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Quality Performance of 'Smyrna' Type Figs Grown under Mediterranean Conditions of Tunisia

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Abstract

'Smyrna' type figs (Zidi 'ZD': dark fruit and Thgagli 'THG'; Bidhi 'BD' and Khedri 'KHD': white fruit) originated from two areas of fig production in Tunisia were subject to physico-chemical description and spectrophotometric analysis for their sugar (glucose, fructose and sucrose) and organic acid (citric and malic) contents. Fruit weight ranged between 54 and 82 g, fruit width between 47 and 59 mm, ostiole width between 5.5 and 13.7 mm, total soluble solids (TSS) between 16.1 and 18.4% and titratable acidity (TA) between 2.0 and 4.7 mEq/kg of fresh weight (FW). Tunisian figs were characterized by the predominance of glucose (6.3 g/100g FW) and fructose (5.1 g/100g FW). Citric acid (0.38 g/100g FW) was the major organic acid in all cultivars and almost three times higher than malic acid (0.13 g/100g FW). Differences between cultivars were significant ($p \leq 0.05$). Highly significance was recorded related to malate content contrary to citrate levels which were almost the same in the four cultivars. Purple black 'ZD' fruit was the richest on reducing sugars and malic acid and is more suitable for fresh consumption. 'BD' fig had the most interesting physico-chemical properties with round shape, light skin colour and highest concentrations on soluble solids and is better adapted to drying Compared to common fruits, figs are exceptionally rich on sugars responsible in major part of enhancing food ration and intake of people living in the Mediterranean region. Quality parameters described in the present work are fundamental to judge about the potential of local cultivars. Considering quality a prime target for plant breeders, present data could help for fig breeding and cultivars selection.

Keywords: Citric acid, *Ficus carica*, Glucose, TSS, Tunisian climate, 'Zidi' black fruit.

INTRODUCTION

Behind olive tree, fig tree (*Ficus carica*) is among oldest species cultivated in the Mediterranean area. In Tunisia, fig tree is widely spread and found all over the country occupying about 33800 ha (MARH, 2010). National production was estimated about 25000 t (FAOSTAT, 2011) and is entirely locally marketed. Figs are mainly consumed as fresh. A small portion is sun dried and little quantities are used for jam and alcoholic beverage production (Mars *et al.*, 2008).

Tunisian fig cultivars are numerous and well adapted to local agro-ecological conditions (Mars *et al.,* 2009). Some are of the Common type that produces figs without caprification (pollination). Many others are of Smyrna type that need caprification (Mars *et al.,* 1998). Not all the fig types are equally represented in orchards. Cultivars of Smyrna type were dominant in south Tunisia, while in the north, cultivars of Common type were equally represented (Mars, 2003).

The species is recognized to produce fruit with a peculiar sweet taste when fully ripe making figs in demand by a great number of consumers at harvest time. Perception of flavour is based on sugar rates developed by the fruit and cultivar and maturity stage had a significant effect on consumer acceptance (Crisosto *et al.*, 2010). Sugars and organic acids are biochemical components encountered in all fruit species. Figs are very rich on sugars (Ozer and Derici, 1998; Vinson, 1999). Sugar content and its fractions are known to be among the significant quality attributes. In most cases, the fruits are classified according to the dominant sugar (Hakerlerler *et al.*, 1998). Those nutrients are very important for the assessment of the quality of fresh and dried foodstuff (Genna *et al.*, 2005). The relative concentrations of individual sugars vary greatly between species and cultivars, as well as with the stage of maturation and ripening. For example, in apple, pear, strawberry (*Fragaria* × *ananassa* Duch.) and grape, the concentrations of glucose and fructose are higher than that of sucrose, whereas in banana, pineapple (*Ananas comosus*), peach, and melon (*Cucumis melo*), the major soluble sugar at ripeness is sucrose (Passam *et al.,* 2011).

