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Organic acids and sugars composition of harvested pomegranate fruits

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Abstract For two consecutive seasons, 40 Spanish pomegranate cultivars (cvs) were analysed and their individual organic acids and sugars compositions were examined. Intervarietal differences in acidity content reported by different authors were confirmed. According to organoleptic characteristics and chemical compositions three groups of varieties were established: sweet (SWV), soursweet (SSWV) and sour (SV). On average, for two seasons, total organic acids on a dry basis ranged between 0.317 g/100 g (SWV) and 2.725 g/100 g (SV). Citric, malic, oxalic, acetic (first reported here), fumaric, tartaric and lactic acids were detected, although lactic and fumaric were not quantifiable. On average, for both seasons, citric acid was predominant with a range of 0.142–2.317 g/100 g (average content for all CVS, 0.282 g/100 g). Malic acid was the second most abundant, with a range of 0.135–0.176 g/100 g (average of 0.139 g/100 g). Total sugars ranged between 11.43 g/100 g and 13.5 g/100 g. Glucose, fructose, sucrose and maltose were detected, although maltose (first reported here) was not quantifiable. Fructose ranged between 5.96 g/100 g and 7.04 g/100 g, with an average of 6.58 g/100 g, quite similar to that of glucose (6.14 g/100 g). Sour cv showed the lowest fructose and glucose contents. The average sucrose content was 0.01 g/100 g. Other differences among the groups of cvs were detected. Low total sugars and high acids were found in SV. The SSWV group had higher sugars than the SV. However, no difference in total sugars between SSWV and SWV was found. A lower acids content than SV but higher than SWV was found in the SSWV group. No other studies have been published so far on the individual organic acids and sugars of pomegranate fruit.

Key words Pomegranate · *Punica granatum* (Punicaceae) · Sugars · Organic acids · Fruit quality

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Introduction

Part of the south of Spain has a serious problem with the process of desertification of the agricultural lands, extending to almost all Mediterranean countries. Alternatives for economic agricultural exploitation of this area are very limited. In this sense pomegranate trees (*Punica granatum,* Punicaceae), specially adapted to saline and poor soils in semiarid climates, could be an adequate cultivation choice for this area, and thus contribute to the reduction of the risk of desertification. Pomegranate trees are also generally very well adapted to the Mediterranean climate, being a typical cultivation of this Spanish zone as well as of many other Mediterranean countries.

The separated edible fresh part of the pomegranate fruit is mainly consumed directly, but is also used after separation of seeds, for the preparation of fresh juice or canned beverages, even alcoholic beverages, jellies, jams and for flavouring and colouring drinks. The edible part of the fruit contains considerable amounts of sugars, vitamins, polysaccharides, polyphenols and minerals. In spite of its importance as a semiarid cultivar (cv), little effort has been made in the study of the chemical composition of the edible part of the pomegranate. Some studies have focused on establishing a chemical composition table, mainly for oriental cvs. Studies based on general analysis [total sugars, reducing and non-reducing sugars, total nitrogen, soluble

solids content (ssc), titratable acidity (TA), pectin content and ash], of the fruit and its juice have been conducted [1–17]. Some chemical changes during ripening and cold storage in Spanish pomegranate cvs, including colour and pigmentation, total lipids and fatty acids composition, have been more recently studied [18–21]. However, as far as we know, there are no references in the scientific literature to studies of the individual sugars and organic acids of pomegranate fruit.

The aim of the present work was to study the individual organic acids and sugars of 40 pomegranate cvs, growing under Mediterranean climate conditions.

Materials and methods

Plant material. During two consecutive seasons, pomegranate fruits were hand-harvested in September and October, from randomly selected trees in commercial or experimental orchards, in the typical growing area of the Spanish provinces of Alicante and Murcia on the Mediterranean coast of Spain. Fruits were harvested when fully mature, according to commercial practice, to ensure their best flavour and colour, since being non-climacteric they do not ripen off the tree [19]. Fruit were transported by ventilated car to the laboratory, where pomegranates with defects (sunburns, cracks, cuts and bruises in the husk) were discarded. A total of 40 pomegranate cvs were selected. The general description of these different cvs has been reported, and they have been classified according to the external characteristics of the tree as well as to external and internal characteristics of the fruit [21–23].

