

# CULTIVAR AND HARVEST DATE EFFECTS ON FLAVOR AND OTHER QUALITY ATTRIBUTES OF CALIFORNIA STRAWBERRIES

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Accepted for Publication September 30, 2004

## ABSTRACT

*“Aromas,” “Diamante” and “Selva” strawberries were harvested in early and mid-season and evaluated for quality attributes, flavor components, fermentative metabolites and physiological characteristics. Preference and flavor tests by consumer panels were also conducted. Cultivar variation was greater than harvest date variation as were differences in color, concentrations of anthocyanins, firmness, total soluble solids, sugars, pH, titratable acidity (TA), organic acids and aroma compounds. “Diamante” and “Selva” had higher aroma quality than “Aromas” fruits. The levels of fermentative metabolites were too low to have an impact on the aroma quality. “Diamante” and “Selva” strawberries had better overall flavor quality and were more preferred by consumers than “Aromas.” These differences were consistent over two harvest dates.*

## INTRODUCTION

“Aromas” and “Diamante” are day-neutral strawberry cultivars released in 1994 by the Breeding Program at the University of California, Davis. They

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were also introduced into other countries like Mexico a few years later. These cultivars are replacing "Selva," which had been the major commercial strawberry cultivar in California and in other producing areas of the world, but their flavor and other quality attributes have not been reported. Sugars and acids are important determinants of the sensory quality of strawberries (Alavoine and Crochon 1989; Haffner and Vestrheim 1997; Wozniak *et al.* 1997). Shaw (1988) reported small differences in total sugars, but a significant genotypic variation in the content of sucrose, glucose and fructose in his breeding population. Kalt and McDonald (1997) also reported differences in the sucrose level among cultivars and an increase in the glucose/fructose ratio with sequential harvests in a 2-year study, suggesting that a combination of genetic and environmental factors influences the proportion of specific sugars in ripe strawberries. Although the titratable acidity (TA) and the organic acid content are reported to be mainly genetically determined (Shaw 1988, 1990), substantial differences in the level of citric and malic acids between seasons due to water stress were reported by Kalt and McDonald (1997). Total soluble solids (TSS) and TA vary in strawberries harvested at commercial ripeness from 5 to 12% and from 0.50 to 1.87%, respectively, depending on cultivar and preharvest factors (Kader 1991; Perkins-Veazie 1995). Duewer and Zych (1967) found a strong cultivar variation in TSS, while Shaw (1988, 1990) reported that this variable was mostly affected by environmental factors.

Qualitative and quantitative differences in strawberry aroma compounds among cultivars have been reported by several authors (Pyysalo *et al.* 1979; Dirinck *et al.* 1981; Miszczak *et al.* 1995; Pérez *et al.* 1997b). The specific proportion of the alkyl fractions methyl and ethyl, of the acyl fractions butyrate and hexanoate and of esters are cultivar dependent (Forney *et al.* 2000). Furaneol and linalool have been identified in many commercial cultivars at varying levels (Larsen *et al.* 1992; Sanz *et al.* 1995; Pérez *et al.* 1996). On the basis of concentration and of odor threshold values, Larsen *et al.* (1992) found that the importance of the contribution of  $\gamma$ -decalactone and 2-heptanone to the aroma of strawberries was cultivar dependent. Dirinck *et al.* (1981) observed a good relationship between flavor intensity and total concentration of aroma compounds in different cultivars over seasons. An approach to categorize the aroma quality of strawberry cultivars based on aroma values was presented by Pérez *et al.* (1997b), but no sensory evaluation was conducted to support these results.

In addition to flavor components, other quality attributes are influenced by stage of development and genetic and environmental factors. Cultivar and maturity are the factors considered to have the greatest effect on strawberry color (Sistrunk and Morris 1985). The content of pelargonidin-3-glucoside (Pg-3-glu) and cyanidin-3-glucoside (C3G), the main anthocyanins in strawberries, varied among the cultivars "Cavendish," "Honeoye" and "Kent," but

not with harvest dates during the typical 2–4-week production cycle of the plants (Kalt and McDonald 1997). The correlations between internal and external color are low, suggesting that these traits are controlled by separate genes (Shaw 1991). The degree of softening at the ripe stage of strawberries is highly dependent on cultivar and preharvest environment (Kader 1991; Perkins-Veazie and Collins 1995).

Our objective is to evaluate the strawberry cultivars “Selva,” “Aromas” and “Diamante” for quality attributes, flavor components, fermentative metabolites, physiological characteristics and consumer preferences at two harvesting dates during the season.

## MATERIALS AND METHODS

### Fruit Source

Three replicates of 10 kg of strawberries (*Fragaria* × *ananassa* Dutch.) of each cultivar (“Aromas,” “Diamante” and “Selva”) and harvesting date (May 25 and August 10, 2000) were obtained from a packinghouse collecting strawberries from different orchards in Watsonville, California, U.S.A. The fruits were harvested at commercial ripeness (more than 75% showing red color), packed in 1 lb baskets and flat containers and air-force cooled to 0C. The fruits were transported to the University of California, Davis in an air conditioned car on the same day of harvest and placed at 0C overnight. The next morning, the strawberries were sorted to eliminate defective, overripe or undersized ones.

