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Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage

M. Esti[a,*], L. Cinquanta[a], F. Sinesio[b], E. Moneta[b], M. Di Matteo[c]

[a]*DISTAAM Dip. di Scienze e Tecnologie Agro-Alimentari Ambientali e Microbiologiche-Università degli Studi del Molise, Via De Sanctis 86100 Campobasso, Italy*

[b]*Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione (INRAN), via Ardeatina, 546-00178 Roma, Italy*

[c]*Dipartimento di Ingegneria Chimica ed Alimentare, Università di Salerno, Fisciano (SA), Italy*

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Abstract

Physicochemical and sensory fruit characteristics were studied to assess the effects of cool storage on quality attributes of sweet cherries of the *Sciazza* variety, widespread in the Campania region and *Ferrovia* variety, marketed in Italy and abroad. The major sugar and organic acid constituents, anthocyanin composition, colour (CIE L^*, a^*, b^*), firmness, volatile neo-formation compounds (acetaldehyde, ethanol and methanol) and sensory attributes were determined at harvest and after 15 days of fruit storage at 1 °C and 95% RH. The ANOVA and PCA plots showed that both cherry varieties and storage conditions affected sensory/chemical quality but the variation caused by cool storage seemed to be dependent on the varieties under study: *Ferrovia* cherries apparently varied less than *Sciazza*. The total anthocyanin and its qualitative composition were confirmed to be distinctive of the cherry varieties and important indicators of cool storage.

Keywords: Sweet cherry; Cool storage; Anthocyanin; Firmness; Colour; Sensory attributes

1. Introduction

Sweet cherries are one of the few non-surplus fruit crops in Europe. The high respiratory rate of the fruits, and consequently their rapid decay, is the main problem for successful transport and marketing. The respiratory rate halves every 7–8 °C of temperature reduction (Kupfermann, 1994). Post-harvest sweet cherry quality attributes involve size, bright red colour, firm flesh, green stem colour and flavour (Dever, Mac Donald, & Cliff, 1996). Colour is the most important indicator of quality of fresh cherries; it depends on anthocyanin content (Wang, Cao, & Prior, 1997), which ranges from few mg per 100 g in light-coloured to about 700 mg/100 g in dark cherries. Cyanidin 3-rutinoside and cyanidin 3-glucoside are the most represented anthocyanins in dark-coloured cherry cultivars (Gao & Mazza, 1995). Firmness is another important attribute of sweet cherries and it is often used for fruit quality assessment; for instance selective/multiple picking and post-harvest sorting at the packing-house can provide, besides colour, quality consistency for cherries destined for the fresh market (Girard & Kopp, 1998). Mitcham, Clayton, and Biasi (1998) compared non-destructive cherry devices with the firmness-testing performance of an Instron Testing Machine, which is widely accepted as a reliable firmness-testing instrument for biological materials. The softening and changes in texture of cherries during storage (Vidrih, Zavrtanik, & Hribar, 1998) influence the organoleptic qualities of fruit and often dictate shelf life (Batisse, Buret, & Coulomb, 1996). Instrumental and sensory assessment of quality attributes is hardly practised during sweet cherry storage but would be desirable for ongoing research.

This study characterises and compares two sweet cherry cultivars: *Sciazza,* local to the Campania region and *Ferrovia*, marketed in Italy and abroad. Moreover, to assess the effects of refrigeration on quality attributes of the cherries, their main physicochemical, and sensorial characteristics after 15 days of storage at 1 °C and 95% RH, were evaluated.

* Corresponding author. Tel.: +39-0874-404-718; fax: +39-0874-404-652.

E-mail address: esti@unimol.it (M. Esti).

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2. Materials and methods

2.1. Cherry samples

Samples of two cultivars of sweet cherry (*Prunus avium* L.) at commercial maturity were obtained during the month of July 1999 from different Italian orchards in the Campania region (*Sciazza*), and Puglia region (*Ferrovia*). The samples were packed in cardboard boxes of about 2 kg with an unclosed plastic liner and, within 2 h of harvesting, stored at 1 °C and 95% RH. The fresh cherries were evaluated for skin and flesh colour, firmness, soluble solids content, titratable acidity, reducing sugar, anthocyanins, volatile contents, and sensory analysis by a trained panel test. The same analyses were repeated after 15 days of storage.

