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Apricot (*Prunus armeniaca* L.) fruit quality attributes and phytochemicals under different crop load

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ABSTRACT

Three apricot (*Prunus armeniaca* L.) cultivars were subjected to different degrees of fruit thinning during pit hardening. At harvest fruit quality characteristics were assessed, along with phytochemicals' concentration, such as carbohydrates, phenolic compounds and organic acids. Antioxidant capacity of the pulp was estimated by diphenyl picryl hydrazyl and ferric reducing antioxidant power assays. Thinning improved fruit weight in two of the three cultivars with a subsequent decrease in fruit firmness, without significant effect on total soluble solid content and titratable acidity. The skin color was not influenced by thinning, but carbohydrate concentration and sweetness index increased. Total phenol concentration increased with thinning, without any similar increase of the major individual phenolic compounds detected (neo-chlorogenic acid, chlorogenic acid, rutin, catechin, epicatechin, ferulic acid, p-coumaric acid and caffeic acid). The antioxidant capacity of the pulp was not influenced by thinning. In overall, thinning enhanced the pomological traits of apricot fruits as well as their phytochemical content.

1. Introduction

The apricot tree (*Prunus armeniaca* L.) is one of the most important fruit species grown in the world, as the fruit is highly appreciated by consumers. Consumers cherish the flavour and aroma of high quality apricots, with the sugar content being one of the most appreciable quality characteristics (Ruiz and Egea, 2008).

Under favourable conditions, apricots usually set abundant flowers. However, high fruit numbers lead to imbalance of fruit to leaf ratio and consequently to smaller, less desirable fruit, alternate bearing, limb breakage, pre-mature fruit drop, delayed fruit maturation and reduced fruit quality, exhaustion of reserves and reduced cold hardiness (Wünsche and Ferguson, 2005).

Fruit thinning is among the most important agricultural practices in fruit production systems (Meland, 2009). It is a widely applied practice in various fruits (e.g. apples, peaches, apricots) aiming in altering the sink/source relationship, by adjusting the number of fruits on the tree (based on fruit to leaf ratio), in order to attain adequate size for commercial sales (Rettke and Dahlenburg, 1999; Wünsche and Ferguson, 2005).

Numerous pomological traits determine apricot fruit quality, such as size, color, taste, aroma and firmness (Souty et al., 1991) as well as sugar and organic acid content and volatile compounds (Ruiz and Egea, 2008). Since the past decade, consumers are strongly interested in attractive, tasty fruits, which not only do they cover the basic need for nutrient supply but also posses health promoting or disease preventing properties. Although much is known on the effect of thinning on fruit size and simple fruit quality characteristics, little is known on the effect on neutraceticals' concentration. Apricot fruits contain significant levels of various phytochemicals such as vitamins, carotenoids and polyphenols, which contribute significantly to their taste, color and nutritive values. There is a considerable interest in polyphenols because of their antioxidant properties and ability to alleviate chronic diseases (Gardner et al., 2000; RiceEvans et al., 1997; Vinson et al., 1998). The major phenolic compounds in apricot are chlorogenic and neochlorogenic acids, (+)-catechin, (−)-epicatechin, and rutin (or quercetin-3-rutinoside), which have a positive and highly significant relationship with the antioxidant capacity of apricots (Dragovic-Uzelac et al., 2007).

The aim of the present manuscript was to study the effects of fruit thinning on apricot's common quality characteristics such as size, weight, color, soluble solids and titratable acidity as well as on antioxidant capacity and phytochemicals such as phenolic compounds, carbohydrates and organic acids.

2. Materials and methods

2.1. Plant material

The trial was conducted during the growing periods of 2009 and 2010. Full bearing apricot trees of cv. Bebecou, grown in

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Megalos Valtos, Korinthia County (commercial farm) (latitude: 38°0′ N, longitude: 22°38′ E, altitude 506 m) and of two newly released hybrids, i.e. "Veecot" × "Bebecou" cv. Niove and "Stark Early Orange" × "Bebecou" cv. Nafsika grown in the orchard of Agricultural University of Athens (latitude, 37°58′ N, longitude, 23°32′ E, altitude 30 m) were used.

2.2. Fruit thinning

Four trees were chosen per cultivar. Thinning treatments were applied in each tree, one treatment per limb. Limbs of similar crop load were chosen and they were manually de-fruited during the period of pit hardening, in order to achieve four levels of fruit bearing, i.e. the control, where no fruit was removed, 25 (light), 50 (moderate) and 75% (heavy) fruit thinned, compared to the initial fruit number. The accuracy of fruit thinning percentage was measured by counting the number of fruits per limb cross sectional area (LCSA) i.e. the crop load.

