Journal of Food and Nutrition Research, 2017, Vol. 5, No. 11, 844-851
Available online at http://pubs.sciepub.com/jfnr/5/11/8

DOI:10.12691/jfnr-5-11-8

Bioactive and Volatile Compounds in Sweet Cherry Cultivars

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Abstract The organoleptic and nutritive quality of sweet cherry is largely influenced by the genotype. Phenolic compounds, antioxidant activity, organic acids, sugars and volatile compounds of seven sweet cherry cultivars (*Lory, Burlat, Brooks, Summit, Prime Giant, Van,* and *57*) grown in Alicante (Spain) were evaluated. The most important organic acid was malic acid and fructose and glucose were found in greater quantity in the sweet cherry cultivars. The cultivars with the highest antioxidant activity were *Burlat* and Brooks, very important from a health point of view. Regarding volatile compounds thirty one were isolated having Van the highest contents. *57*, and *Burlat* sweet cherry genotypes were the most interesting with respect to "health benefits". However, if the most important factor is "organoleptic quality" (combination of dark red colour and intense flavor), our recommendations are *Van*, *57*, and *Prime Giant*.

Keywords: *antioxidant activity, aroma, colour, organic acids, phenolics*

Cite This Article: P. Legua, A. Domenech, J.J. Martínez, L. Sánchez-Rodríguez., F. Hernández, A.A. Carbonell-Barrachina, and P. Melgarejo, "Bioactive and Volatile Compounds in Sweet Cherry Cultivars." *Journal of Food and Nutrition Research*, vol. 5, no. 11 (2017): 844-851. doi: 10.12691/jfnr-5-11-8.

1. Introduction

Sweet cherry is one of the most popular fruit and this popularity is based on its highly appreciation by consumers due to its excellent quality. Fruit quality is determined by pomological and biochemical characteristics, mainly dependent on the cultivar genotype, although the different size controlling rootstock also had a significant effect [1]. The main characteristics related to cherry fruit quality are skin colour, sweetness, sourness and firmness [2,3,4,5].

Sweet cherries have been reported to contain phenolic compounds and anthocyanins [6,7,8,9]. Besides, there are numerous studies supporting the hypothesis that fruits, including sweet cherries, contain several compounds that may be useful in reducing the risk of several degenerative diseases, such as cancer and cardiovascular illness [8,10]. A reduction of arthritis and gout pain has been associated to the specific consumption of cherries.

Volatile compounds are key elements in determining fruit quality and finally consumers' acceptance [11,12]. Sometimes and especially in early cultivars, the odour and aroma of fruits (sensory attributes linked to the volatile composition), including sweet cherry, have very low quality due to low contents and low number of odour active compounds [12]. Therefore, it is essential to study the volatile composition of sweet cherries to be able to recommend farmers cultivars of high interest to be cultivated.

Consequently, the aim of this investigation was to quantify the contents of several bioactive compounds (sugars, organic acids, total phenolic compounds, and antioxidant activity), colour (it is important in determining consumers' acceptance), volatile composition, and sensory quality of 7 cultivars of Spanish sweet cherries in order to indicate the best varieties for growers.

2. Materials and Methods

2.1. Plant Material and Experimental Design

Seven commercial sweet cherry (*Prunus avium* L.) cultivars were harvested during the months of May (*Lory*, *Burlat*, *Brooks*, *Summit*, and *Prime Giant*), and June (*Van* and *57*) 2013. The samples were obtained from a commercial farm in Alicante (Spain). The maturity criteria used to establish harvest dates were based on weight, colour, texture, and taste characteristics [13,14].

Sweet cherries were randomly harvested and immediately transport to the laboratory for analysis. After proper selection to have homogeneous samples, 30 fruits per variety were selected, and 3 subsamples (batches) of 10 fruits were prepared for each variety. The parameters analysed in these 3 batches were: sugars, organic acids,

total phenolic compounds content, antioxidant activity, and volatile compounds.

2.2. Organic Acids and Sugar Content

In the laboratory, the subsamples were squeezed using a commercial blender. The crude juices were sieved to eliminate solid particles, and the pre-filtered juices were centrifuged at 10,000 *g* for 20 min. One millilitre of the centrifuged liquid was passed through a 0.45µm Millipore filter, and then injected into a Hewlett-Packard HPLC series 1100. The elution system consisted of 0.1% phosphoric acid with a flow rate of 0.5 mL/min. Organic acids were separated on a Supelcogel TM C-610H column (30 cm × 7.8 mm i.d.; Supelco, Bellefonte, PA, USA) and Supelguard column (5 cm x 4.6 mm; Supelco, Inc., Bellefonte, PA) and detected using absorbance at 210 nm. For sugar determinations, the same HPLC, elution system, flow rate, and columns were used, but the sugars detection was conducted using a refractive index detector (HP 1100, G1362A).