2.2. Standard analysis

Skin and pulp colour (L^*, a^*, b^*) of 20 cherries were assessed with a Minolta CR-200 Chromameter having an aperture size of 10 mm (Minolta, Japan). The chroma $[(a^*)^2+(b^*)^2]^{1/2}$ and hue, attributes of chromaticity, indicate a measure of the colour intensity and of the visual property normally regarded as colour, respectively. The hue was calculated as [arctan b^*/a^*] (radian) and as [(arctan b^*/a^*)*360°/(2*3.14)] (degrees). Fruit juice was extracted with a hand-press juicer. Soluble solids content of the juice was measured with an Abbe refractometer; titrable acidity was determined by titration with 0.1 N NaOH to pH 8.1 and expressed as percent (w/w) of malic acid. Acetaldehyde, ethanol, and methanol were measured by injection, at 120 °C, of diluted and filtered juice samples (50 μl) into a Fisons Mega II GC with a flame ionisation detector (at 120 °C), and a glass column (2 mm x 1 m) containing 5% Carbowax on 60/80 Carbopack as stationary phase (at 70 °C). Glucose + sorbitol, fructose and saccharose were determined by HPLC in a Waters 600 apparatus (Milford, MA 01757, USA) with a refractometer detector (Waters 470), and with a 300×4 (id) mm column μ-Bondapack/Carbohydrate (Waters), according to AOAC (1989).

L-malic acid (Cat. No 139106), was determined by using the enzymatic bio-analysis kit from Boehringer Mannheim GmbH (Mannheim, Germany).

2.3. Firmness measurement

The mechanical parameters of cherry fruits were estimated by performing compressive stress-strain experiments by means of an Instron 4301 material testing machine (Instron, Canton, MA, USA) equipped with a load cell of 1 kN at a compressive rate of 1 mm/min, and at a temperature of 25 °C. For each test, 10 samples, randomly chosen, were used.

2.4. Anthocyanin analysis

2.4.1. Extraction

A random selection of 100 g of cherry pulp was immediately frozen in nitrogen and ground in a Waring blender, about 5 g of the powder was poured in 15 ml of a HCL/water/ethanol solution (1/29/70) and stirred for 15 min at 4 °C. The extraction was performed three times. Duplicates of all samples were analysed for pigment content.

2.4.2. Total anthocyanin analysis

Aliquots of the extract were diluted, filtered and recorded on a spectrophotometer DS100S (Varian, Australia) using 1 cm path length quartz cells. The total anthocyanin content was expressed as cyanidin-3-rutinoside. The E_{molar} abs of cyanidin-3-rutinoside was equal to 32800 at λ_{max} absorbance (about 534 nm), in HCl/water/ethanol (1/29/70) at 20 °C, on known dilutions of cyanidin-3-rutinoside chloride. For molar absorptivity calculation, the molecular weight used did not include the weight of the chloride counterion.

2.4.3. Individual anthocyanin analysis

After removing ethanol in a rotary evaporator (30 °C) the residual extract was adsorbed onto a C_{18} Sep-Pak cartridge (Waters Associates, Milford, MA, USA), previously activated with 3 ml of methanol and 3 ml of 0.01% HCl, and eluted as described by Garcia-Viguera, Zafrilla and Tomàs-Barberàn (1997). The identification was performed by chromatographic behaviour characterised by HPLC and UV-visible absorption spectra (260–600 nm), by comparison with authentic standards, when available, and with data found in the literature.

Anthocyanin detection and quantification were carried out by HPLC in a Waters 600 apparatus (Milford, MA 01757, USA) with a photodiode array detector (Waters 991). The 3.9×300 mm column used was filled with Nova-Pak® C_{18} (Waters) and the flow rate was 0.8 ml min^{-1} . The volume of injection was 20 μl. The eluates were detected at 520 nm, at 25 °C. The mobile phase used was HCOOH (10%) (A) and methanol (50%) (B) with a gradient from 5 to 22% of (A) in 40 min.

2.5. Chemicals and reference compounds

The reagents (Carlo Erba, Milan, Italy) were analytical or HPLC grade, as required. Cyanidin 3-glucoside chloride, cyanidin 3-rutinoside chloride, and peonidine-3-glucoside chloride were purchased from Extrasynthèse (Genay, France).