### Color, Firmness, TSS, pH and TA

At each harvest three, 15-berry samples of each cultivar were selected randomly and kept at room temperature for at least 1 h. Firmness and surface color were evaluated on opposite sides of each fruit. An Ametek Penetrometer (Mansfield & Green Division, Largo, FL) equipped with a 3 mm flat tip and mounted on a drill press stand was used for firmness measurements. Color variables (lightness,  $L^*$ , chroma,  $C^*$  and hue angle,  $h^*$ ) were measured using a Minolta chromameter (Minolta Corporation Ramsey, NJ). The same fruits were cut in small pieces, wrapped in cheesecloth, squeezed with a hand press and the clear juice used for analysis. TSS, pH and TA were quantified as described by Gil *et al.* (1997).

### Anthocyanins

The total anthocyanins were measured using a modified pH differential method (Wrolstad 1976). Five mL of the fresh juice was centrifuged at

13,400 × g for 10 min. Two 1-mL aliquots of the supernatant were diluted to 5 mL with pH 1.0 KCl-HCl buffer and pH 4.5 acetate buffer, respectively. The absorbance at 520 nm was measured in both solutions. The concentration of pigments based on Pg-3-glu, the dominant anthocyanin in strawberries, was calculated by subtracting the absorbance at pH 4.5 from the absorbance at pH 1 and by using the molar extinction coefficient of Pg-3-glu. Using the same analytical procedure, the anthocyanin content of the internal and external tissues separated as previously described by Holcroft and Kader (1999), of three, 15-berry samples of each cultivar at each harvest was also quantified.

### Total Phenolic Compounds

At each harvest three, five-berry samples, randomly selected from each cultivar, were directly frozen in liquid N<sub>2</sub> and stored at -20C for subsequent analysis. Frozen strawberries were thawed and homogenized in a blender. From the homogenate, three samples of 10, 10 and 15 g were used for the analysis of phenolics, sugars and organic acids and furaneol, respectively. Phenolics were analyzed by using the Folin-Ciocalteu spectrophotometric method (Singleton and Rossi 1965). The quantification was based on a *p*-coumaric acid standard curve.

### Flavor Components

Sugars (glucose, fructose and sucrose) and organic acids (citric and malic) were analyzed according to Perez *et al.* (1997a) by HPLC (Hewlett-Packard, Palo Alto, CA) using a photodiode array detector (DAD model 1040M, Hewlett-Packard, Palo Alto, CA) in series with a refractive index detector. Organic acids detected at 210 nm and sugars were identified by the retention times of the reference compounds and were quantified by standard curves. Furaneol, a thermo-unstable aroma compound, was analyzed according to the procedure described by Sanz *et al.* (1994) using the HPLC system that was previously described. Furaneol was identified by the retention time of a standard solution and quantified by a standard curve. For aroma compounds other than furaneol, a minimum amount (equivalent to approximately 10% of a juice volume) of a NaOH + EDTA solution was added to fresh strawberry juice to obtain a final pH of 6.2–6.5 and a 50 mM concentration of the chelating agent. Ethylene diamine tetra acetic acid (EDTA) was added to limit enzymatic and chemical reactions and therefore to prevent the generation of aroma artifacts. Juice samples were frozen in liquid N<sub>2</sub> and stored at -20C until the analysis of aroma compounds was conducted.

Five-mL samples of this juice were placed in a crimp-seal 16-mL vial containing 2 g of NaCl (to facilitate the release of aroma compounds), sealed with a black viton septum and 20 mm crimp caps, agitated for 30 s and

analyzed by a headspace solid-phase micro extraction technique using a HP 5890 gas chromatograph (Hewlett Packard, Palo Alto, CA) coupled to a mass spectrometer (HP 5971 with an electronic upgrade to a Model 5972) and a Varian 8200 cx autosampler (Walnut Creek, CA). This system was operated by HP MSD ChemStation software. The MS detector was operated in the scan mode ranging from 40 to 330 mass/charge. The GC oven was fitted with a 60 m length  $\times$  0.32 mm internal diameter and 1  $\mu$ m film thickness DB-WAXETR capillary column (J & W Scientific, Folsom, CA). The temperature was 50C for 1 min, then increased to 110C at 5C/min and to 180C at 20C/min and finally held for 10 min (total cycle time, including oven cool-down, approximately 29 min). The injector and the detector were kept at 200 and 280C, respectively. The autosampler was fitted with a 65  $\mu$ m Carbowax Divinylbenzene SPME fiber (Supelco, Bellefonte, PA) and programmed for an 11-min cycle: 10-min adsorption time for sampling the headspace and 1 min for desorption in the GC injector. During desorption, the injector was in the splitless mode; subsequently, it was put into the split mode for the rest of the run. The headspace samplings were done at 25–30C. The identification of aroma compounds was initially accomplished by matching mass spectra with library values. The confirmation of the identity of the major volatiles was performed by injecting standard aqueous solutions of each compound directly into the Gas Chromatograph-Mass Spectrometer (GC-MS) and also by trapping the volatiles from the headspace by the Solid Phase Microextraction (SPME) fiber under the same conditions as those used for the strawberry juice samples. Quantification was carried out by comparing peak areas of analytes to that of 2,6 dimethyl-5-heptenal added at 280 nL/L as the internal standard to the strawberry samples (Ulrich *et al.* 1995).

The approach reported by Pérez *et al.* (1997b) to evaluate the aroma quality of cultivars was used in the present work. The aroma compounds of strawberries were first classified into three groups according to their odor characterization. The group of fruity notes included methyl and ethyl butyrate, methyl and ethyl hexanoate and butyl acetate; the group of green odor notes included hexanal (E) 2-hexenal and hexyl acetate and the group of sweet odor notes included only furaneol. Then, by considering the concentration of every aroma compound present in the fruit of each cultivar and their corresponding threshold values, as reported by Pérez *et al.* (1997b) and Schieberle and Hofmann (1997), the aroma values were calculated.