Standard curves of pure organic acids (oxalic, citric, tartaric, malic, ascorbic, quinic, shikimic, succinic, acetic, and fumaric acids) as well as of pure sugars (glucose, maltose, fructose, sucrose, and sorbitol) purchased from Sigma (Poole, Dorset, UK), were used for quantification. Data on organic acids and sugars were presented as mean ± standard error, SE (n=3), and were expressed as g *per* 100 g (%).

2.3. Antioxidant Activity and Total Phenolic Compounds

Total antioxidant activity (TAA) and total phenolic compounds (TPC) content were quantified as described by Serrano et al. [2] in the whole fruit, skin and pulp; this methodology enables the determination of TAA as the addition of the hydrophilic and lipophilic compounds in the same extraction. Briefly, for each sub-sample, 5 g of sweet cherry tissue, after pit removal, were homogenized in 5 mL of 50 mM phosphate buffer (pH=7.8) and 3 mL of ethyl acetate; then, the mixture was centrifuged at 10,000 *g* for 15 min at 4°C. The upper fraction was used to quantify the antioxidant activity due to lipophilic compounds (L-TAA) and the lower one for the antioxidant activity due to hydrophilic compounds (H-TAA) and TPC. The total antioxidant activity was determined in triplicate in each extract using the enzymatic system consisting of the chromophore 2,2´-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), the horseradish peroxidase enzyme (HRP), and the oxidant substrate (hydrogen peroxide), in which $ABTS^{+}$ radicals are generated and monitored at 730 nm. The decrease in absorbance after adding the extract was proportional to the TAA of the sample. A calibration curve was prepared with Trolox ((R)-(+)-6-hydroxy-2,5,7,8-tetramethyl-croman-2-carboxylic acid) in the range 0-20 nmol. Data on TAA were presented as mean ± SE (n=3), and expressed as mg of Trolox equivalent *per* 100 g fresh weight. Calibration curves, in the range 0.01-5.00 mmol Trolox L^{-1} were used for the quantification of antioxidant activity showing good linearity ($r^2 \geq 0.998$).

The TPC content was quantified using Folin-Ciocalteu reagent [15]. Absorption was measured for the sample at 760 nm using spectrophotometer (ThermoSpectronic Heγios, made England). Data on TPC were presented as mean ± SE (n=3), and expressed as mg gallic acid equivalent (GAE) *per* 100 g of fresh weight, fw. Calibration curves, with a concentration range between 0 and 0.25 g GAE L^{-1}, were used for the quantification of TPC, and showed good linearity ($r^2 \geq 0.996$).

2.4. Colour

Colour was measured in sweet cherries according to Manera et al. (2013), using a Minolta C-300 Chroma Meter (Minolta Corp., Osaka, Japan) coupled to a Minolta DP-301 data processor. This colourimeter uses an illuminant D65 and a 10˚ observer as references. Colour was assessed according to the Commission Internationale de l'Éclairage (CIE) and expressed as *L**, *a**, *b**. The coordinate *L** indicates lightness, and takes values within the range 0–100 (black-white, respectively), and *a** and *b** are the chromatic coordinates, green-red, and blue-yellow coordinates, respectively. The green-red coordinate takes positive values for reddish colours and negatives for greenish ones, whereas *b** takes positive values for yellowish colours and negative values for bluish ones. Colour data were presented as mean ± SE (n=3, with 3 measurements made for each replication).

2.5. Extraction of Volatile Compounds

Headspace solid phase micro-extraction (HS-SPME) was the method selected to evaluate the volatile profiles of sweet cherry cultivars, according to Hernández et al. [16]. For the extraction of volatile compounds, approximately 2 g of ground fresh sweet cherry, including the skin, plus 15 mL of ultrapure water were placed in 50 mL vials with a polypropylene cap and a PTFE/silicone septum; the ratio solution (salty water + cherry) to headspace was approximately 1:4. A magnetic stirring bar was added, together with NaCl (15%) to avoid enzymatic reactions and to promote volatiles release. The vials were equilibrated in a water bath for 15 min at 40°C (simulating the temperature of the human mouth); after this equilibration time, a 50/30 µm DVB/CAR/PDMS fiber was exposed to the sample headspace of the vial for 50 min at 40ºC. This specific fiber was selected because its high capacity of trapping fruits volatile compounds.

Extraction experiments were run in triplicate. After sampling, the desorption of the volatile compounds from the fiber coating was carried out at the GC-MS injection port during 3 min; the injector temperature was 230°C.