2.6. Sensory analysis

Ten professional panellists, of the trained staff at INRAN, profiled the cherry samples. They had been

selected for their reliability, consistency and discriminating ability (ISO 8586-1, 8586-2, 1994) and trained in sensory lexicon and methodology and had former experience in assessing a variety of vegetable/fruit products other than cherries.

Samples were presented in coded dishes and evaluated at random in two testing sessions. The experiment was designed so that two replicates were obtained on each batch.

The list of sensory terms included 11 descriptors chosen by the assessors to describe differences between the two varieties and times of sampling. The descriptors were rated on an anchored line scale that provided a 0–9 score range, "low intensity" and "high intensity" being the anchor points; only the flavour terms 'fermented', 'acetaldehyde' and 'alcoholic' were judged along an intensity scale anchored 0 = none, 9 = high intensity.

Sensory evaluations were recorded via a direct computer entry system (self made). The assessment took place in isolated sensory tasting booths under cool white fluorescent light for colour evaluations, and under red light for flavour and texture evaluations, to mask cherry appearance in order to avoid flavour and texture bias. Evaluations were performed at ambient room temperature (20 °C), according to current ISO regulation (ISO 8589, 1988).

2.7. Statistics

A two-way analysis of variance (ANOVA of variety per time and interaction) was undertaken, specifying the two factors as fixed effects on chemical, physical and sensory data, to get an indication of the variation in the material and error level in the data.

A joint Principal Component Analysis of the correlation matrices was performed on analytical and sensory indices (a total of 43 variables).

The average values over replicates for analytical variables, and over judges and replicates for sensory

Table 1
Mean values and analysis of variance for main effects and interactions of physicochemical parameters

	Sciazza		Ferrovia		ANOVA		
	T0	T15	T0	T15	Variety (X)	Time (Y)	XY
Humidity (%)	78.3±0.3	76.0±0.1	80.5±0.4	78.1±0.8	38.2[b]	45.8[b]	0.01
Total acidity.(g/100 g)	0.98±0,1	0.82±0.04	0.81±0.05	0.67±0.01	14.8[a]	12.2[a]	0.1
Malic acid (g/100 g)	0.77±0.1	0.62±0.03	0.64±0.02	0.55±0.01	13.0[a]	17.1[a]	1.3
SSC°(Brix)	17.2±0.3	16.2±0.4	16.3±0.3	15.2±0.5	13.0[a]	15.8[a]	0.1
Glucose + Sorbitol (g/100 g)	7.5±0.4	6.2±0.1	6.4±0.4	5.8±0.4	8.0[a]	12.9[a]	1.8
Fructose (g/100 g)	6.4±0.3	5.8±0.3	5.1±0.4	4.8±0.4	28.1[b]	4.0	0.4
Saccharose (g/100 g)	0.05±0.01	0.04±0.01	0.06±0.01	0.06±0.01	3.6	0.1	0.1
Acetaldehyde (ppm)	0±0.0	0.9±0.2	0±0.0	0.3±0.1	14.4[a]	48.4[b]	14.4[a]
Methanol (ppm)	0±0.0	9.6±0.6	0±0.0	13.7±1.8	9.1[a]	294[c]	9.1[a]
Ethanol (ppm)	0±0.0	4.0±1.3	0±0.0	0.3±0.1	15.4[a]	20.7[b]	15.4[a]
Total anthocyanins (mg/100 g)	510±8.5	245±0.7	51±5.7	30±4.2	7406[c]	1340[c]	976[c]
Cyanidin 3-gluc (mg/100 g)	48±4.2	10±0.0	3.0±0.1	0.4±0.1	1255[c]	678[c]	510[c]
Cyanidin 3-rut (mg/100 g)	393±7.8	186±3.5	60.3±1.0	28.4±6.2	3774[c]	870[c]	479[c]
Peonidin 3-gluc (mg/100 g)	3.0±1.4	2.5±0.7	0.5±0.1	0.7±0.2	27.5[b]	0.2	0.2
Pelargonidin-3-rut (mg/100 g)	3.5±0.7	0±0.0	0.5±0.1	0±0.0	34.6[b]	61.5[c]	34.6[b]
Peonidin 3-rut (mg/100 g)	27.5±3.5	8±1.4	0.6±0.0	0.5±0.3	382[c]	129[c]	129[c]
L^*(external)	20.8±0.7	20.8±0.6	36.1±4.2	22.5±0.6	30.0[b]	19.4[b]	19.3[b]
a^*(external)	7.61±1.3	5.98±1.1	21.3±6.6	25.64±1.3	45.7[b]	0.3	1.5
b^*(external)	−2.14±0.2	−1.05±0.6	3.45±2.2	4.14±0.9	39.1[b]	1.1	0.1
Hue ext (degree)	344±40	350± 7.2	8.7±3.1	9.1±1.5	11324[c]	0.9	0.6
Hue ext (radian)	6.0±0.07	6.1±0.15	0.15±0.05	0.16±0.05	11032[c]	1.0	0.6
Chroma ext	7.9±1.2	6.1±1.0	21.6±6.9	26±1.3	43.3[b]	0.2	1.5
L^*(internal)	20.5±0.1	19.5±3.4	45.0±6.1	39.96±0.6	82.5[c]	1.5	0.7
a^*(internal)	19.0±1.6	14.3±0.3	32.1±4.0	26.99±4.4	34.5[b]	5.0	0.01
b^*(internal)	0.32±0.3	0.86±0.4	14.3±0.0	12.1±3.6	96.2[c]	0.4	1.1
Hue int (degree)	0.9±0.9	3.4±1.5	24.2±2.7	23.9±2.9	204.1[c]	0.5	0.9
Hue int (radian)	0.015±0.02	0.06±0.03	0.42±0.05	0.42±0.05	190.3[c]	0.4	1.0
Chroma int	19.1±1.6	14.3±0.3	35.1±3.7	29.6±5.5	42.1[b]	4.5	0.02
Energy (Yield) J	0.036±0.01	0.044±0.01	0.063±0.001	0.088±0.002	90.1[c]	19.3[a]	4.8
Load KN	0.012±0.001	0.013±0.002	0.019±0.001	0.026±0.01	19.0[a]	3.4	1.7
Stress (Mpa)	0.031±0.001	0.026±0.005	0.027±0.003	0.032±0.001	0.2	0.02	6.8
Strain (mm/mm)	0.281±0.01	0.236±0.03	0.210±0.01	0.289±0.01	0.6	0.02	0.3
Modulus (Mpa)	0.138±0.03	0.143±0.001	0.136±0.02	0.127±0.002	0.5	1.6	21.9