### **Fermentative Metabolites**

Samples of 5 mL of fresh strawberry juice were placed in crimp-seal 10-mL vials containing 2 g of NaCl, sealed and frozen at –20C until the analysis of fermentative metabolites (acetaldehyde, ethanol and ethyl acetate) was

conducted. The frozen samples were thawed and the vials incubated at 30C for 15 min. After a 10 s agitation period, a sample of 1 mL was withdrawn from the headspace and injected into a HP 5890 GC equipped with a flame ionization detector (FID) and analyzed using 60/80 Carbopack B/5% Carbowax 20 M, 6 ft × 2-mm I.D. column (Supelco, Bellefonte, PA). The operation conditions were: injector temperature 115C, detector temperature 200C and oven temperature program 80C, increased to 130C at 10C/min and held for 6 min. Fermentative metabolites were identified by the retention times of reference compounds and concentrations calculated by using standard aqueous solutions of every analyte and by preparing the corresponding standard curves under the same conditions as those used for the strawberry samples.

### **Physiological Variables**

At each harvest date three, 25 berry samples of each cultivar were selected randomly and placed in 3.6-L glass jars. The jars were placed at 5C and ventilated with a continuous flow of humidified air at a rate of 150 mL/min using flow boards and capillary tubing (Claypool and Keefer 1942). The respiration rates were based on the analysis of CO<sub>2</sub>, measured with an infrared gas analyzer (HORIBA 2000R; Horiba Instruments, Irvine, CA) in the samples withdrawn at regular intervals from the jar atmospheres. The ethylene production rates were measured by a static system. The strawberry jars were closed for 1–3 h before a sample from the headspace was withdrawn from every jar. Ethylene was quantified by a Carle Analytical Gas Chromatograph 211 (EG & G Chandler Engineering, Tulsa, OK) equipped with a flame ionization detector using an alumina packed column, N<sub>2</sub> as a carrier gas and an isothermal separation at 80C. Based on areas of standard gases, concentration of CO<sub>2</sub> and ethylene were calculated.

### **Sensory Evaluation**

At each harvest, more than one hundred fruits of each cultivar were selected randomly for a preference test and a similar number for a scaling flavor test. The tests were carried out 24–36 h after harvest using 0C refrigerated fruits previously rinsed with tap water and warmed at room temperature. The samples consisting of whole fruits were coded with random numbers in identical containers and the order of presentation to each consumer was also randomized. One hundred and five consumers were randomly recruited for each sensory test from the University of California, Davis population, mainly, from the Department of Pomology. In the preference test, the consumers ranked the fruits from the three cultivars for overall preference and the results were analyzed by converting ranks to scores (1 = least preferred, 3 = most preferred). In the scaling flavor test, the flavor of the strawberries

was scored by the consumers using an unstructured 0–10 scale with 0 corresponding to poor flavor and 10 to excellent flavor. The results were analyzed by computing the points assigned to each sample.

### Statistical Analysis

SAS System, version 7 (1998; SAS Institute Inc., Cary, NC) was used to perform analysis of variance (ANOVA) and to obtain cultivar-harvest interactions and least significant difference (LSD) (5%) values of each of the main effects.

## RESULTS AND DISCUSSION

### Color, Anthocyanins, Phenolic Compounds and Firmness

The color of strawberries was significantly different between harvest dates and among cultivars (Table 1). As indicated by the lower  $h^*$  and the higher  $C^*$  and  $L^*$  values, the fruit color was more red, vivid and light in August than in May, probably due to differences in field temperatures and light intensity during fruit development and maturation (Sistrunk and Morris 1985; Kalt and McDonald 1997). Among cultivars, “Aromas” was more red (lower  $h^*$  value) and dark (lower  $L^*$  values) than “Diamante” and “Selva,” while “Diamante” and “Selva” were similar in color. However, a clear differ-

TABLE 1.  
COLOR, TOTAL CONTENT OF ANTHOCYANINS AND PHENOLIC COMPOUNDS AND FIRMNESS OF THREE STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST

| Harvest date and cultivar        | Color     |        |       | Anthocyanins (mg/L) | Total phenolics (mg/100 g) | Firmness (Newtons/kg <sup>2</sup> ) |
|----------------------------------|-----------|--------|-------|---------------------|----------------------------|-------------------------------------|
|                                  | Lightness | Chroma | Hue   |                     |                            |                                     |
| May                              |           |        |       |                     |                            |                                     |
| Aromas                           | 33.2b     | 36.6a  | 29.1b | 128a                | 157a                       | 2.7a                                |
| Diamante                         | 37.2a     | 37.7a  | 31.2a | 86b                 | 167a                       | 2.7a                                |
| Selva                            | 36.8a     | 37.5a  | 31.9a | 92b                 | 165a                       | 3.2a                                |
| August                           |           |        |       |                     |                            |                                     |
| Aromas                           | 34.5b     | 36.7b  | 24.0b | 146a                | 149b                       | 2.5b                                |
| Diamante                         | 38.2a     | 41.3a  | 28.6a | 85b                 | 170a                       | 3.9a                                |
| Selva                            | 38.2a     | 42.6a  | 29.3a | 137a                | 179a                       | 3.0b                                |
| SE                               | 0.84      | 1.05   | 1.13  | 11.3                | 4.3                        | 0.21                                |
| LSD <sub>Harvest date (5%)</sub> | 0.46*     | 0.64*  | 1.12* | 17.8*               | 14.5                       | 0.39                                |

Means followed by the same letter are not significantly different, LSD ( $\leq 0.05$ ).