2.6. Chromatographic Analyses

The isolation and identification of the volatile compounds from sweet cherry were achieved on a GC-MS system [16] consisting of: (i) a gas chromatograph, Shimadzu GC-17A (Shimadzu Corporation, Kyoto, Japan), and (ii) a Shimadzu mass spectrometer detector GC-MS QP-5050A. The system was equipped with a TR-820262 Meta.X5 column (Teknokroma S. Coop. C. Ltd, Barcelona, Spain; 60 m x 0.25 mm x 0.25 µm film thickness). Analyses were carried out using the chromatographic conditions previously described by Vázquez-Araújo et al. [17].

Most of the compounds were identified using three different analytical methods: (1) retention indexes, (2) GC-MS retention times of pure standards, and (3) mass spectra (pure chemicals and Wiley spectral library collection). Identification was considered tentative when it was based on only mass spectral data [18].

The quantification of the volatile compounds was performed on a gas chromatograph, Shimadzu 2010, with a flame ionization detector (FID). The column and chromatographic conditions were those previously reported for the GC-MS analysis. The injector temperature was 250°C and nitrogen was used as carrier gas (1 mL min^{-1}).

For the quantification of the volatile compounds, *trans*-anethole was added as internal standard; this chemical was used as internal standard after checking that it was absent in the volatile compounds profiles of sweet cherries and under the proposed conditions, it separated well from all other compounds. Data included in this study should be considered as semi-quantitative, because no standard curves were carried out for each one of the quantified volatile compounds. However, relative values are useful to compare differences among samples from different cultivars.

2.7. Statistical Analyses

Data were examined by analysis of variance (ANOVA) using SPSS 22.0 for Windows (SPSS Science, Chicago, IL, USA). Wherever *F* values were significant, Tukey's multiple range test was used to separate the mean effects. Significance was defined at $p \leq 0.05$. Graphics were created using Sigma Plot 9.0 (SPSS Science, Chicago, IL, USA).

3. Results and Discussion

3.1. Organic Acids and Sugar Content

Malic, tartaric, ascorbic, and shikimic acids contents in different cultivars of sweet cherry fruits are shown in Table 1. The predominant organic acid in sweet cherry was malic acid (1200-1895 mg/100 g fw), which is in agreement with Serrano et al. [2], Girard and Kopp [19], Usenik et al. [20,21], Esti et al. [5] and Ballistreri [22]. Ascorbic and tartaric presented intermediate contents (10-44 mg/100 g fw), while shikimic acid was only a minor constituent, with its content being below 2.5 mg/100 g fw. Cultivar "Prime Giant" had the highest content of malic, ascorbic and shikimic acids and a high content of tartaric acid. In general, lower contents of organic acids in cultivars "Burlat", "Summit", and "Van" were measured in the study by Usenik et al. [20], and Girard and Kopp [19]; these differences could be due, among other factors, to farming conditions and rootstocks.

The major sugars found in the 7 sweet cherry cultivars were fructose and glucose (Table 2). Generally, fructose was found to have the highest content (range 8.3-10.5 g/100g fw) followed by glucose (6.6-9.2 g/100 g fw), arabinose (<0.4 g/100 g fw) and sorbitol (traces). Similar content of total sugars for cultivar "Burlat" were measured by Sturm and Stampar [23] and Usenik et al. [19]. Fruits of the cultivar "Prime Giant" had the highest total content of sugars (22.2 g/100 g fw) while "Brooks" had the lowest content (14.9 g/100 g fw). Sorbitol was only detected in fruits of some cultivars, "Prime Giant", "Summit", "Van" and "57", and was below the detection limit in the rest of cultivars.

3.2. Antioxidant Activity and Total Phenolic Compounds

The total antioxidant activity (TAA) was measured separately as hydrophilic (H-TAA) and as lipophilic (L-TAA) fractions by the ABTS method (Figure 1). It was clearly observed that H-TAA (range 53-112 mg Trolox equivalent/100 g) was always significantly higher than L-TAA (range 8-29 mg Trolox equivalent/100 g).

Table 1. Organic acids content (mg/100 g fw) in sweet cherry as affected by cultivar

Cherry cultivar	Malic acid	Tartaric acid	Ascorbic acid	Shikimic acid	Total acids
	(mg/100 g fw)				
Brooks	1239 ± 13 a[†]	19.8 ± 6.03 ab	30.5 ± 0.30 abc	1.7 ± 0.03 b	1291 ± 8.67 a
Burlat	1269 ± 74 a	21.3 ±3.47 ab	26.8 ± 0.46 a	1.1 ± 0.17 a	1319 ± 77.18 a
57	1315 ± 67 a	32.6 ± 8.54 bc	31.9 ± 2.87 bc	2.1 ±0.17 b	1382 ± 77.95 ab
Lory	1209 ± 27 a	10.9 ± 2.68 a	27.6 ± 0.38 ab	0.7 ±0.02 a	1248 ± 29.32 a
Prime Giant	1895 ± 12 d	33.9 ± 11.42 bc	41.3 ± 2.15 d	2.1 ± 0.10 b	1973 ± 26.62 d
Summit	1445 ± 11 b	20.8 ± 5.61 ab	31.8 ± 0.85 bc	1.9 ± 0.09 b	1500 ± 16.24 b
Van	1596 ± 42 c	43.5 ± 7.30 c	33.6 ± 1.45 c	2.0 ±0.16 b	1675 ± 49.49 c

[†]Values were the mean of 3 replications (± standard error); values followed by the same letter, within a column, were not significantly different at p<0.05.