[a] $P < 0.05$.
[b] $P < 0.01$.
[c] $P < 0.001$.

descriptors, provided input data for the data analysis. Each variable was standardised prior to analysis.

Multivariate analysis was performed using UNSCRAMBLER Software, version 7.01 (CAMO ASA, Trondheim, Norway).

3. Results and discussion

Two-way ANOVAs performed on the physical-chemical parameters revealed a significant variety effect for most of the variables (Table 1).

The cool storage, 15 days at 1 °C, affected cherry humidity, acid and sugar contents, bearing in mind the high respiratory rate of these fruits (about 5 ml CO_2/kg h at 0 °C). Besides the storage temperature, these results can be influenced by the immediate cooling of the fruits (Hevia, Wilckens, Lanuza, Mujica, & Olave, 1998). Both cultivars showed higher values for glucose (not resolved by sorbitol) and fructose. Small decreases were observed during the storage (not statistically significant for fructose). Moreover, volatile neo-formation compounds, resulting from fermentative decay (acetaldehyde and ethanol), occurred mainly in the *Sciazza* variety, and methanol, resulting from pectolytic decay, was higher in the *Ferrovia* (Cinquanta, La Notte, Di Matteo, & Ferrari, 1997). With regard to the rheological parameters, the energy (lower surface at yield point of the stress-strain curve) showed highly significant differences between the varieties ($P<0.001$), with higher values in *Ferrovia*, as did load values (strength at the yield point), to a smaller extent ($P<0.05$). In both varieties, only energy values increased markedly after cool storage. Differences in strain (threshold of irreversible transformation in the pulp due to viscosity changes), elastic modulus (tissue strength to irreversible modification as a consequence of tensioning of its elastic bonds), and yield stress, were not statistically significant as they were probably masked by inter-fruit variability.