The fruits were characterised by chemical and physical parameters (size, weight, seeds, SSC, pH, TA, organic acids, sugars and fatty acids contents). Some of the results have been partially reported [20–23].

The most important group is that of sweet cvs, comprising different clones of Mollar de Elche (ME), Mollar de Albatera (MA), Mollar de Orihuela (MO), Albar de Blanca (AB), San Felipe de Blanca (SFB), Piñón Tierno de Ojós (PTO), Piñón Duro de Ojós (PDO) and Casta del Reino de Ojós (CRO). The sweet varieties (SWV) group is the most abundant and practically the only one of interest to the fresh market. The main characteristics are SSC ranging between 14.3°B and 16.8°B, TA between 0.16 g/100 g and 0.42 g/100 g, and a ratio of SSC/TA at commercial harvest, also known as the maturity index, ranging approximately between 32 and 96. Differences in size, weight and external appearance among groups of pomegranate cvs have not yet been observed.

Clones of PTO and Agridulce de Ojós (ADO) comprised the soursweet varieties (SSWV) group, and had lower commercial interest (only occasional) for fresh consumption. The main characteristics of this group were SSC ranging between 14.0°B and 15.1°B, TA between 0.53 g/100 g and 0.85 g/100 g, and a maturity index, with an approximate range of 17–28.

Finally, Borde de Albatera (BA) and Borde de Blanca (BB) comprised the sour varieties (SV) group, commonly used for rootstock, ornamental and even industrial purposes. The main characteristics of this group were SSC ranging between 14.0°B and 15.5°B, TA between 2.3 g/100 g and 3.0 g/100 g, and a maturity index, with an approximate range of 32–96.

Chemical analysis. Chemical composition was determined on the juice obtained by squeezing the seeds (arils). According to [24], ten fruits from each cv were weighed and hand peeled and the arils were weighed. The arils were squeezed with a commercial turmix blender (Moulinex, France). The juice was pooled, filtered through filter paper and used for chemical analysis.

For organic acids and sugars analysis the juice sample was centrifuged (2 min at 12000 rpm), filtered through a Sep-Pak C18 cartridge (Millipore, Milford, USA) to remove interferences and stored at –20 °C until analysis [25]. The extracts were analysed on a Waters HPLC equipment, with an Ion 300 column, (Supelco, Barcelona, Spain), 1% H_2SO_4 as a mobile phase and UV-Vis detector. Individuals sugars were determined in the clarified juice using the same HPLC equipment, with a μbondapak-NH_2 column (Waters), acetonitrile/H_2O (85 : 15, v/v) as mobile phase and a refractive index detector. Values were given on a dry weight basis.

Statistical analysis. For statistical analysis the SPSS statistical package was used. To establish the level of significance of differences between the three groups of cvs for each individual organic acid and sugar, an analysis of variance was conducted. When significant differences occurred ($P < 0.05$), means were separated by Duncan's New Multiple Range Test.

Results and discussion

Organic acids content

The highest organic acids content, 2.92 g/100 g, was found in BA1 (sour cv) and the lowest, 0.22 g/100 g in MO2 (sweet cv) (Table 1). The average value for every group is shown in Table 2. The average of total organic acids content (as the sum of individuals acids) in the two seasons was around 0.47 g/100 g and varied from 0.32 g/100 g for the SWV group to 2.72 g/100 g for the SV. Confirming organoleptical characteristics, the SV group had the highest acids contents and SWV the lowest.