\* Significant at the indicated level.

ence in the visual color was observed between “Diamante” and “Selva” fruits (pale red and red, respectively) over the 2000 harvest dates and over the two seasons when observations from the previous year were considered. Either the differences in the color values between these two cultivars could be masked by data variability or the individual  $h^*$ ,  $C^*$  and  $L^*$  values could not reflect the color sensory perception. Maybe, a single value, computed from  $h^*$ ,  $C^*$  and  $L^*$  data that was more related with sensory perception, needs to be established for strawberries. The anthocyanin content was different in “Aromas” and “Selva” fruits depending on the harvest date, but it was the same in “Diamante” strawberries harvested in May and August. Similar results were observed when previous data from strawberries that were harvested in September 1999 were considered (Aromas = 136, Diamante = 67 and Selva = 106 mg of anthocyanin/L juice). These data show that the concentration of pigments in strawberries can be influenced by harvest date and by harvest season depending on cultivar. The pigment content over the May and August 2000 harvest dates (average: “Aromas” = 137, “Diamante” = 85.5 and “Selva” = 114.5 mg/L) and the 1999–2000 harvest seasons (average: “Aromas” = 136, “Diamante” = 79 and “Selva” = 112 mg/L) was consistent with the characteristic external visual color of “Aromas” (dark-red), “Diamante” (pale red) and “Selva” (red) (Larson 2000) but not with the internal color of strawberries (“Aromas” = mostly white with dark red areas, “Diamante” = mostly white with pale red areas and “Selva” = uniformly red). The reason for this lack of consistency is that only approximately 20% of the total anthocyanin content was present in the internal tissues of “Aromas” and “Diamante” strawberries, whereas approximately 50% in the internal tissues of “Selva” fruits. These results confirm the lack of relationship between external and internal color in strawberries reported by Shaw (1991) and categorize “Aromas” and “Diamante” strawberries as more suitable fruits for fresh consumption, because an intense internal red color is essential for processing (Perkins-Veazie and Collins 1995).

The harvest date did not affect the total phenolic content, but an influence of harvest season on the content of these compounds was observed in “Diamante” and “Selva” fruits (data not shown). “Aromas” had the lowest level of total phenolics in the August harvest (Table 1). The firmness was not affected by the harvest date, but an influence of cultivar on this variable was observed. The firmness values of “Aromas” and “Selva” fruits were more consistent over the harvest dates than of “Diamante” values (Table 1).

### **Sugars, Organic Acids and Related Variables**

The TSS contents were higher in the strawberries harvested in May than in those harvested in August and “Diamante” and “Selva” had a higher TSS



content than “Aromas” fruits (Table 2). The main contribution to TSS is given by sugars, followed by organic acids and soluble pectins. A high correlation between the TSS and the total sugars was found in our study ( $r^2 = 0.82$ ). Thus, the TSS could be considered a good indicator of sugar content in these cultivars. Similar results were reported by Kader (1991), working with nine California strawberry cultivars ( $r^2 = 0.71$ ) and by Kallio *et al.* (2000), for “Senga Sengana” in a 2-year study ( $r^2 = 0.63$ – $0.84$ ).

The total sugar content was not affected by the harvest dates (Table 2) and it was higher in “Diamante” and “Selva” than in “Aromas” fruits, with no difference in the level of total sugars between “Diamante” and “Selva” strawberries. Fructose was more abundant than glucose and the ratio fructose/glucose was similar in the three cultivars (“Aromas” = 1.3, “Diamante” = 1.2 and “Selva” = 1.1–1.2) and consistent over the harvest dates. Thus, the sucrose index, a value considering the contribution of individual sugars to sweetness, essentially provided the same information as the total sugar content, i.e., “Diamante” and “Selva” were sweeter than “Aromas” fruits. This result was consistent over two harvest seasons (1999–2000, data not shown).

The harvest date did not affect pH and TA (Table 2). “Aromas” or “Diamante” strawberries had the lowest pH depending on harvest date, but only “Diamante” fruits had the highest TA at both harvest dates. No good correlation between pH and TA was found in this study ( $r^2 = 0.42$ ). The level of citric and malic acids were not affected by the harvest date, but “Diamante” exhibited the highest level of citric acid (the dominant organic acid in strawberries) in the May harvest and “Selva” had the highest concentration of malic acid in the August harvest (Table 2). Thus, “Diamante” and “Selva” fruits showed the highest content of total organic acids in the May and August harvests, respectively.

## Aroma Compounds

Qualitatively, the same aroma compounds were identified in the two harvest dates of the three cultivars. Quantitatively, the level of total aroma compounds varied with harvest date and cultivar in “Aromas” and “Selva” fruits, but it was consistent in “Diamante” fruits over the two harvest dates. Esters and furaneol were the most abundant aroma compounds in the three cultivars (Figs. 1 and 2A) followed by linalool and, depending on cultivars, benzaldehyde or C6 aldehydes (Fig. 3). Methyl esters dominated over ethyl esters in the “Aromas” strawberries harvested in May and in fruits of the three cultivars harvested in August (Fig. 1). Apparently, the ratio of methyl/ethyl esters was not dependent only on cultivar, as indicated by Forney *et al.* (2000), but also on harvest date.