Table 2
Anthocyanin composition (% of total anthocyanins) of sweet cherries

	Sciazza		*Ferrovia*	
	0 days	15 days	0 days	15 days
Cyanidin-3-glucoside	10.1	4.9	4.6	1.3
Cyanidin-3-rutinoside	82.8	90.0	92.9	94.7
Peonidin-3-glucoside	0.6	1.2	0.8	2.3
Pelargonidin-3-rutinoside	0.7	0	0.8	0
Peonidin-3-rutinoside	5.8	3.9	0.9	1.7

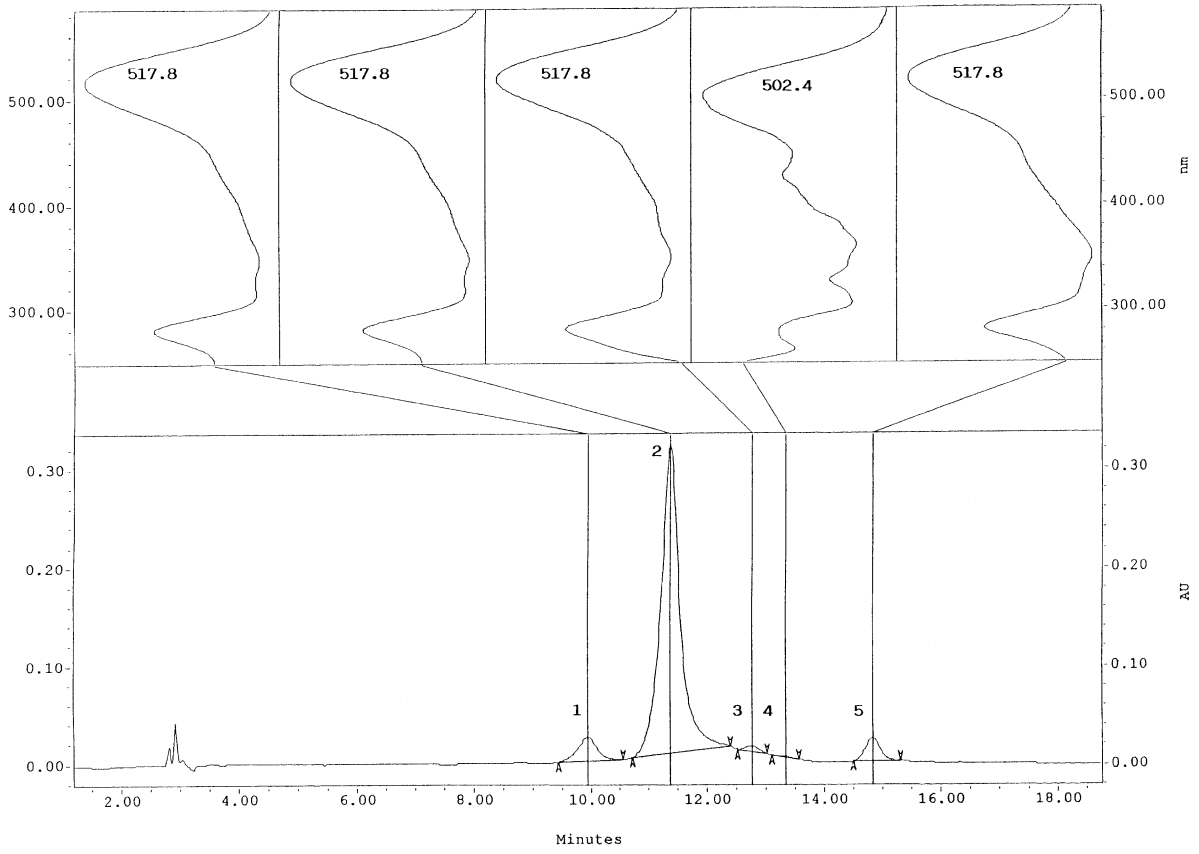

Fig. 1. HPLC/Spectral Array Detection chromatogram of anthocyanin in the *Sciazza* cherries. Peak number (520nm): (1) Cyanidin-3-glucoside; (2) Cyanidin-3-rutinoside; (3) Peonidin-3-glucoside; (4) Pelargonidin-3-rutinoside; (5) Peonidin-3-rutinoside.

The anthocyanin profile of the fruits at harvest was distinctive of the two varieties (Table 2): about 93% of total anthocyanin in *Ferrovia* and 83% in*Sciazza* was represented by cyanidin-3-rutinoside. Moreover, higher cyanidin-3-glucoside and peonidin-3-rutinoside contents were peculiar to *Sciazza*.

