Revaluation of underutilized lemon fruits of southeastern Spain as a potential source of bioactive compounds and to be used in creative cuisine

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Abstract

In the present research colour, weight, morphological parameters and total antioxidant activity (TAA) of the edible tissues of three underutilised cultivars of lemon fruits was quantified. In addition, other fruit quality properties, such as organics acids and sugars concentrations in the lemon juices were analysed. Also, the evaluation of organoleptic attributes, such as sweetness, aroma, firmness, lack of bitterness, overall impression and notable feature of fruits was performed by a sensory panel. Results show significant differences on the analysed parameters among lemon cultivars. The relative proportion of each fruit tissue was similar for the three cultivars. 'Fino' and 'Sanguino' lemons showed the highest TAA, while the most appreciated by consumers according to the sensory panel results was 'Sanguino' lemon which could be due to their original colour. These traditional cultivars of lemon fruits could be used as ingredients in creative cuisine due to their attractive properties providing also nutritional and antioxidant compounds.

Keywords: traditional cultivars, total antioxidant activity, sugars, organic acids

INTRODUCTION

The use of traditional cultivars and their wild relatives for plant breeding is highly valuable for agricultural development, since these plants have acquired many desirable characteristics as a consequence of their long exposure to natural selection. Traditional cultivars and wild species are also appreciated by their nutritional value, versatility of use and even by their health beneficial effects (Egea et al., 2010; Romojaro et al., 2013). On the other hand, they are responsible for the unique taste of the local cuisine and have high economic importance in rural and urban areas (Frison et al., 2012; Pardo de Santayana et al., 2007; Reyes-García et al., 2015). In this sense, several traditional *Citrus* species and cultivars, that have been cultivated for a long time, still survive in the orchards of southeastern Spain, which are well-adapted to Mediterranean climatic conditions and highly valued due to their excellent quality (Pretel et al., 2004; Rivera et al., 1998). Lemon fruits represent a good source of organic acids, sugars and bioactive compounds (Cui et al., 2015; Nikolaou et al., 2017) and also offer promising prospects in preventing cardiovascular and neurodegenerative diseases and certain types of cancer, which are being studied nowadays with increasing interest (Gironés-Vilaplana et al., 2014; Legua et al., 2014; Cui et al., 2015). The antioxidant activity, organic acid and sugars content vary depending on several factors, such as species, cultivars, irrigation and climatic conditions, among others (Pretel et al., 2004; Albertini et al., 2006; Legua et al., 2014).

Then, the aim of this study was to evaluate the TAA of the edible tissue of three traditional lemon fruits in the south of Spain. In addition, other fruit properties, such as organics acids and sugars in the fruit juice were analysed. This knowledge could be useful to reconsider the utilisation of certain traditional *Citrus* species and cultivars in future breeding programs to help

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the efficient conservation of an important part of the agricultural biodiversity in the *Citrus* group species and cultivars. In addition, the use of traditional or new cultivars with high antioxidant activity would improve the health beneficial effect of *Citrus* fruits composition.

MATERIALS AND METHODS

The lemon fruits used in this study were (Figure 1): *Citrus* × *limodulcis* D. Rivera y cols. etnovar. 'Dulce', *Citrus limon* (L.) Burn. etnovar. 'Fino' and *Citrus* × *limoroseus* D. Rivera y cols. etnovar. 'Sangrino' (= pink flesh). These cultivars have been classified according to Rivera et al. (1998). For each lemon cultivar, 40 fruit, homogeneous in size and colour were selected, and divided into 4 lots, 3 of them (or replicates) were used for analytical determinations and the remaining for sensory analysis. Colour was determined in each cheek of each fruit by a Minolta colourimeter (CRC200, Minolta Camera Co., Japan), using the CIELAB coordinates. L*, a* and b* parameters were measured and colour expressed as citrus colour index (CCI = a*1000/L*b*). Fruit diameter (D), length (L) and weight were also measured in each fruit.

'Dulce' lemon		'Fino' lemon		'Sanguino' lemon	
					
D:47.71±1.53	L:65.11±2.57	D:55.37±4.61	L:70.98±5.40	D:55.48±2.14	L:72.04±9.12
CCI:-0.29±0.06	Nºs/f:8.7±1.5	CCI:-0.25±0.37	Nºs/f:19.7±4.0	CCI:0.28±0.32	Nºs/f:9.3±6.7

Figure 1. Photographs of the different lemon cultivars. Values of fruit diameter (D, mm), length (L, mm), citrus index colour (CIC) and number of seeds per fruit (N° s/f). Data are the mean±SE of tree replicates of ten fruits each.