TABLE 2.  
SUGARS, ORGANIC ACIDS AND RELATED VARIABLES OF THREE STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST

| Harvest date and cultivar        | TSS (%) | Sucrose (%) | Glucose (%) | Fructose (%) | Total sugars (%) | pH   | TA (%) | Citric acid (%) | Malic acid (%) | Total organic acids (%) |
|----------------------------------|---------|-------------|-------------|--------------|------------------|------|--------|-----------------|----------------|-------------------------|
| May                              |         |             |             |              |                  |      |        |                 |                |                         |
| Aromas                           | 6.0c    | 1.42c       | 1.36c       | 1.71c        | 4.49b            | 3.6c | 0.74b  | 0.52b           | 0.17b          | 0.69b                   |
| Diamante                         | 9.0b    | 2.12a       | 1.87b       | 2.23b        | 6.22a            | 3.7b | 0.87a  | 0.67a           | 0.18a          | 0.85a                   |
| Selva                            | 10.1a   | 1.78b       | 2.17a       | 2.48a        | 6.43a            | 3.8a | 0.75b  | 0.51b           | 0.18a          | 0.69b                   |
| August                           |         |             |             |              |                  |      |        |                 |                |                         |
| Aromas                           | 6.4b    | 1.08c       | 1.43b       | 1.81b        | 4.32b            | 3.7a | 0.76b  | 0.54b           | 0.14b          | 0.68bb                  |
| Diamante                         | 7.5a    | 1.87a       | 1.50b       | 1.82b        | 5.19a            | 3.6b | 0.83a  | 0.62a           | 0.15b          | 0.77ab                  |
| Selva                            | 7.8a    | 1.49b       | 1.89a       | 2.30a        | 5.68a            | 3.7a | 0.77b  | 0.60a           | 0.25a          | 0.85a                   |
| SE                               | 0.62    | 0.15        | 0.13        | 0.13         | 0.35             | 0.03 | 0.02   | 0.03            | 0.02           | 0.03                    |
| LSD <sub>Harvest date (5%)</sub> | 0.89*   | 0.17*       | 0.22        | 0.21         | 0.59             | 0.08 | 0.04   | 0.04            | 0.04           | 0.07                    |

Means followed by the same letter are not significantly different, LSD ( $\leq 0.05$ ).

\* Significant at the indicated level.

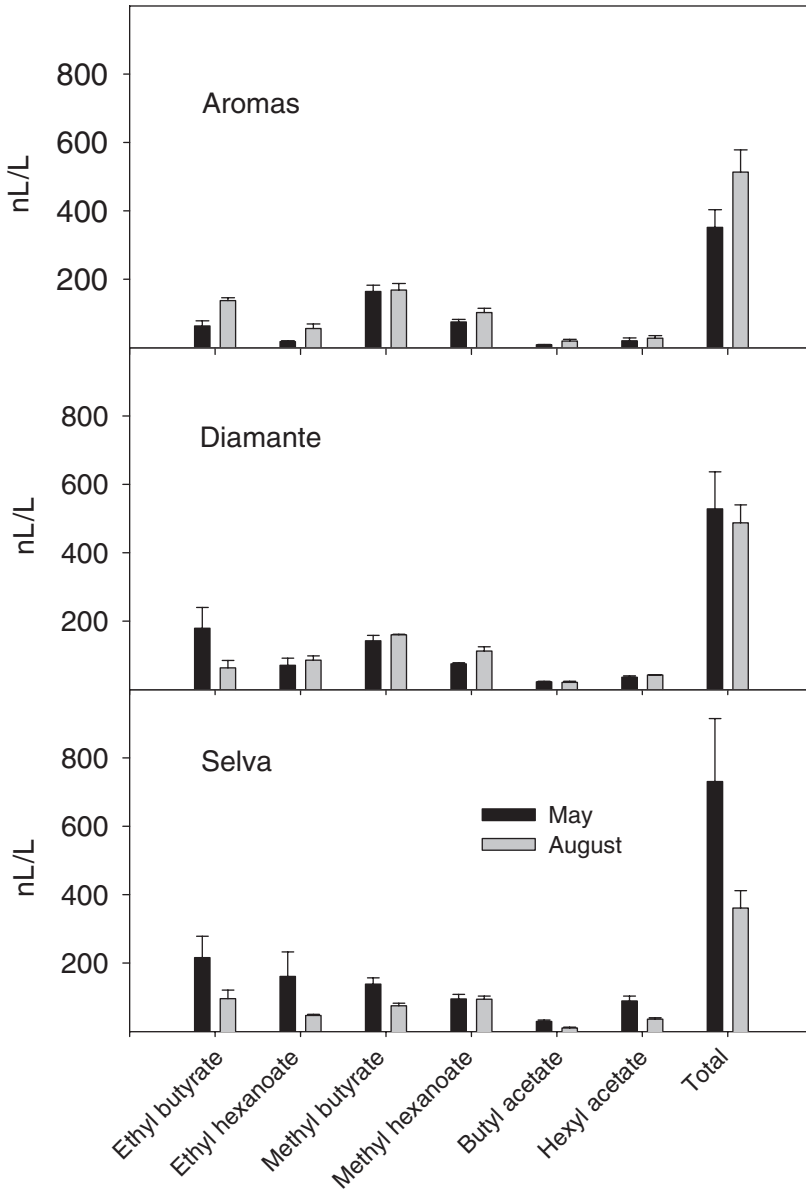


FIG. 1. ESTERS OF THREE STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST  
Means of three replicates  $\pm$  SD.