Table 2. Sugars content (g/100 g fw) in sweet cherry as affected by cultivar.

Cherry cultivar	Glucose	Fructose	Arabinose	Sorbitol	Total
	(g/100 g fw)				
Brooks	6.47 ± 0.17 a	8.32 ± 0.22 a	0.27 ± 0.05 a	nd	15.06 ± 0.42 a
Burlat	7.14 ± 0.34 b	9.28 ±0.41 b	0.27 ± 0.01 a	nd	16.71 ± 0.69 b
57	9.00± 0.23 d	9.44 ± 0.35 bc	0.34 ± 0.01 b	1.81 ±0.12 c	20.60 ± 0.70 d
Lory	6.7 ± 0.13 ab	8.85 ± 0.19 ab	0.32 ± 0.01 ab	nd	15.84 ± 0.33 ab
Prime Giant	9.25 ± 0.10 d	10.51 ± 0.11 d	0.48 ± 0.01 c	1.86 ± 0.10 c	22.1 ± 0.31 e
Summit	7.80 ± 0.15 c	9.09 ± 0.16 b	0.37 ± 0.01 b	1.01 ± 0.08 a	18.27 ± 0.37 c
Van	8.87 ± 0.16 d	10.15 ± 0.24 cd	0.28 ± 0.01 a	1.47 ±0.15 b	20.77 ± 0.45 de

[†]Values were the mean of 3 replications (± standard error); values followed by the same letter, within a column, were not significantly different at p<0.05.

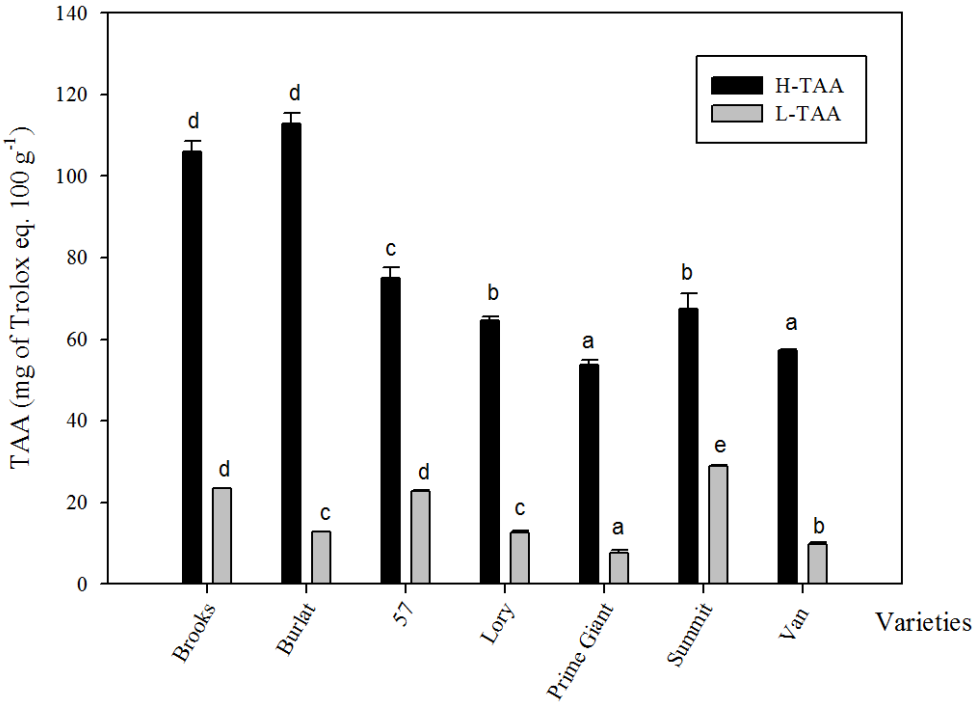

Figure 1. Antioxidant activity (mg of Trolox equivalent/100 g) in sweet cherry as affected by cultivar