In both varieties, total anthocyanin contents decreased markedly with cool storage (Table 1). Particularly, cyanidin-3-rutinoside, was halved after 15 days' storage, and the unstable cyanidin-3-glucoside was reduced five and seven times in *Sciazza* and *Ferrovia* varieties, respectively. Cyanidin 3-glucoside has the

Table 3
Mean values and analysis of variance for main effects and interactions of sensory attributes

	Sciazza		Ferrovia		ANOVA (Fvalue)		
	T0	T15	T0	T15	Variety (*X*)	Storage (*Y*)	*XY*
Colour tone	8.7±0.38	8.6±0.33	6.1±0.55	5.9±0.73	488.2[c]	1.6	0.3
Fruity flavour	7.1±0.96	7.3±0.84	6.4±0.94	6.3±0.70	19.2[c]	0.01	0.9
Ripe flavour	7.0±0.32	7.0±1.56	6.4±0.57	6.1±0.83	11.2[c]	0.4	0.7
Fermented flavour	0.2±0.55	1.4±1.00	0.2±0.39	0.4±0.61	13.0[c]	18.8[c]	10.6[b]
Acetaldehyde flavour	0.1±0.32	0.5±0.79	0.2±0.51	0.1±0.25	1.9	1.5	3.1
Alcoholic flavour	0.1±0.32	0.2±0.38	0.1±0.24	0.1±0.14	3.5	1.1	0.9
Sweet taste	6.8±0.71	6.8±1.00	5.8±1.01	5.7±1.04	22.8[c]	0.2	0.3
Sour taste	4.3±0.88	3.2±1.59	3.0±1.04	2.3±0.70	18.6[c]	13.0[c]	0.5
Hardness	5.4±0.81	5.4±1.33	5.6±0.86	4.8±1.21	1.0	2.9	2.4
Crunchiness	5.0±1.05	5.0±1.68	5.6±1.22	4.4±0.99	0.1	4.6[a]	4.0[a]
Juiciness	7.1±0.99	7.1±1.14	6.7±0.81	6.5±0.98	4.4[a]	0.5	0.2

[a] $P<0.05$.
[b] $P<0.01$.
[c] $P<0.001$.