Sweetness is an important indicator of fruit quality and highly correlated with ripeness in most fruit. Behind sugar nutrients, organic acids are important factor for development of the fruit flavour. They have been quoted for their antioxidant properties (Pande and Akoh, 2010). Maturity is generally accompanied by changes in acid contents principally, malic and citric acids. Organic acids in fruits possess acidic properties due to the presence of their carboxyl (COOH) group(s). Apart from their role in cell metabolism (i.e., as components of the tricarboxylic acid cycle or in photosynthesis), organic acids significantly contribute to the flavor and aroma of fresh fruit (Kays, 1991). Although most organic acids within fruits are present only in trace amounts, some occur in much larger concentrations. For example, citrus fruit (e.g., oranges, lemons [*Citrus* × *limon* L.]) contain particularly large amounts of citric acid; apples, pears (*Pyrus communis*) and peaches (*Prunus persica*) contain mainly citric and malic acids, whereas in grapes tartaric and malic acids predominate. In other fruits (e.g., bananas, cranberries), quinic acid and benzoic acid, respectively, are important aromatic constituents (Kays, 1991; Vicente *et al.,* 2009). Sugars and organic acids remain important ingredients of fruits (Ersoy *et al.,* 2007).

The current study aims to identify quality parameters in Smyrna type figs grown under two contrasting environment of Tunisia: mild coastal environment and harsh continental climate, and to quantify sugars and organic acids in Tunisian fresh figs with the object to characterize morphological and biochemical relevant aspects of quality in local fig cultivars; Otherwise, to emerge the determinant criterion of quality for fig growers and plant breeders.

MATERIAL AND METHODS

Plant Material

Smyrna type figs from 'Zidi' (ZD) (dark skin figs), 'Thgagli' (THG), 'Bidhi' (BD) and 'Khedri' (KHD) (light skin figs) were selected for this study. Fruit were gathered from two main zones of commercial fig production: 'Beja' in the North West and '*Monastir*' representing the Central East of Tunisia (Fig. 1). Fig cuttings were planted in 1991 for the first two cultivars originated from '*Beja*' and commercially grown as irrigated. 'BD' and 'KHD' cultivars were planted since 1997 in the coastal zone of '*Monastir*' and growing without irrigation. In the two areas, the orchard was conducted with an open vase training system. Caprification (artificial pollination) is practiced at the receptivity time of female syconia. Twenty fruit per tree and 3 trees per cultivar were harvested in late august 2009 and 2010 to form a sample of sixty ripe fruit from which thirty (three replicates of 10 fruit each) were randomly picked to compose the final fig samples for each cultivar. The samples were immediately stored at -20°C until used. They were then ground in liquid nitrogen using an IKA®A11 basic analytical mill (Ika Labortechnik, Staufen, Germany) and the powder stored at -80°C.

Morphological and Physico-chemical Analysis

Main descriptors for fig fruit (IPGRI and CIHEAM, 2003) were assessed for each variety. Parameters measured were: fruit size, shape, length, neck length, width and ostiole width. Firmness was measured using durofel (Duro10, SETOP GIRAUD Technology, Cavaillon, France) and external fruit colour was established according to IPGRI scale (IPGRI and CIHEAM, 2003). Total Soluble Solids (TSS) were determined with a digital refractometer (PR-101 ATAGO, Norfolk, VA) and expressed in percent (%) at 20°C. Titrable acidity (TA), expressed as mEq/kg FW, was determined by titrating fig juice with 0.1M NaOH.

Determination of Reducing Sugars and Organic Acids

From each sample, 5 g of frozen powder are mixed with 20 ml ultra pure water. Samples were ground with an ultraturrax T25 equipment (Ika Labortechnik, Staufen, Germany) to obtain a slurry. The mixture was homogenized and then centrifuged for 5 min. at 4°C (9000 rpm). Samples were then filtered and the supernatant recovered. The extracts were kept at -20°C until analysis. Glucose, fructose and sucrose, and malic and citric acids were quantified using enzymatic methods with kits for food analysis (Boehringer Mannheim Co., Mannhein, Germany) and expressed in g/100g of fresh weight. Spectrophotometric measurements were performed using an automatic analyser BM-704 (Hitachi, Tokyo, Japan).