After that, fruit of each replicate were separated into their edible portions (albedo, carpelar membranes and juice vesicles), which were weighed. Carpelar membrane and albedo were lyophilised to obtain a homogeneous sample of each replicate and stored at -20°C until total antioxidant activity (TAA) was measured. The number of seeds per fruit was recorded and the juice vesicles from the ten fruits of each lot were ground to obtain juice, which was centrifuged at 10,000 g for 10 min and the supernatant used for organic acids, sugars and TAA analysis. Organic acid and sugar concentrations in juice vesicles were quantified in duplicate in each sample as previously reported (Amorós et al., 2003). Total antioxidant activity (TAA) was determined on duplicate in each sample according to Pretel et al. (2004). Sensory analyses of lemon fruits cultivars were carried out by 10 trained adults, aged from 25 to 40 (5 female and 5 male). The panel was trained in a pre-test in which Citrus fruits with extremely low or high attributes ranked scale from 1 (very low) to 5 (very high) (Pretel et al., 2004; Sanchez-Bel et al., 2015). Data were statistically analysed by ANOVA and Student's t-test was performed for each cultivar to assess if differences between control and saline treatments were significant.

RESULTS AND DISCUSSION

Significant differences in TAA were found among lemon cultivars. 'Fino' and 'Sanguino' lemons showing the greatest TAA levels, more than 95 mg 100 g^{-1} while the 'Dulce' lemon showed the lowest, 10.01±0.15 mg 100 g^{-1} (Figure 2). However, in albedo and carpelar membrane the TAA was very low as compared to TAA of fruit juice, and differences among cultivars were not as strong

as in the juice, according to a previous report in a wide range of orange cultivars (Pretel et al., 2004). Thus, TAA in albedo ranged between 2.3±1.0 and1.6±0.0 mg 100 g^{-1} in 'Sanguino' and 'Fino' lemon, respectively. In carpelar membrane tissue, TAA was very low.

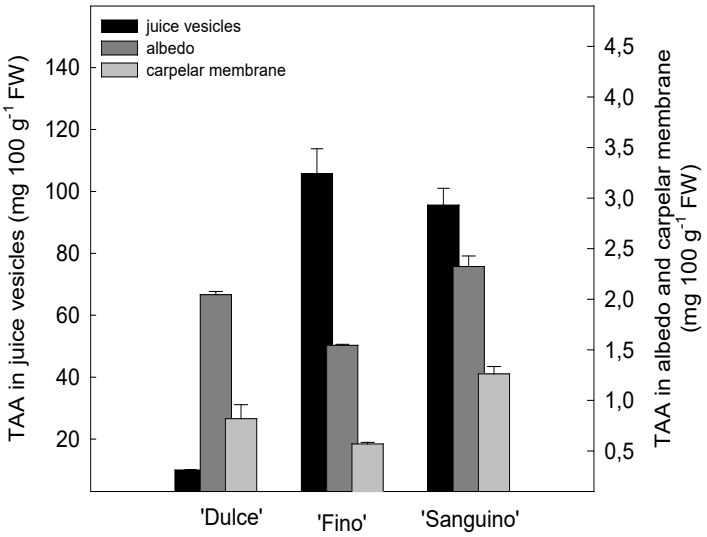

Figure 2. Total antioxidant activity (TAA) in the juice of different lemon cultivars. Means±SE from two replicates of ten fruits each one.

Organic acids, ascorbic acid and sugars are the major components of juice of *Citrus* fruits, although their profile and concentration depend on fruit species and cultivars, (Albertini et al., 2006; Legua et al., 2014). The main organic acid in the studied *Citrus* fruits was citric acid, and as expected, the highest concentrations of citric acid, 6.78±0.20 and 5.44±0.22 g 100 g^{-1} FW, were obtained in 'Fino' and 'Sanguino' lemons, respectively. However, in 'Dulce' lemon, citric acid concentration was very low, 0.11±0.01 g 100 g^{-1} FW (Figure 3). Malic acid was the major organic acid in 'Dulce' lemon. This acidless fruit had also the highest concentration of succinic acid. The present results show that in 'Dulce' lemon the major organic acid was malic acid, while in the acidic fruits citric acid was the major one. In the case of ascorbic acid, the concentration varied significantly among lemon cultivars. The highest concentration was found in 'Fino' and 'Sanguino' lemons, (more than 50 mg 100 g^{-1} FW) and the lowest in 'Dulce' lemon, 4.75±0.03 mg 100 g^{-1} FW (Figure 3).

In lemon fruits the main sugar was different depending on the cultivar (Figure 4). Thus, in 'Sanguino' lemon the major sugar was glucose, ca. 4 g 100 g^{-1} FW, while in 'Dulce' and 'Fino' lemons this was fructose with concentrations of 3.03±0.23 and 2.69±0.35 mg 100 g^{-1} FW, respectively. Fructose is one of the most important dietary monosaccharides and it is known to be the sweetest of all naturally occurring carbohydrates (Barros et al., 2010), which together with the lack of acid content makes 'Dulce' lemon an excellent edible source to make delicious jams and dessert, especially for children, due to its sweetness and delicate pleasant flavour (Rivera et al., 1998).

