however, the TSS increased slightly to 17.9%. Compared with harvest, at 0°C storage for 49 day, the pulp color turned to yellow and the chilling injury index was 0.06, with no visible chilling injury and rot; at day 87, the pulp color turned to red and some chilling injury occurred: flesh translucency, browning, off-flavor, and the chilling injury index increased to 0.56, the rotted rate was 9.1%, too.[22] After cold storage followed by shelf life at 20°C for 7 days, the chilling injury was more serious, the rotted rate increased to 10%, and the fruit flavor also had no significant improvement. The result was consistent with the findings on the research of aroma components during cold storage and shelf life. Based on the study of the aroma components in peach (cv. Bayuecui) during storage in modified atmosphere and shelf life, Guo et al.[18] found that transferring to room temperature after harvest directly elevated the content of linalool and γ-decalactone, and by transferring to room temperature after storage for 60 days again, these components remained at the level of out-store or declined.

### Conclusion

A total of 51 components were identified from the ripe fruit of *Prunus salicina* L. cv. *Friar* using extracts of dichloromethane and analyzed by GC-MS. Alcohols, aldehydes, esters, lactones, ketones, acids, and phenols were the major constituents. The composition and content of the different types of aroma components are quite different. Nine compounds having an $I > 1$, 1-butanol, 2-methyl-1-butanol, 3-methyl-2-butene-1-ol, butane-2,3-diol, hexanal, butyl acetate, (E)-2-hexenal, hexyl acetate, and γ-dodecalactone are the would-be impact odorants of *Prunus salicina* L. cv. *Friar*. Their content was 12.5 μg/g, representing 24.7% of the total content. Study of the would-be impact odorants during cold storage and shelf life showed that their species and relative contents at harvest reached the maximum, then gradually decreased with extended storage time, and were the least at day 87 of cold storage. At this time, the fruit also showed a certain degree of chilling injury. After the shelf life of 7 days, the would-be impact odorants and fruit quality had no obvious improvement. γ-Dodecalactone and hexyl acetate, contributing to fruit aroma largely, were not detected during cold storage and shelf life. The present study suggests that when the ‘Friar’ plum was stored at 0°C in bags of perforated polyethylene (thickness 20 μm), the storage period should be within 50 days. Extending the cold storage time will lead to chilling injury, decreased aroma components, and lower fruit quality. Such damage of fruit due to a long period of low temperature almost could not be restored by transferring to room temperature.

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### Table 4. Changes of the fruit quality during cold storage and shelf-life period.

| Fruit quality parameters | At harvest | At 0°C for 49 days | At 0°C for 87 days | At 0°C for 87 days and 20°C for 7 days |
|--------------------------|------------|-------------------|-------------------|---------------------------------------|
| Fruit firmness (kg/cm²)  | 5.70 ± 0.75 | 4.50 ± 0.66       | 4.16 ± 0.49       | 3.87 ± 0.65                           |
| Total soluble solids(%)  | 18.3 ± 0.23 | 18.1 ± 0.25       | 17.6 ± 0.29       | 17.9 ± 0.30                           |
| Total acid content(%)    | 1.14 ± 0.11 | 1.05 ± 0.16       | 0.94 ± 0.18       | 0.89 ± 0.20                           |
| Rotted rate(%)           | 0          | 0                 | 9.1 ± 0.33        | 10.0 ± 0.31                           |
| Chilling injury index    | 0          | 0.06 ± 0.02       | 0.56 ± 0.03       | 0.94 ± 0.06                           |
| Fruit pulp color         | Yellowish-green | Yellow      | Red               | Red and purple                      |

Note: The results were expressed as the average of three cultivars.