Statistics

The determination of metabolites (sugars and organic acids) content in fig extracts were carried out in triplicate from samples harvested over 2 years. Data were subject to one-way analysis of variance (ANOVA). Significant differences were assessed with Duncan's multiple range test ($p \leq 0.05$) and cultivars from homogeneous subsets were displayed. The final data results are means of analysis over the 2 years. Statistics were performed using Statistical Package for the Social Sciences (SPSS version 13.0; SPSS Inc.).

RESULTS AND DISCUSSION

Morphological and Physico-Chemical Aspects

Colour of the figs varied from black purple ('ZD') to yellow-green ('THG', 'BD' and 'KHD') (Table 1). Morphological diversity was observed in the fruit shape with 'THG' being oblate, 'ZD' oblong and 'BD' and 'KHD' having a round form. Fruit shape becomes important when packaging or carrying product. In this case round shape seems to be more suitable (Condit, 1947). All figs, harvested at full ripeness, were relatively soft as shown by their low firmness values (16 - 17 durofel units; 0.34 - 0.36 kg/cm2). Figs soften drastically once ripened and become very malleable. Fruit length varied from 46 to 65 mm, width ranged between 47 and 59 mm and ostiole width between 5.5 and 13.7 mm (Table1). It is important to note that a large ostiole in the fig is an undesirable characteristic. The smaller the ostiole width is, the better is the fruit stored and preserved from infectious agents (Michailides et al., 1996). Average fresh weight was 67 g. Zidi developed the heaviest fruit (82 g). Smallest fruit was recorded in 'KHD' cultivar (54 g). Similar studies related to other cultivars showed values of fresh weight between 22 and 52 g (Caliskan and Polat, 2008) and 24 to 92 g (Sahin *et al.*, 2001). Among the four cultivars studied, Zidi is the only one producing figs with a neck. The presence of a neck in figs facilitates picking the fruit from the tree, consequently harvesting operation.

Total Soluble Solids (TSS) average was 17.2%. Cultivar 'BD' reached the highest value with 18.4%, i.e. a fairly narrow range compared with most other fruits. In apricot, soluble solids content is about 12.3% (means of several cultivars) (Bureau *et al.,* 2009). Turkish varieties of fig ('Sarilop' and 'Bursa siyahi') showed values of 23.0% and 20.1% respectively, with the same levels of acidity (0.19%) (Caliskan and Polat, 2008). Titratable Acidity (TA) was around 2.8 mEq/Kg. The highest score was recorded in cultivar 'KHD' (4.7 mEq/Kg). As a result, maturity index (TSS/TA) was much higher for 'THG' and 'BD' than for the rest of fruit cultivars implying increasing level of flavour and taste within the receptacle. Cultivars 'Mission', 'Brown Turkey', 'Calimyrna' and 'Kadota' grown in California reached respectively 19.1%, 18%, 18.9% and 19.3% of TSS and 0.38%, 0.29%, 0.42% and 0.22% of TA (Crisosto *et al.,* 2010). In Tunisia, as well in other *Ficus carica* growing area, figs develop a high amount of sugars when fully ripe influencing sweetness and flavour. The selected varieties showed an obvious diversity in shape, size and ostiole width of the fruit. Fruit weight is very important for fig fresh consumption and marketing (Aksoy., 1992). Total soluble solids and titratable acidity were in agreement with those found by Caliskan and Polat (2008), Aksoy *et al.* (1992) and Mars *et al.* (1998). The sugar/acid ratio is one of the most important factors in fruit taste (Karaçali, 2002). In our study, 'THG' and 'BD' fruits showed higher TSS:TA ratios than the two other fruit cultivars.