Citric, malic, oxalic, acetic, fumaric, tartaric and lactic acids were detected in fruits. Due to their low levels, lactic and fumaric acids could not be quantified. On average for two seasons, citric was the predominant acid with an average content of 0.28 g/100 g followed by malic acid with an average of 0.14 g/100 g, and oxalic acid (0.03 g/100 g) (Table 2). Among the SWV cvs SFB1 showed the highest citric acid content (0.32 g/100 g) and ME2 and ME3 the lowest (around 0.09 g/100 g). On the other hand, AB1 showed the highest malic acid content (0.21 g/100 g) followed by MA4 (0.19 g/100 g) while SFB1 and ME10 had the lowest (around 0.1 g/100 g). The highest oxalic acid content was found in ME13 (0.07 g/100 g), and the lowest in SFB1 and ME20 (around 0.01 g/100 g). The highest citric acid content among the SSWV cvs was found in ADO4 (0.7 g/100 g), while in PTO7 only 0.4 g/100 g was detected. Malic acid was 0.17 g/100 g in PTO8 and 0.15 g/100 g in PTO7, while oxalic acid was highest in PTO7 and ADO4 with around 0.02 g/100 g followed by PTO8 with 0.01 g/100 g. The highest tartaric acid content (0.05 g/100 g) was found in ME16, a sweet variety. There were 18 SWV, 1 sour (BB1) and the 3 SSWV without tartaric acid. Fumaric acid could be quantified in 3 SWV (ME3, ME5 and ME10) and detected only as traces in 30 cvs. Fumaric acid was not detected in the soursweet ADO4, or in six SWV (Table 1). Lactic acid was not quantified in

Table 1 Average of organic acids contents in pomegranate *cv* for 1992 and 1993 (g/100 g). Values are the mean of two seasons ± standard deviation. *nd* Not detected, *tr* traces below 0.001 g/100 g. *ME* Mollar de Elche, *MA* Mollar de Albatera, *MO* Mollar de Orihuela, *AB* Albar de Blanca, *SFB* San Felipe de Blanca, *PTO* Piñón Tiemo de Ojós, *PDO* Piñón Duro de Ojós, *CRO* Casta del Reino de Ojós, *BA* Borde de Albatera, *BB* Borde de Blanca, *ADO* Agridulce de Ojós