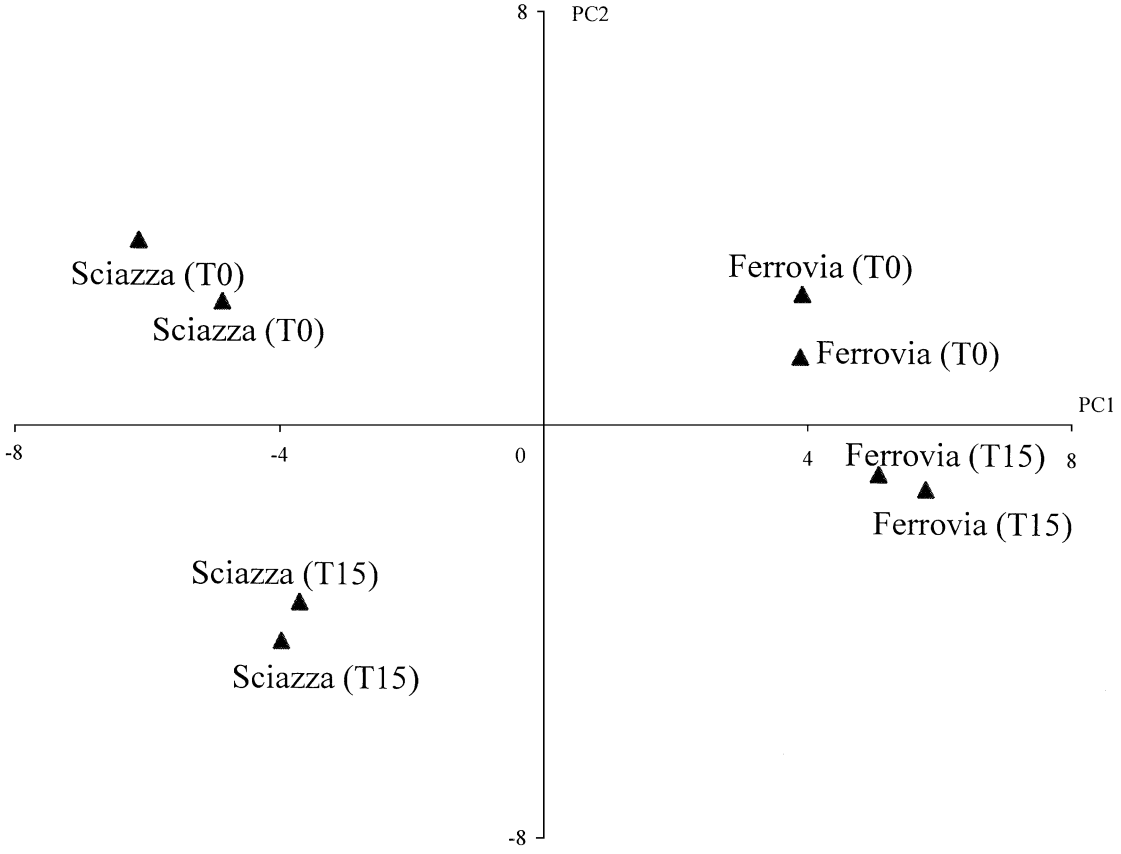

Fig. 2. Score plot of cherries samples by the dimensions 1 and 2 from PCA.

highest oxygen radical absorbance capacity (ORAC), which was estimated as 3.5 times stronger than Trolox (vitamin E analogue; Wang et al., 1997).

An example of an HPLC/Spectral Array Detection chromatogram of the anthocyanins for *Sciazza* cherries at 15 days' storage is shown in Fig. 1.

The differences in anthocyanin contents between varieties, validated by ANOVA, were also confirmed by differences in colorimetric and sensory indices. *Sciazza* fruits with a uniform dark red colour of the skin (lower L^* values), were less red (lower a^* value) and less yellow (lower b^* value) with respect to the *Ferrovia* (Table 1).

Moreover the external hue varied markedly between the two varieties, with values of about 350° for *Sciazza* (red-blue) and $<10°$ for *Ferrovia* (red-yellow).

Non-significant changes of these indices with storage were observed for both varieties, except for L^* external (decreasing in *Ferrovia*).

The average values for sensory attributes and the main variety and storage effects and interactions from ANOVA are shown in Table 3.

As for the physicochemical variables, sensory attributes describe major differences between the two varieties. They distinguished for colour: dark red for the *Sciazza* variety and light red for *Ferrovia*. *Sciazza* was scored higher for 'fruity' and 'ripe' flavours, 'sweet' taste, 'sour' taste and 'juiciness'. The storage affected 'sour' taste, causing lower scores in both varieties, and 'crunchiness' in *Ferrovia*; in addition, another sensory change was the development of a light 'fermented' off-flavour in *Sciazza*.

Results were further summarised and displayed by Principal Component Analysis (PCA) to explore the inter-relationship between physical, chemical and sensory parameters.

Principal Component Analysis, carried out on sample by replicate means, showed two interpretable factors that described about 69% of the total variation in the samples (52% for PC1 and 17% for PC2, respectively).

The plot of scores, shown in Fig. 2, summarises the information on differences between samples: the two varieties are scored in opposite directions on dimension 1, with the cool storage samples negatively loaded on dimension 2. This effect was more evident for *Sciazza* because of off-flavour occurrence. Consistent results are observed for replicated samples.

A summary of the total variation in both the sensory and physicochemical variable blocks is presented in Fig. 3. Considering PC1 as the dimension which explains the main differences between varieties, it is confirmed that colour (sensory-measured) discriminates between varieties due to the high anthocyanin content,