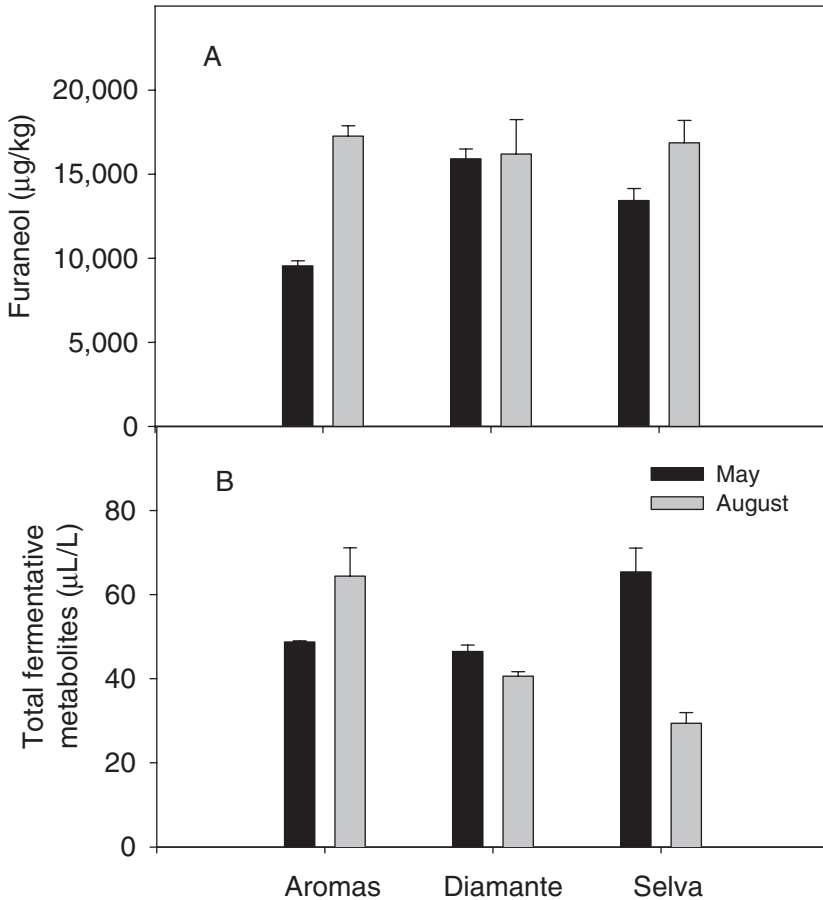


FIG. 2. FURANEOL (A) AND FERMENTATIVE METABOLITES (B) OF THREE STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST  
Means of three replicates  $\pm$  SD.

The influence of the harvest date on the total aroma value was observed in “Aromas,” but not in “Diamante” and “Selva” strawberries, which exhibited similar total aroma values at both harvest dates (Table 3). “Diamante” and “Selva” fruits had the highest average total aroma value. The aroma values for individual aromatic notes were more consistent over the harvest dates for “Diamante” than for “Aromas” and “Selva” strawberries. “Diamante” had greater average green and sweet aroma values than “Selva,” but the largest average fruity aroma value corresponded to “Selva” fruits.

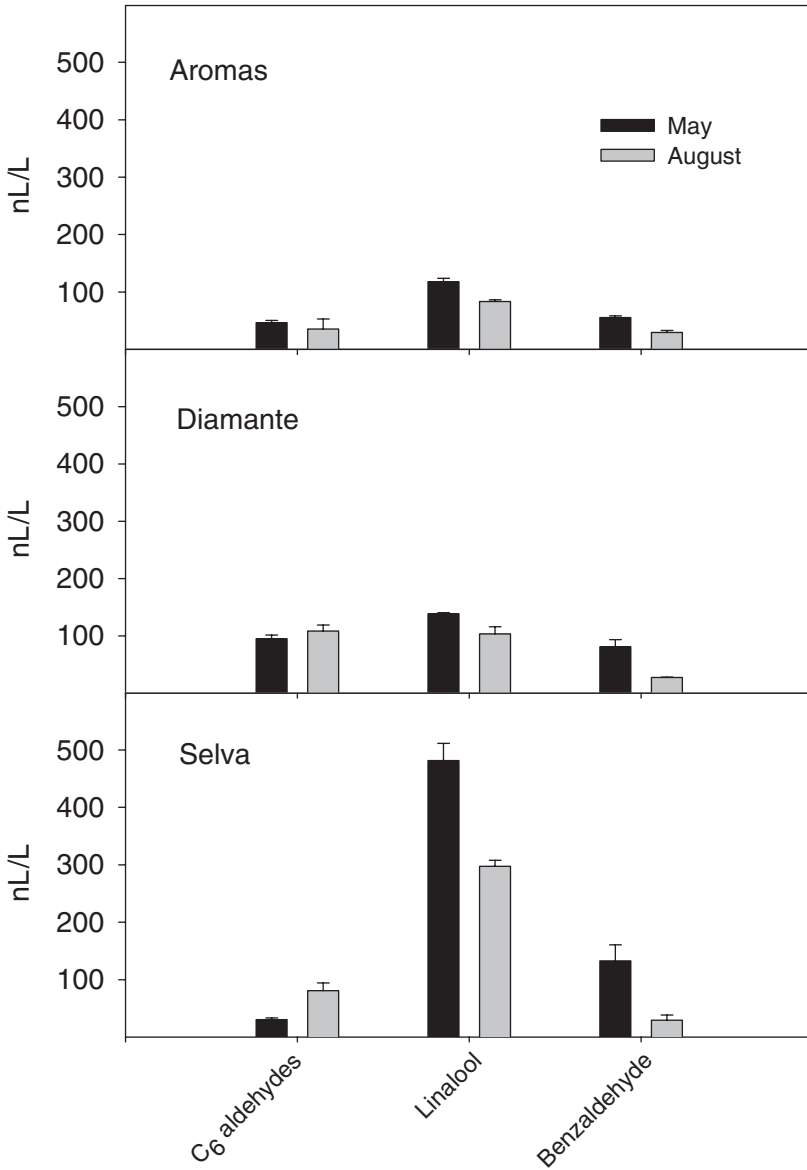


FIG. 3. C<sub>6</sub> ALDEHYDES, LINALOOL AND BENZALDEHYDE OF THREE STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST  
Means of three replicates ± SD.