cv	Oxa lic	Citric	Malic	Lactic	Fumaric	Tartaric	Acetic	Total
Sweet varieties								
ME2	0.035 ± 0.010	0.095 ± 0.009	0.126 ± 0.007	tr	tr	0.013 ± 0.030	nd	0.268 ± 0.027
ME3	0.030 ± 0.008	0.084 ± 0.012	0.117 ± 0.010	tr	0.01	nd	nd	0.231 ± 0.030
ME4	0.050 ± 0.029	0.167 ± 0.003	0.163 ± 0.015	tr	tr	nd	nd	0.380 ± 0.047
ME5	0.044 ± 0.017	0.130 ± 0.017	0.117 ± 0.011	tr	0.003 ± 0.001	0.007 ± 0.003	nd	0.298 ± 0.047
ME6	0.054 ± 0.004	0.078 ± 0.007	0.124 ± 0.012	nd	nd	0.018	nd	0.273 ± 0.023
ME7	0.042 ± 0.012	0.082 ± 0.015	0.130 ± 0.009	nd	tr	0.011 ± 0.004	nd	0.264 ± 0.040
ME8	0.040 ± 0.014	0.104 ± 0.002	0.161 ± 0.010	tr	tr	nd	nd	0.305 ± 0.026
ME9	0.054 ± 0.032	0.113 ± 0.023	0.149 ± 0.021	nd	tr	0.011 ± 0.014	nd	0.316 ± 0.076
ME10	0.041 ± 0.003	0.149 ± 0.000	0.104 ± 0.006	tr	tr	nd	nd	0.294 ± 0.010
ME11	0.037 ± 0.006	0.123 ± 0.023	0.148 ± 0.021	tr	0.001	0.010 ± 0.003	nd	0.318 ± 0.053
ME13	0.071 ± 0.014	0.128 ± 0.011	0.139 ± 0.005	tr	tr	0.019 ± 0.001	nd	0.337 ± 0.031
ME14	0.062 ± 0.045	0.132 ± 0.005	0.163 ± 0.016	tr	tr	0.016 ± 0.006	nd	0.372 ± 0.065
ME15	0.047 ± 0.004	0.112 ± 0.028	0.172 ± 0.034	tr	nd	0.016 ± 0.007	nd	0.331 ± 0.066
ME16	0.050 ± 0.009	0.118 ± 0.008	0.113 ± 0.021	nd	nd	0.051 ± 0.058	nd	0.331 ± 0.038
ME17	0.030 ± 0.003	0.087 ± 0.011	0.123 ± 0.016	tr	tr	0.014 ± 0.003	nd	0.253 ± 0.030
ME18	0.036 ± 0.011	0.122 ± 0.010	0.136 ± 0.015	tr	nd	nd	nd	0.293 ± 0.035
ME19	0.041 ± 0.014	0.154 ± 0.033	0.128 ± 0.019	nd	tr	0.01	nd	0.322 ± 0.067
ME20	0.011 ± 0.003	0.188 ± 0.047	0.122 ± 0.005	tr	nd	0.011 ± 0.008	nd	0.320 ± 0.063
ME21	0.028 ± 0.011	0.248 ± 0.052	0.088 ± 0.007	tr	tr	nd	nd	0.276 ± 0.070
MA1	0.044 ± 0.022	0.147 ± 0.008	0.173 ± 0.029	tr	tr	nd	nd	0.363 ± 0.059
MA2	0.051 ± 0.012	0.153 ± 0.035	0.120 ± 0.005	tr	tr	0.009 ± 0.011	nd	0.324 ± 0.052
MA3	0.053 ± 0.018	0.165 ± 0.023	0.152 ± 0.022	tr	tr	nd	nd	0.370 ± 0.062
MA4	0.028 ± 0.005	0.153 ± 0.017	0.189 ± 0.004	tr	tr	0.011 ± 0.007	nd	0.370 ± 0.026
MA5	0.044 ± 0.013	0.141 ± 0.027	0.159 ± 0.022	tr	tr	nd	nd	0.344 ± 0.062
MO2	0.030 ± 0.011	0.078 ± 0.029	0.108 ± 0.024	nd	tr	nd	nd	0.216 ± 0.064
MO3	0.020 ± 0.008	0.110 ± 0.012	0.113 ± 0.016	nd	tr	nd	nd	0.243 ± 0.036
MO4	0.038 ± 0.006	0.117 ± 0.014	0.144 ± 0.017	tr	tr	0.011 ± 0.008	nd	0.299 ± 0.037
MO5	0.027 ± 0.008	0.175 ± 0.015	0.150 ± 0.003	tr	tr	nd	nd	0.352 ± 0.026
MO6	0.023 ± 0.004	0.109 ± 0.025	0.119 ± 0.018	nd	tr	0.01	nd	0.251 ± 0.048
AB1	0.048 ± 0.009	0.138 ± 0.002	0.208 ± 0.033	tr	tr	nd	nd	0.394 ± 0.043
SFB1	0.012 ± 0.000	0.320 ± 0.008	0.109 ± 0.008	tr	nd	nd	nd	0.441 ± 0.017
PTO2	0.016 ± 0.000	0.180 ± 0.011	0.119 ± 0.009	tr	tr	nd	nd	0.314 ± 0.020
PTO4	0.011 ± 0.003	0.251 ± 0.014	0.120 ± 0.017	tr	tr	nd	nd	0.382 ± 0.034
PDO2	0.040 ± 0.011	0.155 ± 0.006	0.132 ± 0.005	tr	tr	nd	nd	0.327 ± 0.022
CRO2	0.013 ± 0.003	0.203 ± 0.012	0.098 ± 0.009	tr	tr	nd	nd	0.314 ± 0.024
Sour varieties								
BA1	0.021 ± 0.003	2.459 ± 0.055	0.213 ± 0.036	nd	tr	tr	0.230 ± 0.026	2.923 ± 0.107
BB1	0.013 ± 0.003	2.174 ± 0.261	0.140 ± 0.018	tr	tr	nd	0.200 ± 0.013	2.527 ± 0.282
Soursweet varieties								
PTO7	0.019 ± 0.002	0.445 ± 0.009	0.152 ± 0.023	tr	tr	nd	nd	0.615 ± 0.034
PTO8	0.010 ± 0.001	0.569 ± 0.092	0.172 ± 0.024	tr	tr	nd	nd	0.751 ± 0.117
ADO4	0.018 ± 0.004	0.686 ± 0.050	0.158 ± 0.033	tr	nd	nd	0.13 ± 0.02	0.991 ± 0.108