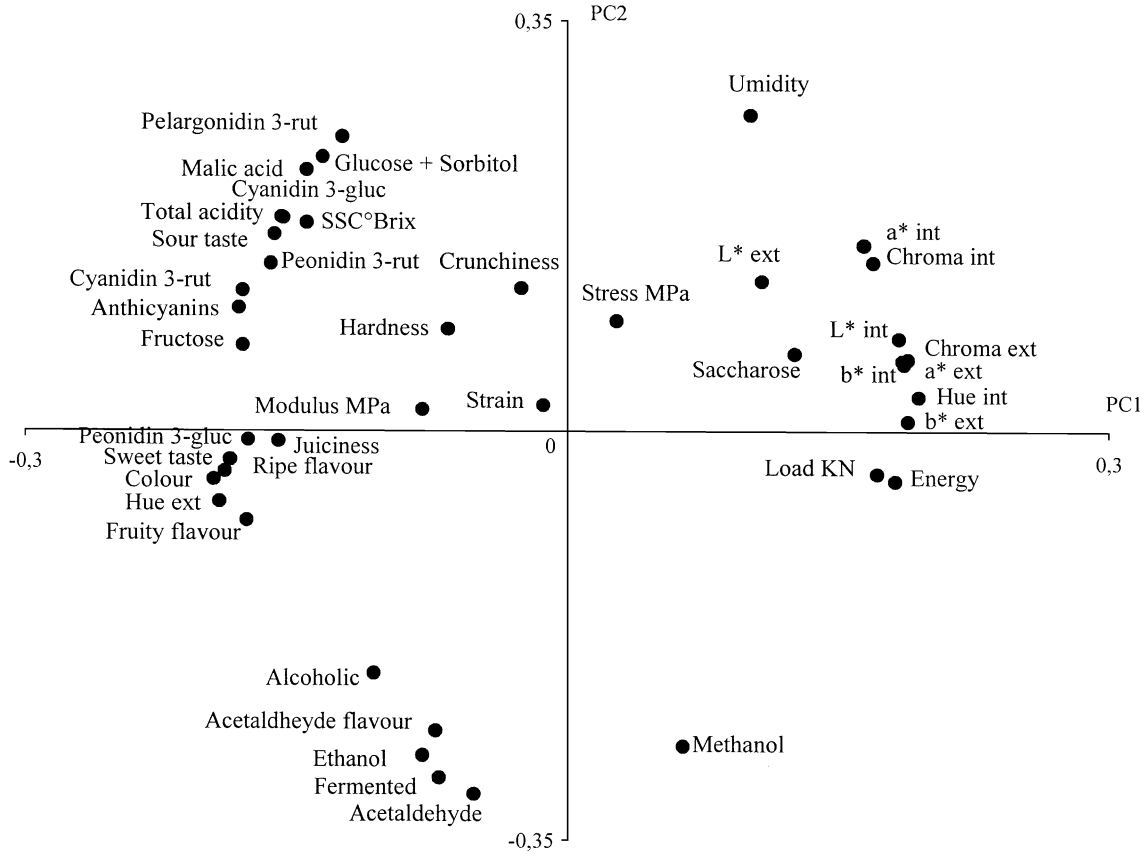

Fig. 3. Loading of variables by the dimensions 1 and 2 from PCA.

which is responsible for the dark red colour of skin and the red colour of pulp in the *Sciazza* variety, also represented by lower L^*, a^* (less red), b^* (less yellow) and chroma values. In Fig. 3, external hue has a negative loading on the first dimension as does the sensory value of colour (red-blue) that characterises the *Sciazza* variety.

Anthocyanin content decreased with storage but this reduction did not affect the instrumental and sensory evaluation of colour.

The taste terms 'sweet', 'fruity' and 'ripe' (negatively loaded on dimension 1) also contribute to the variance described by this factor. Total sugar, glucose + sorbitol and fructose contents, which are higher in *Sciazza* variety, are related to the sensory perception of sweetness on the first dimension. Total acidity and malic acid content are also higher in *Sciazza* and well correlated with the sensory perception of sourness on both the dimensions. A main relative sensory change during storage was the development of off-flavour (fermented) and decrease in sourness, whereas sweetness did not change.

The texture variation, along dimension 2, was only expressed by the sensory term crunchiness. Owing to the different rheological behaviours of the varieties during storage, no other sensory or instrumental measurement of firmness was of any relevance to describe the texture differences between the two cherry varieties and variation with storage conditions. These results confirm that the analysis of cherry firmness does not correlate with storage (Lurie & Aharoni, 1997), analogous results were obtained with respect to the sensory evaluation of crispness by Batisse et al. (1996).

4. Conclusion

The ANOVA and PCA plots showed that both cherry varieties and storage conditions had an impact on sensory/chemical quality although the variation caused by cool storage seems to be dependent on the varieties under study: *Ferrovia* cherries apparently varied less than *Sciazza*.

The total anthocyanin and its qualitative composition were confirmed as distinctive of the cherry varieties and important indicators of cool storage.

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