Sugars and Organic Acids

Glucose was the main sugar determined in figs followed by fructose. Average concentrations were respectively 6.3 and 5.1 g/100g FW. Concentration of sucrose was about the one third that of glucose. Differences between cultivars were highly significant ($p \leq 0.01$). Zidi exhibited the highest amount of sugars among all varieties (Fig. 2) with glucose and fructose representing 47% and 37% respectively. Aljane et al. (2006) found concentrations of 3.8 and 3.2 g/100g FW glucose and fructose respectively in 'ZD' fruit origin from southern Tunisia. Thgagli and Khedri, two white coloured fruit, had the lowest concentrations of the two main sugars. The two cultivars belong to the same homogenous subset (Fig. 2).

Figs are very rich fruits on sugars with glucose and fructose being the major ones (Melgarejo *et al.,* 2003; Genna *et al.,* 2005). Melgarejo *et al.* (2003) proved that glucose and fructose are the major sugars identified not only in the main crop but also in the first breba crop producing 'parthenocarpic' figs. All cultivars tested in this work showed presence of glucose, fructose and sucrose in the pulp with rates differing from one cultivar to another. But for all cultivars, glucose is described as the main sugar.

Organic acids concentrations were striking different between the four cultivars. Citric acid was the major organic acid found in figs (0.38 g/100g FW average content) and almost three times higher than malic acid concentrations ranging from 0.11 to 0.17 g/100g FW. In cultivar 'ZD', citric and malic acid rates were 0.43 and 0.17 g/100g FW respectively, illustrating the highest values. In addition to malate and citrate, Melgarejo *et al.* (2003) described oxalic acid with high proportions in figs growing in Spain. However, citric and malic were predominant acids in pulp of all cultivars. Organic acids are important constituents in figs, with sugars they contribute to their healthy diet and nutritional quality.

Glucose and fructose levels are higher in dark 'ZD' figs. Sucrose levels are almost the same in the two coloured fruit. Dark skin figs are richer on reducing sugars than lighter fruit. Differences can be first genetically explained. However, epidermis of the fruit may contribute to the discrepancy recorded between the two types of figs. Citrate and malate concentrations are similar in both dark and white coloured figs. No differences could be noticed in organic acids content between dark and white fruit.

CONCLUSIONS

Glucose, fructose and citric acid are the main sugars and organic acid identified in Tunisian fresh figs. Among the four cultivars studied, Zidi, possessing the heavy receptacle with high concentrations on reducing sugars and organic acids, had the most interesting quality traits making the fruit well appreciated for fresh consumption. People living in North Tunisia prefer this cultivar and dark coloured fruit in general for taste, dessert serving and fresh eating. Among the three light skin cultivars, Thgagli developed the most important fruit size. Bidhi had the sweetest fruit with high total soluble solids and lower value of titratable acidity. Reducing sugar and acid rates were almost the same between the three light coloured fruit cultivars. Bidhi and Khedri, by their light coloured skin and round shape fruit, are well suitable for drying. People living in rural zones of central East and southern Tunisia use more the fruit product for drying purposes.

Sugars and organic acids have an important contribution to nutritive fig value. Flavour and quality taste in figs are enhanced by their high soluble solids content with elevated concentrations on reducing sugars, especially glucose and fructose. The fruit has long been regarded as essential component of the Mediterranean diet. Cultivars selection must takes into account the destiny of the fruit crop (fresh eating or processing). Physical aspects (shape, size and external colour) associated with sugar content represent interesting constituents for fig quality assessment.