Table 2 Average content in organic acids (g/100 g) for different pomegranate *cv* groups

cv groups	O xalic	Citric	Malic	Lactic	Fumaric	Tartaric*	Acetic*	Total
Average	0.034 ± 0.009	0.282 ± 0.028	0.139 ± 0.016	tr	0.003 ± na	0.014 ± na	0.015 ± na	0.474 ± 0.052
Sweet	0.037 ± 0.011a	0.142 ± 0.016a	0.135 ± 0.014a	tr	0.005 ± na	0.014 ± na	nd	0.317 ± 0.042a
Soursweet	0.015 ± 0.002b	0.566 ± 0.050b	0.160 ± 0.027b	tr	tr	tr	0.06 ± na	0.786 ± 0.053b
Sour	0.017 ± 0.003b	2.317 ± 0.206c	0.176 ± 0.027b	tr	tr	tr	0.215 ± 0.019	2.725 ± 0.194c

na: Not applicable
tr: Traces

a-c Means in a column with the same letter are not significantly different, $p<0.05$
* Average of *cv* where the individual acid was present

any cv, was not detected in one sour variety (BA1) and in eight SWV and the rest of the cvs showed only traces. Acetic acid was detected and quantified only in the two SV (around 0.2 g/100 g) and in the sour sweet variety ADO4 (0.13 g/100 g). As far as we know, acetic acid has not previously been reported in pomegranate fruits.

Sugars content

Total sugar content (as the sum of individuals sugars) on average for both seasons was 12.62 g/100 g. The SV showed the lowest average of total sugar content (11.43 g/100 g), and the SSWV and the SWV showed the highest values (without significant differences), with 12.94 g/100 g and 13.50 g/100 g respectively (Table 4). Glucose and fructose were detected and quantified in all cvs tested. Fructose ranged between 8.24 g/100 g (ME15) and 5.54 g/100 g (BA1) (Table 3). On average for two seasons, fructose content, at 6.58 g/100 g, was higher than that of glucose (6.14 g/100 g). Sucrose was not detected in only one sour variety (BA1) and one sweet variety (ME3). ME9 (sweet) and PTO8 (soursweet) showed the highest sucrose content (0.07 g/100 g). Maltose was detected in almost all cvs, except for three SWV (ME7, ME17 and PTO4), the soursweet PTO8 and the sour BB1, but could not be quantified. To the best of our knowledge, the presence of maltose in pomegranate fruit has not previously been reported.

Table 3 Average of sugars content (g/100 g) in pomegranate *cv* for 1992 and 1993