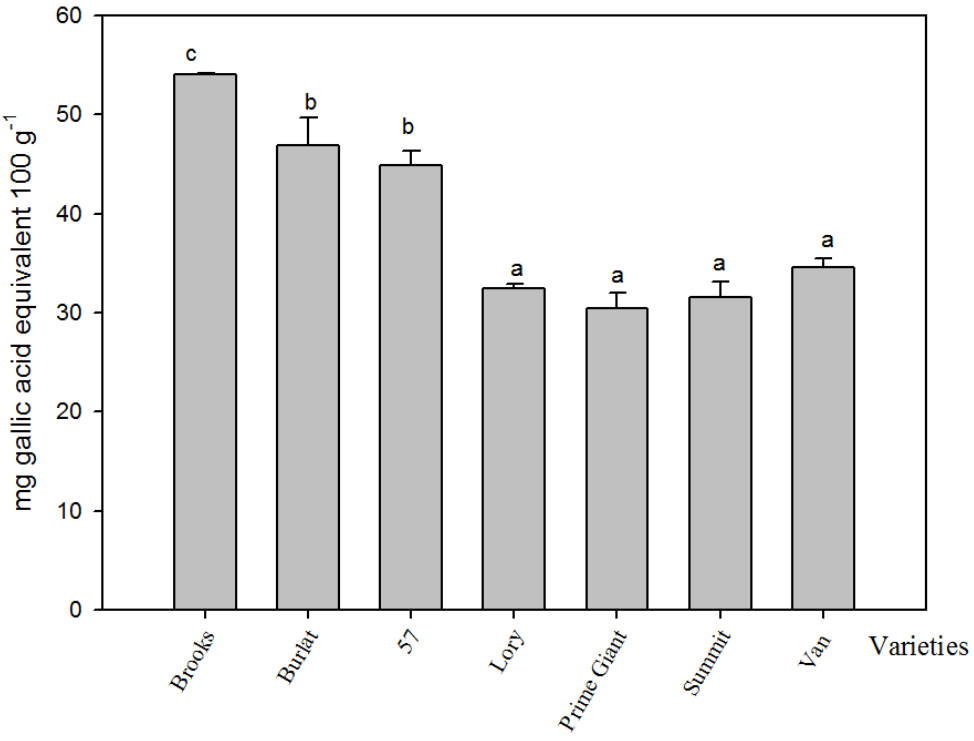

Figure 2. Total polyphenols content (mg gallic acid equivalent/100 g) in sweet cherry as affected by cultivar

The cultivars with the highest H-TAA values were "Brooks" and "Burlat" (>100 mg Trolox equivalent/100 g), while the lowest H-TAA values were found in "Prime Giant" and "Van" (<60 mg Trolox equivalent/100 g). The methods used to measured antioxidative capacity vary widely [24]. Vangdal and Slimestad [24] and Halvonsen et al. [25] reported values of antioxidant activity ranging from 0.44 to 2.67 mmol/100 g fw and from 0.62 to 1.42 mmol/100 g fw, respectively. However, Usenik et al. [20] reported their values as ascorbic acid equivalent antioxidant capacity (AEAC), with a mean value of 17.2 mg AAE/100 g fw) for cultivar "Burlat".

On the other hand, the cultivar with the highest L-TAA was "Summit" (29 mg Trolox equivalent/100 g) while the lowest was "prime Giant" (8 mg Trolox equivalent/100 g). These results are in concordance with L-TAA obtained in "Cristalina" and "Prime Giant" [26].

Very few reports have examined separately the antioxidant activity in the two fractions in sweet cherry.

The total phenolics contents (TPC) of the seven sweet cherry cultivars under study are summarized in Figure 2.

Total phenolics ranged from 54.02 to 30.4 mg GAE/100 g fw. Experimental results were lower than those previously reported by other authors [7,8,20] but similar to the ones obtained by Vangdal and Slimestad [24]. The highest content of total phenolic content was found in "Brooks" (54.02 mg GAE/100 g fw), a cultivar with early ripening time. It is well known that phenolic compounds contribute to fruit quality and nutritional value in terms of modifying colour, taste, aroma, flavour, and in providing health beneficial effects [27].

3.3. Colour

Cherry skin colour is an important quality attribute, especially for consumers, and it is crucial in determining product acceptance. The different colour coordinates of sweet cherries are reported in Table 3. The cultivar significantly affected all colour coordinates. The cherries under study were characterized by *L** values above 27 for all cultivars, and reaching values as high as 36. The "Lory", "Prime Giant" and "57" cultivars had the highest values of the green-red coordinate, *a** (19.22, 17.06, and 16.22, respectively). Otherwise, the low values of the blue-yellow coordinate, *b** (ranging from 0.87 to 5.40) suggested that these fruits were mainly red with the characteristic garnet colour (hue angle and chroma ranging from 7.17-19.83 and 6.27-17.62, respectively), being a mixture of red and blue colours.

3.4. Volatile Compounds

Thirty one volatile compounds were isolated using the headspace solid phase microextraction, HSSPME (Table 4); this isolation technique has been successfully used in studying the volatile composition of different fruits, for instance apricots, pomegranates, and tomatoes [12,28,29].