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Tables

Table 1. Morphological and physico-chemical characteristics of Tunisian figs
ZD: Zidi, THG: Thgagli, BD: Bidhi, KHD: Khedri cv. (Means ± SD; N=3)

	Cultivar				**Mean value**
	ZD	**THG**	**BD**	**KHD**	
Fruit size (g)	82 a ±17	76 a ±18	56 b ±12	54 b ±11	67
Length (mm)	65 a ±5	50 b ±4	46 b ±4	47 b ±5	52
Neck length (mm)	10.2 a ±0.9	0 b	0 b	0 b	-
Width (mm)	51 b ±5	59 a ±4	49 b ±3	47 b ±2	52
Ostiole width (mm)	9.9 b ±0.6	13.7 a ±3.2	6.2 bc ±0.7	5.5 c ±1.1	8.8
Firmness (durofel)	16	16	17	17	17
TSS (°Brix)	16.2 b ±1	16.1 b ±1	18.4 a ±1	17.9 ab ±1	17.2
TA (mEq/kg FW)	2.7 b ±0.02	2.0 c ±0.01	2.3 c ±0.01	4.7 a ±0.02	2.9
IM (TSS:TA)	60	80	80	38	65
Shape[1]	Oblong	Oblate	Round	Round	-
Colour[1]	Purple black	Yellow green	Yellow green	Yellow green	-

[1] descriptors for fig (IPGRI and CIHEAM, 2003)
Means are compared horizontally for each parameter. Identical letters (a, b, c) refer to cultivars from homogenous group performed by DUNCAN test (α=0.05).
TSS: total soluble solids, TA: titratable acidity, IM: maturity index.

Figures

	I. 'Béjà' (Thibar)	II. 'Monastir' (Bekalta)
Location	North West	Central East
Altitude	327 m	20 m
Latitude	36°31'N	35°37'N
Longitude	9°5'E	11°2'E
Climate	Sub-humid	Semi-arid
Ann.means T°	20°C	18°C
Ann. rainfall	600 mm	300 – 350 mm

Fig. 1. Location and data environments of the two experimental sites in Tunisia. Ann.: annual, T° : temperature.

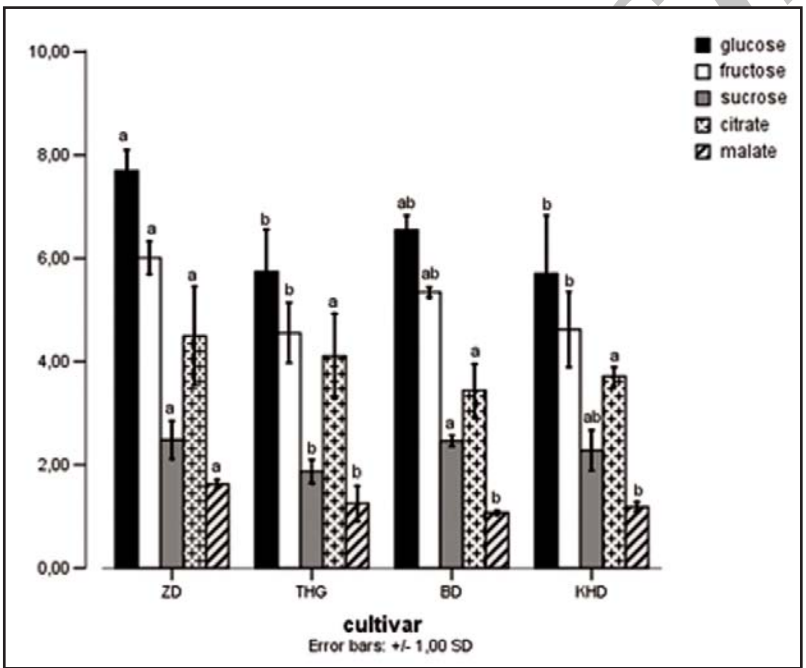

Fig. 2. Sugars (g/100g FW) and organic acids (g/kg FW) in Tunisian fig fruit (means N=3 ±SD). Identical letters (a, b, c) refer to cultivars from homogenous group performed by DUNCAN test (α =0.05). ZD: Zidi, THG: Thgagli, BD: Bidhi, KHD: Khedri cv.