TABLE 3.  
ODOR CHARACTERIZATION BASED ON THE AROMA VALUES OF INDIVIDUAL  
COMPOUNDS WITH FRUITY, GREEN AND SWEET AROMATIC NOTES OF THREE  
STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST

| Harvest date<br>and cultivar     | Aroma value |       |        |        |
|----------------------------------|-------------|-------|--------|--------|
|                                  | Fruity      | Green | Sweet  | Total  |
| May                              |             |       |        |        |
| Aromas                           | 142c        | 0.7b  | 955c   | 1098b  |
| Diamante                         | 432b        | 1.3a  | 1592a  | 2025a  |
| Selva                            | 768a        | 1.2a  | 1343b  | 2112a  |
| August                           |             |       |        |        |
| Aromas                           | 343a        | 0.6c  | 1726a  | 2070a  |
| Diamante                         | 371a        | 1.5a  | 1620a  | 1993a  |
| Selva                            | 262a        | 1.2b  | 1687a  | 1950a  |
| SE                               | 139.0       | 0.16  | 110.1  | 219.8  |
| LSD <sub>Harvest date (5%)</sub> | 142.8       | 0.16  | 113.1* | 225.8* |

Means followed by the same letter are not significantly different, LSD ( $\leq 0.05$ ).

\* Significant at the indicated level.

### Fermentative Metabolites

The total content of fermentative volatiles was low ( $\sim 50\text{--}70/\mu\text{L}$ ) (Fig. 2B), with ethanol predominating (about 95% of the total concentration). Although differences in the level of fermentative metabolites between harvest dates and among cultivars were observed, their contribution to the aroma quality of the fruit was probably not significant because of the high odor threshold of ethanol (100–800 mg/kg) (Larsen 1994) and the low levels of acetaldehyde and ethyl acetate ( $\sim 2$  and  $0.2 \mu\text{L/L}$ , respectively).

### Physiological Variables

The respiration rate was higher in strawberries picked in May than in those harvested in August and “Aromas” and “Diamante” exhibited the lowest respiration rates in this harvest date (Table 4). The ethylene production was not affected by the harvest date and “Aromas” cultivar showed the lowest production rate in the May harvest. The ethylene production rates of “Aromas” and “Selva” fruits were notably 15 and 7 times lower, respectively, at the two harvest dates than those we observed in a previous harvesting season (data not shown), in contrast with the similar ethylene production rate of “Diamante” fruit in the two harvesting dates and in both seasons.

TABLE 4.  
RESPIRATION AND ETHYLENE PRODUCTION OF THREE STRAWBERRY CULTIVARS  
HARVESTED IN MAY AND AUGUST

| Cultivar                         | CO <sub>2</sub> (mg/kg/h) |        | C <sub>2</sub> H <sub>4</sub> (nL/kg/h) |        |
|----------------------------------|---------------------------|--------|---|--------|
|                                  | May                       | August | May                                     | August |
| Aromas                           | 11.9c                     | 9.8bb  | 7.0b                                    | 6.4b   |
| Diamante                         | 16.5b                     | 11.9ab | 12.1a                                   | 6.9b   |
| Selva                            | 23.1a                     | 14.1a  | 12.4a                                   | 11.3a  |
| SE                               |                           | 1.9    |   | 1.1    |
| LSD <sub>Harvest date (5%)</sub> |                           | 1.0*   |   | 4.5    |

Means followed by the same letter are not significantly different, LSD ( $\leq 0.05$ ).

\* Significant at the indicated level.

### Sensory Evaluation

The preference test results indicated that “Diamante” and “Selva” were more preferred than “Aromas” in the May harvest and “Diamante” was preferred over “Aromas” and “Selva” fruits in the August harvest. Similarly, “Diamante” and “Selva” obtained higher flavor scores than “Aromas” fruits in the May harvest and “Diamante” had the highest flavor score in the August harvest (Fig. 4). The preference test results obtained in a previous season indicated a significant difference (SD) among cultivars, with “Diamante” and “Selva” having similar preference scores (2.2 and 2.3, respectively) and being preferred over “Aromas” strawberries (preference score = 1.5). The highest correlations between sensory scores and flavor components corresponded to the total aroma values ( $r^2 = 0.62$  for preference and  $r^2 = 0.73$  for flavor scores), followed by total sugars ( $r^2 = 0.53$  for preference and  $r^2 = 0.4$  for flavor scores) and TSS ( $r^2 = 0.53$  for preference and  $r^2 = 0.40$  for flavor scores). Thus, the preference by consumers and the higher flavor scores of “Diamante” and “Selva” fruits may be related to their higher aroma values and to their greater content of sugars.