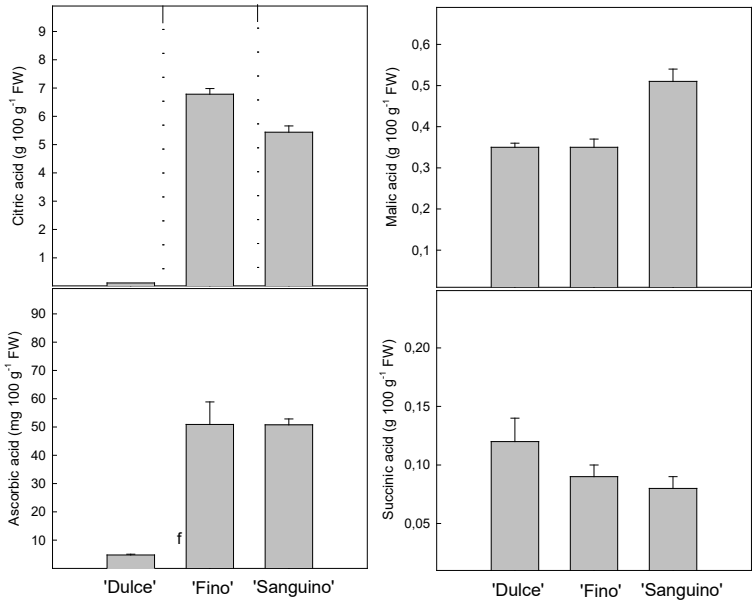

Figure 3. Organic acids (citric, malic, succinic) and ascorbic acid concentrations in orange juice in the different lemon cultivars. Date are the mean±SE of ten fruits in duplicate.

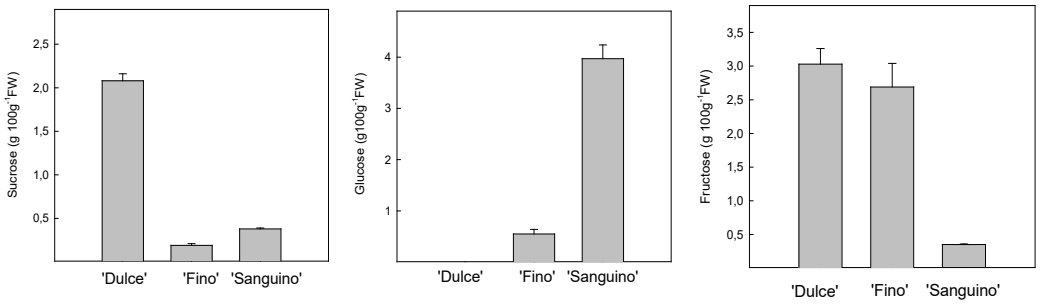

Figure 4. Sugars (sucrose, glucose and fructose) concentrations in different lemon fruit cultivars. Date are the mean±SE of ten fruits measured in duplicate.

Sensorial analysis showed significant differences among fruits related to sweetness, aroma, firmness and lack of bitterness of segments (Table 1). The lemon fruit with the highest score for sweetness was "Dulce' lemon (4.8±0.4), while those with the lowest scores were 'Fino' (1.1±0.3) and 'Sanguino' (1.2±0.4) lemons. The fruits with highest scores for aroma were 'Fino' and 'Sanguino' lemons. 'Dulce' and 'Sanguino' lemons had lower bitterness degree, meaning bitterness absence (close to 5) while 'Fino' lemon had the highest bitterness with score of 2.5±0.5 bitterness. Firmness was very high in the three cultivars. In relation to overall impression, the judges emphasize the 'Sanguino' lemon for its original color and aroma. Thus, the lemon fruits evaluated in the present study had a wide range of aroma, sweetness, bitterness and firmness values, showing their potential to be used in restaurants to make delicatessen food (Reyes-García et al., 2015; Romojaro et al., 2013; Sanchez-Bel et al., 2015) or in the agro food industry.

Table 1. Sensory analysis including sweetness, aroma, firmness, lack of bitterness, overall impression and notable feature of underutilized Spanish lemon fruits. Data are the mean±SE of ten replicates.

Local names	Sweetness	Aroma	Firmness	Bitterness	Overall impression	Notable feature
Dulce	4.8±0.4	2.8±0.7	4.8±0.4	5.0±0	3.3±0.5	Original
Fino	1.1±0.3	4.1±0.3	4.8±0.4	2.5±0.5	4.1±0.3	Aromatic
Sanguino	1.2±0.4	4.2±0.6	5.0±0	5.0±0	4.8±0.4	Colour

CONCLUSIONS

Results show significant differences in among lemon cultivars for the analysed parameters. TAA of fruit juice was different depending on the lemon cultivar, 'Fino' and 'Sanguino' lemons being the cultivars that showed the highest TAA. On the other hand, organic acids and sugar profiles and concentrations were also dependent on fruit cultivars. The fruit most appreciated by the consumers were 'Sanguino' lemon because of its original colour. These results could be useful for considering the reutilisation of certain traditional lemon cultivars in breeding programs to increase the agricultural biodiversity in southeastern Spain.

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