2.3. Fruit sampling

At least 25 free of defects fruits were carefully hand harvested per limb, at commercial maturity stage (based on their skin ground color, i.e. fully coloured) (Kader, 1999). They were put into plastic bags, in an insulated box filled with ice gelpacks and transferred under low temperature (approximately 10 °C, based on a minimum–maximum thermometer placed in the insulated box) to the laboratory. The weight of each individual fruit along with its diameter and length was recorded with a calibrated electronic balance (Kern 470, Kern and Sohn, GmbH, Germany) and a digital calliper (Starrett, 727 Series, Athol, New England, USA), respectively. Surface color of each sampled fruit was measured at three different points around the equatorial region of each fruit, using a Minolta CR 300 reflectance Chroma Meter calibrated to a white porcelain reference plate (Minolta, Osaka, Japan), which provided CIE L^*, a^* and b^* values. These values were then used to calculate Hue angle degree [$h^\circ = \arctan(b^* a^{*-1})$], where 0° = red-purple; 90° = yellow; 180° = bluish-green and 270° = blue and Chroma ($C^* = [a^{*2} + b^{*2}]^{1/2}$), indicative of the intensity or color saturation. Fruit firmness was assessed in 10 fruits, on opposite cheeks, by a hand-held penetrometer equipped with a 6.3 mm diameter conical plunger, after slightly peeling off the fruit. These fruits were further used to determine the fresh to dry weight ratio, after drying them in an oven at 70 °C till constant dry weight. The remaining fruits were carefully de-stoned and homogenized by a home processor. The pulp derived was stored in a freezer (−25 °C) till analysis.

2.4. Assessment of fruit quality characteristics

2.4.1. Total soluble solids (TSS), titratable acidity (TA) and pH determination

A small fraction of the homogenous mixture was centrifuged at 4000 g for 6 min. The supernatant clear juice was analyzed for TSS, pH and TA. Total soluble solids were evaluated at 20 °C with an Atago 8469 hand-refractometer (Atago Co. Ltd., Tokyo, Japan) and expressed as °Brix. pH was measured after dilution of the juice at a ratio 1:20 with distilled water. Titratable acidity was determined in the same diluted juice solution by titrating to pH 8.2 using 0.1 N NaOH.

2.4.2. Total phenol content and individual phenolic compound determination

Approximately 2.0 g of the frozen apricot fruit mixture were extracted twice with 5 ml 100% methanol under periodical stirring at 45 °C. After centrifugation the supernatant was assessed for total phenol and total o-diphenol content according to Roussos and Pontikis (2001) and the results were expressed as mg equivalent tannic acid (TAE) and caffeic acid (CAE), respectively. The total flavonoid content was determined according to Meyers et al. (2003), while the total flavanol one was determined according to Arnous et al. (2002) and the results were expressed as mg equivalent caffeic acid and catechin (CtE), respectively. The same supernatant was used for the antioxidant capacity assays.

The rest of the supernatant was evaporated under a stream of nitrogen at 45 °C and the residue was dissolved in 1 ml methanol. The solution was filtered through a 0.22 μm pore size nylon syringe filter and analyzed by HPLC. The separation of phenolic compounds was accomplished through a Luna C18 3 μm (250 × 4.6 mm) column Phenomenex, CA, USA), at a flow rate of 0.5 ml min^{-1} at 28 °C with a Varian gradient pump and the phenolic compounds were detected by a UV detector at 280 nm. The mobile phase consisted of two solvents i.e. A: 2% (v/v) acetic acid in water and B: 2% (v/v) acetic acid in acetonitrile. The gradient elution profile was: 0–20 min, 15% of solvent B, from 20 to 22 min, linear increase to 20% of B solvent, which remained until the end of the analysis at 85 min. Eight phenolic compounds were determined i.e. neo-chlorogenic acid, chlorogenic acid, catechin, epicatechin, rutin, caffeic acid, ferulic acid and p-coumaric acid and quantified using authentic standards' calibration curves. Neo-chlorogenic acid was quantified using chlorogenic acid calibration curve.

2.4.3. Carbohydrate and organic acid determination

Carbohydrate extraction and determination in the frozen pulp sample was performed as described by Roussos et al. (2010). For the HPLC analysis a Waters 510 isocratic pump was used at a flow rate of 0.6 ml min^{-1} of water, while the separation of the carbohydrates was achieved through a Hamilton HC-75 cation exchange

Table 1
Effect of thinning severity on crop load and yield efficiency.

Variables	Varieties	Thinning severity			
		Control	Light	Moderate	Heavy
Crop load (n. fruits cm^{-2} LCSA[a])	Bebecou	5.41 a	4.4 ab	2.95 bc	1.62 c
	Nafsika	4.96 a	3.95 ab	2.81 bc	1.84 c
	Niove	8.02 a	5.78 ab	4.2 bc	1.47 c
Yield efficiency (g cm^{-2} LCSA)	Bebecou	393.22 a	327.44 b	228.64 c	131.12 d
	Nafsika	258.94 a	215.17 b	159.5 c	119.89 d
	Niove	251.34 a	193.28 b	144.52 b	53.33 c

Means within the same row followed by the same letter, do not differ significantly according to Tukey HSD test at $a = 0.05$.

[a] LCSA, limb cross sectional area.