Vavoura et al. [30] reported a much lower number of volatile aroma compounds, 18, in the four more popular sweet cherry cultivars grown in Greece; besides, the reported concentrations were lower than the ones found in the Spanish cultivars. However, Serradilla et al. [30] reported the contents of up to 81 compounds in cherry cultivars grown in a different Spanish region, Jerte Valley.

The different volatile compounds found in sweet cherries (Table 4) can be grouped in 7 chemical families: (i) *acids* (3 compounds): butyric, 2-methyl-butyric, and hexanoic acids; (ii) *alcohols* (5 compounds): 3-penten-1-ol, 2-hexanol, cis-3-hexenol, hexanol, and 2-ethyl-1-hexanol; (iii) *aldehydes* (7 compounds): hexanal, *trans*-2-hexenal, heptanal, benzaldehyde, octanal, nonanal, and decanal; (iv) *esters* (3 compounds): isobutyl butyrate, isoamyl butyrate, and *trans*-2-hexenyl valerate; (v) *hydrocarbons* (3 compounds): decane, dodecane, and tetradecane; (vi) *ketones* (1 compound): 6-methyl-5-hepten-2-one; (vii) *terpenes and derivatives* (9 compounds): α-pinene, *p*-cymene, limonene, 1,8-cineole, etc.

Table 3. Values of the external colour coordinates of sweet cherry as affected by cultivar

Cherry cultivar	*L**	*a**	*b**	*h*	*C*
Brooks	30.47 ± 1.44 d	12.21 ± 4.64 e	3.59 ± 1.41 d	12.84 ± 4.53 e	17.62 ± 10.95 b
Burlat	30.33 ± 1.77 d	8.04 ± 1.62 b	0.87 ± 0.58 e	8.10 ± 1.63 b	6.27 ± 3.91 c
57	33.34 ± 2.35 e	17.06 ± 1.80 c	5.40 ± 1.62 c	17.97 ± 1.80 f	17.58 ± 5.28 b
Lory	36.62 ± 1.40 c	19.22 ± 0.98 d	4.81 ± 0.95 bc	19.83 ± 0.99 d	14.05 ± 2.73 ab
Prime Giant	27.20 ± 1.88 b	16.22 ± 1.79 c	4.46 ± 1.79 bc	16.93 ± 1.72 c	15.41 ± 6.57 ab
Summit	28.56 ± 0.90 a	7.97 ± 1.76 b	1.87 ± 1.43 a	8.30 ± 1.83 b	12.98 ± 9.43 ab
Van	28.84 ± 1.73 a	6.51 ± 1.83 a	2.12 ± 2.18 a	7.17 ± 1.87 a	17.22 ± 17.73 b

[†]Values were the mean of 3 replications (± standard error); values followed by the same letter, within a column, were not significantly different at $p<0.05$.

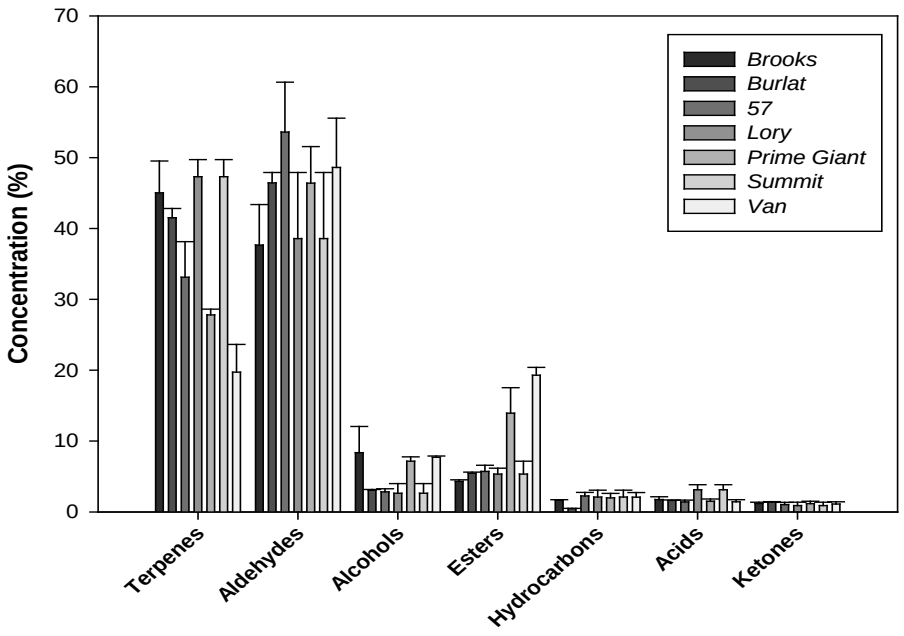

Figure 3. Main chemical families in sweet cherry as affected by cultivar

Table 4. Content of volatile compounds (% total area of identified compounds) of sweet cherry as affected by cultivar