cv	Fructose	Glucose	Sucrose	Maltose	Total Sugars Content
Sweet varieties					
ME2	7.23 ± 0.74	6.91 ± 0.86	0.01	tr	14.15 ± 1.61
ME3	6.39 ± 0.12	5.96 ± 0.06	nd	tr	12.34 ± 0.18
ME4	7.61 ± 1.20	6.21 ± 0.45	tr	tr	13.82 ± 1.65
ME5	7.14 ± 0.31	6.51 ± 0.57	0.04	tr	13.68 ± 0.88
ME6	6.58 ± 0.03	6.04 ± 0.30	tr	tr	12.62 ± 0.33
ME7	6.94 ± 0.35	6.42 ± 0.83	0.04	nd	13.40 ± 1.18
ME8	6.73 ± 0.18	6.26 ± 0.47	0.04	tr	13.03 ± 0.64
ME9	7.08 ± 0.15	6.46 ± 0.96	0.07	tr	13.60 ± 1.11
ME10	7.33 ± 0.25	6.42 ± 0.10	tr	tr	13.75 ± 0.35
ME11	7.36 ± 0.19	6.18 ± 0.13	tr	tr	13.53 ± 0.33
ME13	6.37 ± 0.20	5.94 ± 0.11	tr	tr	12.31 ± 0.30
ME14	7.35 ± 0.07	6.81 ± 0.58	0.05	tr	14.21 ± 0.65
ME15	8.24 ± 0.25	7.66 ± 0.36	tr	tr	15.89 ± 0.61
ME16	7.39 ± 0.60	6.58 ± 0.11	tr	tr	13.96 ± 0.71
ME17	7.32 ± 1.12	6.66 ± 1.23	tr	nd	13.98 ± 2.35
ME18	8.22 ± 0.29	7.12 ± 0.25	tr	tr	15.34 ± 0.54
ME19	6.85 ± 0.06	6.32 ± 0.09	tr	tr	13.16 ± 0.16
ME20	6.42 ± 0.95	6.46 ± 0.62	tr	tr	12.88 ± 1.58
ME21	7.08 ± 0.54	6.40 ± 0.16	0.04	tr	13.52 ± 0.69
MA1	6.66 ± 0.30	6.03 ± 0.44	0.04	tr	12.73 ± 0.74
MA2	7.08 ± 0.47	6.50 ± 0.74	tr	tr	13.58 ± 1.20
MA3	7.32 ± 0.69	6.81 ± 0.76	tr	tr	14.13 ± 1.45
MA4	7.60 ± 0.07	6.79 ± 0.86	0.03	tr	14.42 ± 0.93
MA5	7.15 ± 0.31	6.45 ± 0.11	0.03	tr	13.63 ± 0.42
MO2	6.42 ± 0.01	5.78 ± 0.37	0.04	tr	12.23 ± 0.38
MO3	6.23 ± 0.67	5.73 ± 0.57	tr	tr	11.96 ± 1.24
MO4	7.20 ± 0.41	6.51 ± 0.82	tr	tr	13.71 ± 1.23
MO5	6.83 ± 0.23	5.97 ± 0.52	tr	tr	12.80 ± 0.76
MO6	7.09 ± 0.86	6.82 ± 0.42	0.04	tr	13.94 ± 1.27
AB1	6.86 ± 0.06	6.33 ± 0.51	tr	tr	13.19 ± 0.57
SFB1	8.07 ± 0.07	7.80 ± 0.27	0.06	tr	15.87 ± 0.34
PTO2	6.70 ± 0.27	6.77 ± 0.02	0.02	tr	13.49 ± 0.29
PTO4	6.13 ± 0.85	5.91 ± 0.54	tr	nd	12.04 ± 1.39
PDO2	7.28 ± 0.02	6.52 ± 0.03	tr	tr	13.80 ± 0.05
CRO2	6.32 ± 0.36	5.91 ± 1.09	0.04	tr	12.27 ± 1.45
Sour varieties					
BA1	5.54 ± 0.24	5.53 ± 0.33	nd	tr	11.07 ± 0.57
BB1	6.01 ± 0.16	5.79 ± 0.48	0.04	nd	11.84 ± 0.64
Soursweet varieties					
PTO7	7.06 ± 0.28	7.04 ± 0.57	tr	tr	14.10 ± 0.85
PTO8	6.43 ± 0.27	5.97 ± 0.07	0.07	nd	12.47 ± 0.34
ADO4	6.36 ± 0.25	5.96 ± 0.08	tr	tr	12.32 ± 0.34

nd: Not detected
tr: Traces
Values are the mean of two seasons ± standard deviation

Organic acids content

A wide range of total organic acids contents in pomegranate cvs has been published. In Russian pomegranates, a TA between 0.52% and 2.3% has been reported [1], while for cvs from Yugoslavia 0.37% was determined [3]. A review article [6] reported that pomegranates from different places had mainly citric acid (0.9%) and calculated the average total TA to be 0.62% for diverse cvs [12]. These ranges agree with the higher values obtained in the present work for different groups: 2.9 g/100 g (for sour BA1), around 1.0 g/100 g (for soursweet ADO4) and around 0.4 G/100 g (for SWV SFB1 and AB1). Lower values have been reported in Indian cvs ranging between 0.12 g/100 g and 0.13 g/100 g [11], while in pomegranates from California [26] similar levels (0.11 g/100 g and 0.16 g/100 g) have been found. These last values are at a lower level than in the SWV in the present experiment. Total acidity evolution during fruit development in Israel showed a maximum content of 3% [27], while for the soursweet Wonderful cv, total acidity ranged from 0.05 g/100 g to 0.4 g/100 g [28]. These values are quite different from a total acidity of between 0.03 g/100 g and 0.1 g/100 g obtained in a study conducted in Egypt [8]. Similar values between 0.04 g/100 g and 0.06 g/100 g for Indian cvs were found [13]. El-Nemr et al. [10, 15] reported 0.01 g/100 g in total acidity for Egyptian cvs, while an acidity between 0.02 g/100 g and 0.14 g/100 g was found in Saudi Arabian cvs [17]. In Spanish Mollar cvs values between 0.2 g/100 g and 0.3 g/100 g have been found [14, 24], in agreement with present results.