Notably, no cultivar had an average score above 6 for flavor on a 10-point scale (10 = highest score), even for “Diamante” and “Selva” cultivars at the May harvest when TSS, sugars and some specific aroma volatiles were higher. Other researchers have obtained similar results. After analyzing approximately 300 samples of 10 Californian and European commercial cultivars harvested over a 3-year period, Alavoine and Crochon (1989) reported 11.8 as the highest taste mark on a 20-point scale. In a sensory study with experienced fruit tasters or consumers of 7–10 cultivars, such as “Chandler” and “Parker,” grown in four Australian farms over a 3-year period, Ford *et al.* (1997)

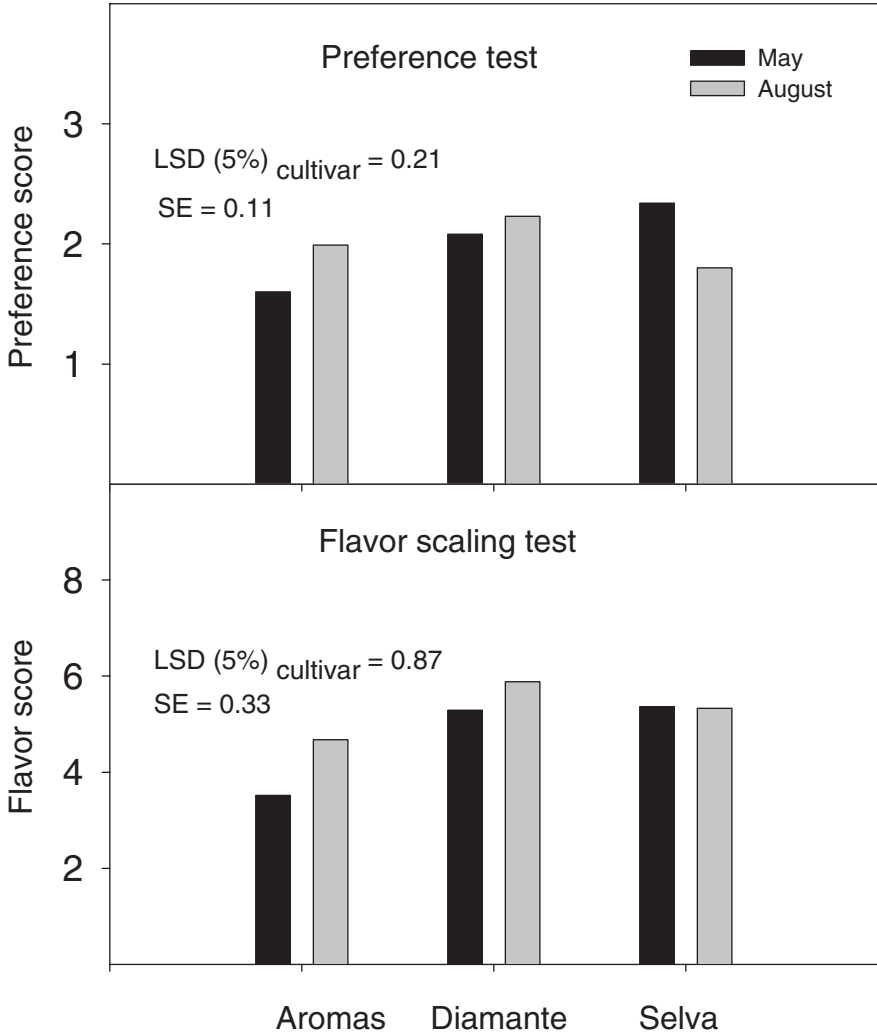


FIG. 4. SENSORY EVALUATION SCORES OF THREE STRAWBERRY CULTIVARS HARVESTED IN MAY AND AUGUST

Means of 105 consumers. Preference score: 1 = least preferred, 3 = most preferred. Flavor score: 0 = poor flavor, 10 = excellent flavor.

reported a flavor intensity range of 43–73 on a 100-point scale. These results suggest that the flavor characteristics of currently available cultivars may not fit consumer expectations of “excellent strawberry flavor,” possibly because the use of flavor profiles in the selection of new cultivars has not been



considered by breeders. Some breeding programs are now incorporating consumer flavor attributes. Native clones of *Fragaria chiloensis* and *Fragaria virginiana* have unique aromas that have not yet been characterized (Hancock 1999).

## CONCLUSIONS

The results of the color and the content of anthocyanins indicated harvest date and cultivar influences on strawberry color and confirmed the reported typical external color of each cultivar (Larson 2000) as well as the poor relationship between external and internal fruit color (Sistrunk and Morris 1985; Shaw 1991). No differences in flesh firmness values were found between harvest dates and “Diamante” strawberries showed the highest firmness value in the August harvest. The only cultivars satisfying the recommended minimum TSS (7%) and maximum TA (0.8%) for an acceptable flavor (Mitcham *et al.* 1996) were “Diamante” and “Selva”. On the basis of the aroma values of compounds with fruity, green and sweet odor notes, “Diamante” and “Selva” exhibited a higher aroma quality than “Aromas” strawberries. The concentration of fermentative metabolites was not high enough to impact the aroma quality of strawberries. The consumer preferences for “Diamante” and “Selva” fruits were consistent over the harvest dates and appear related with greater contents of sugars and higher aroma values and flavor scores as compared with “Aromas” strawberries.

## ACKNOWLEDGMENTS

We thank Betty Hess-Pierce and Da-Mi Jung for their technical assistance, as well as Murray Clayton and Blanca Rosa Perez-Salvador for their advice on statistical analysis. We also thank the National Council on Science and Technology (CONACYT) in Mexico for the financial support of Clara Pelayo-Zaldivar during her Ph.D/studies.

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