Compound	Retention Time (min)	Retention Indexes		*Brooks*	*Burlat*
		Exp.	Lit.	(% total area)	
3-Penten-1-ol	5.57	731	725	0.6	0.1
2-Hexanol	6.28	801	800	0.2	0.3
Hexanal	6.32	803	801	0.8	5.9
Butyric acid	6.63	821	824	0.7	0.2
2-Methyl-butyric acid	6.78	829	837	0.8	0.2
trans-2-Hexenal	7.23	854	854	2.4	12.8
cis-3-Hexenol	7.28	857	858	1.0	1.2
Hexanol	7.53	872	869	4.8	1.3
Heptanal	8.19	906	903	0.3	0.9
α-Pinene	9.22	944	940	0.4	0.5
Isobutyl butyrate	9.47	953	953	0.7	1.0
Hexanoic acid	9.71	962	959	0.2	1.2
Benzaldehyde	10.12	977	978	24.9	14.2
6-Methyl-5-hepten-2-one	10.44	988	988	1.3	1.4
Decane	10.83	1002	1000	0.4	0.1
Octanal	11.08	1009	1006	0.7	1.6
2-Ethyl-1-hexanol	11.87	1030	1030	0.8	0.1
p-Cymene	12.02	1034	1029	0.9	0.4
Limonene	12.19	1039	1036	2.2	2.0
1.8-Cineole	12.40	1045	1044	0.7	5.4
Benzyl alcohol	12.84	1057	1045	23.9	13.4
Isoamyl butyrate	12.84	1057	1061	2.9	3.8
Linalool	14.69	1106	1110	1.0	2.1
Nonanal	14.88	1111	1112	5.5	9.0
Camphor	17.25	1166	1156	0.8	5.5
4-Terpineol	18.52	1196	1191	1.3	0.9
Dodecane	18.97	1206	1200	0.4	0.2
Decanal	19.30	1213	1212	2.9	2.1
trans-2-Hexenyl valerate	20.89	1248	1243	0.9	0.6
IS=Anethole	23.25	1300	1288		
Eugenol	26.21	1365	1364	14.6	11.4
Tetradecane	28.03	1405	1400	0.9	0.2
Total concentration (µg/kg fm)				**103**	**1970**

Compound	*57*	*Lory*	*Prime Giant*	*Summit*	*Van*	*Sensory descriptor*
	(% total area)					
3-Penten-1-ol	0.4	0.2	0.6	1.3	0.9	
2-Hexanol	0.2	0.3	0.3	1.2	0.5	
Hexanal	1.3	1.1	3.3	2.7	3.2	Fatty. green
Butyric acid	0.4	1.4	0.4	0.7	0.3	Cheese
2-Methyl-butyric acid	0.2	3.3	0.4	0.4	0.3	
trans-2-Hexenal	2.7	3.2	9.6	3.4	13.5	Almond. fruity. green. vegetable
cis-3-Hexenol	0.7	0.4	1.5	0.6	2.2	Green
1-Hexanol	0.8	0.9	2.6	1.1	1.6	Green. herbaceous. woody
Heptanal	0.4	0.5	0.5	0.7	0.3	Fruity. woody. nutty
α-Pinene	0.3	0.2	0.4	0.5	0.3	Woody. pine
Isobutyl butyrate	0.6	0.6	0.8	1.3	0.8	Fruity
Hexanoic acid	0.9	1.1	0.8	1.4	0.9	Cheese. fatty. sour
Benzaldehyde	39.3	21.4	19.1	17.7	18.2	Almond. cherry
6-Methyl-5-hepten-2-one	1.0	0.8	1.3	2.0	1.1	Oily. herbaceous. green
Decane	0.2	0.4	0.3	0.9	0.4	
Octanal	1.2	1.0	1.1	0.5	1.0	Honey. fruity. fatty. citrus
2-Ethyl-1-hexanol	0.8	0.6	1.7	1.3	4.0	Oily. rose. sweet
p-Cymene	0.5	0.6	0.6	0.7	0.5	Citrus
Limonene	1.7	3.4	1.9	3.5	1.6	Citrus. lemon. orange. sweet
1.8-Cineole	0.7	0.3	2.2	0.5	0.5	Citrus. herbaceous. spicy. minty
Benzyl alcohol	27.1	19.7	18.9	23.5	19.3	Berry. cherry. grapefruit. citrus
Isoamyl butyrate	3.6	3.5	6.6	4.0	13.1	Apricot. banana. pineapple
Linalool	0.2	0.6	1.1	0.0	0.3	Floral. citrus. sweet
Nonanal	5.6	7.9	7.1	6.3	6.9	Fruity. apple. grape. citrus. rose
Camphor	1.2	6.4	2.4	1.7	0.8	Medicinal. woody. vanilla
4-Terpineol	0.9	1.3	0.8	1.1	0.4	
Dodecane	1.5	0.6	0.7	1.4	1.6	
Decanal	2.1	3.0	2.3	2.6	1.8	Citrus. floral. waxy. sweet
trans-2-Hexenyl valerate	0.5	0.7	0.8	2.3	0.9	
IS=Anethole						
Eugenol	2.1	13.4	9.4	13.7	2.0	Cinnamon. clove. spicy
Tetradecane	1.2	1.4	0.7	0.9	0.9	
Total concentration (µg/kg fm)	**546**	**630**	**1394**	**693**	**2649**	