Intervarietal differences in acidity content reported by different authors have been confirmed in the present work. From the present results Spanish cvs could be classified into three groups: SV, with a mean value of total acids (as the sum of all individuals organic acids) of around 2.72 ± 0.19 g/100 g, SSWV with an average of 0.79 ± 0.05 g/100 g, and SWV with around 0.32 ± 0.04 g/100 g.

Very little quantitative data are available for individual organic acids. Citric acid contents of between 0.22 g/100 ml and 2.16 g/100 ml have been reported in pomegranates from Turkey and the United States of America [7, 29], where it was found to be the predominant acid [6]. A malic acid content below 0.1 g/100 g in Turkish cvs has been reported [16]. Our results, where citric acid was predominant in all groups of cv, agree with [6]. Differences between citric and malic acids were highest in SWV and lowest in SV (Table 2). On average SSWV and SWV had similar values for malic acid. There were significant differences between SV, SSWV and SWV in citric acids content. However no significant differences in malic or oxalic acids contents between SSWV and SV were found.

Acetic acid has not been previously reported in pomegranate fruit. It is unlikely to have come from microbiological contamination, because the samples were carefully packed and handled to avoid any physical damage, or microbiological contamination. The presence of this acid appears to be related to the characteristics of the fruits, and was only detected in the two SV and in one soursweet variety (ADO4). On average the acetic acid content was much higher in SV than in SSWV.

Sugars content

In the cvs studied, the fructose level was almost always higher than glucose. This result contrasts with that from cvs out of the Mediterranean area. In Russian pomegranates, the sugars were mostly glucose and fructose, with more glucose than fructose [1]. Saxena et al. [6] reported that in all reviewed papers, higher glucose than fructose levels were found. In pomegranates from Turkey, similar levels of glucose and fructose were reported [16]. The range of glucose and fructose contents found in the present work agrees with the range in the literature. Levels of fructose content were similar in SWV and SSWV and in both of these were higher than in SV. Differences in glucose content in SV were significantly lower than in SWV. When compared to glucose and fructose contents the low sucrose content agrees with [6, 10–12, 15, 16].

Individual sugar contents correlated well with the sweetness characteristics of the juice. Thus SV had the lowest fructose contents (Table 4). Sucrose levels had a direct relationship with fructose, and glucose, and SWV showed the highest contents. On the other hand, maltose occured only at trace levels. As far as we know, the presence of maltose in pomegranate has not been previously reported.

In conclusion, the differences in relative proportions of individual organic acids correlated well to

Table 4 Average of sugars content (g/100 g) for the different pomegranate *cv* groups

cv group	Fructose	Glucose	Sucrose	Maltose	Total
Average	6.58 ± 0.36	6.14 ± 0.45	$0.01 \pm$ na	tr	12.62 ± 0.81
Sweet	7.04 ± 0.38 a	6.45 ± 0.45 a	$0.39 \pm$ na	tr	13.50 ± 0.83 a
Soursweet	6.62 ± 0.27 a	6.32 ± 0.24 ab	$0.027 \pm$ na	tr	12.94 ± 0.52 a
Sour	5.96 ± 0.25 b	5.66 ± 0.63 b	$0.04 \pm$ na	tr	11.43 ± 0.89 b

na: Not applicable
tr: Traces
Means in a column with the same letter are not significantly different, $p<0.05$

juice sweetness. The SV group contained, on average, higher amounts of citric, malic and acetic acids than SWV, and the SSWV group had higher citric and malic acids contents than SWV.

As with organic acids, significant differences in sugar contents have been found among the groups of pomegranate cvs. The SV had low total sugars contents, with similar levels of glucose and fructose, and high citric acid contents, higher than malic acid, and low oxalic acid contents. The SSWV exhibited higher sugar levels than SV, but similar to SWV, with high citric and malic acids contents. The SWV showed high sugar contents and very low total acids contents.

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