As can be easily seen in Figure 3, the abundance of the different chemical groups can be order as follows:

Aldehydes (42.3%) ≈ terpenes (39.5%) > esters (7.1%) ≈ alcohols (5.3%) > acids (2.3%) ≈ hydrocarbons (2.2%) ≈ ketones (1.3%)

Regarding individual volatile compounds, the predominant ones ordered were (Table 4): benzaldehyde (mean of all cultivars 22.1%), benzyl alcohol (20.8%), eugenol (9.5%), nonanal (6.9%), *trans*-2-hexenal (6.8%), and isoamyl butyrate (5.3%). The main descriptors of these 6 compounds are [32] benzaldehyde: bitter almond and cherry; benzyl alcohol: berry, cherry, grapefruit, and citrus; eugenol: cinnamon, clove, spicy; nonanal: apple, grape, fruity, citrus, and floral; *trans*-2-hexenal: almond, apple, green, and plum; and, isoamyl butyrate: apricot, cherry, banana, and pineapple.

Benzaldehyde is widely recognized as the key compound in the flavor profile of sweet cherry fruit and originates from the enzymatic hydrolysis of the amygdalin in fruit [33]. Serradilla et al. [31] reported that benzaldehyde presented the highest contents in "*picota*" type sweet cherries. **Benzyl alcohol** or benzenemethanol can be formed from benzaldehyde by means of hydrogenation [34]. These two compounds together represented more than 40% of the total volatile compounds found in Spanish sweet cherries; thus, there is no doubt of their importance in the flavor of this fruits. The content of benzaldehyde was especially high in the cultivars *57* (39.3%), *Brooks* (24.9%), and *Lory* (21.4%)

***trans*-2-hexenal** and **hexanal** were the main linear aldehydes in the volatile profiles reported by Serradilla et al. [31], and represented above 39-75% of total concentration of volatiles in their 4 sweet cherry cultivars (*Ambrunés*, *Pico Colourado*, *Pico Negro*, and *Sweetheart*). The main sensory descriptor of these two compounds is "green leaf"; therefore, these four cultivars had a strong "green" flavor. However, in the 7 cultivars of sweet cherry grown in the Mediterranean coast of Spain, the total content of these compounds never reach 20% of the total content of volatiles; therefore, these cultivars can be described predominately as bitter and fruity, but with green and spicy notes.

The spice notes come from the relative high content of **eugenol**, in 4 of the cultivars studied (*Brooks*, *Summit*, *Lory*, and *Burlat*).

The high relative high content of **nonanal** (6.9%) as compared to other previous studies [30,31] justifies the intense fruity flavor of the studied cultivars.

The content of **isoamyl butyrate** was especially high in only one cultivar, Van, with a content above 13%; this compound is not easy to quantify because co-elutes with benzyl alcohol, one of the most abundant compounds in sweet cherry.

4. Conclusions

This study is a clear proof of how difficult is to choose the best cultivar for making optimal recommendations to the farmers. According to the results obtained in the current study, the best 3 cultivars were: *Van*, *57*, and *Prime Giant*. The sweet cherry fruits of the cultivar *Van* had the highest contents of total volatiles, *trans*-2-hexenal, isoamyl butyrate, and isoamyl butyrate, but the lowest one of eugenol; thus, this is the most interesting cultivar from an aromatic point of view. *Van* fruits will have high intensity of fruity and green notes. The fruits from the cultivar *57* had the highest contents of benzaldehyde and benzyl alcohol and total polyphenols, which are normally related to important health benefits. Finally, fruits of cultivar Prime Giant had the highest contents of both organic acids and sugars (meaning that an intense flavor is expected), the darkest colour, but the lowest content of total polyphenols and antioxidant activity. Finally the cultivars with the highest antioxidant activity were *Burlat* and *Brooks*; therefore, these two cultivars are very interesting from a health point of view. As a final conclusion, if the most important factor in taking the final decision on which sweet cherry cultivar should be recommended is "health benefits", our recommendations are *57* and *Burlat*; however, if the most important factor is "organoleptic quality" (combination of dark red colour and intense flavor), our recommendations are *Van*, *57*, and *Prime Giant*.

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