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Phytochemical properties of local and introduced apricot cultivars grown under organic cultivation system in Tunisia

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ABSTRACT

Purpose: Organic apricots are perceived to be healthier than conventional ones. In Tunisia, comparative studies on the phytochemical properties of these fruits are scarce. This work aimed to identify organically grown apricot cultivar(s) with high nutritional value for human health. Phytochemical compounds of organically apricots in local ('Oud Rhayem', 'Oud Hmida' and 'Oud Aouicha') and introduced ('Ninfa' and 'Mogador') cultivars were investigated. **Research Method:** Polyphenols, flavonoids, anthocyanins and carotenoids analysis were performed for 3 lots of 10mixed fruits each. **Findings:** Significant variability in phytochemical properties was obtained between the studied cultivars. 'Mogador' was found to be superior for most phytochemical compounds: β-carotene (0.05mg/100g fresh mass), total phenolics (≥154 mg GAE/100 g of fresh mass) and total flavonoids (27mg catechin/100 g fresh mass). Furthermore, highest phenolics content was found in 'Oud Aouicha' and 'Oud Hmida' (≥160 mg GAE/100 g fresh mass). The highest anthocyanins content was obtained in 'Oud Aouicha' and 'Ninfa' (71 and 62.5 mg cyaniding-3-glucoside /100g fresh mass, respectively). In conclusion, 'Mogador' could be selected as the performing apricot genotype including the most phytochemicals components. Nevertheless, 'Ninfa', 'Oud Aouicha' and 'Oud Hmida' showed good accumulation of many antioxidant components. **Research limitations:** Further researches on other genotypes are required. **Originality/Value:** This study is original related to the phytochemical properties of local and introduced organic apricots. The results can be considered as a preliminary database of the nutritional facts of organic apricots and they could help breeders to select genotypes with large antioxidant capacity of fruit related to the health benefits.

INTRODUCTION

Considerable attention has been recently directed towards the identification of plants with high antioxidant ability (Seal, 2011). Since, a positive relation has been demonstrated between intake of antioxidant rich diets and lower incidence of degenerative diseases including cancer, heart disease, inflammation, arthritis, immune system decline, brain dysfunction and cataracts (Dauchet & Dallongeville, 2008). Within the last decade many studies have been carried out in order to define the nutraceutical properties of fruit with health related benefits (Kaur & Kapoor, 2001; Yao et al., 2004).

Along with other antioxidant components, phenolic compounds and their consumption has been correlated to the prevention of destructive processes (alleviate chronic diseases) caused by oxidative stress (Gardner et al., 2000; Kaur & Kapoor, 2001; Vinson et al., 2001). So, phenolics are thought to act as antioxidant, anti-carcinogenic, anti-microbial, anti-allergic, anti-mutagenic and anti-inflammatory, as well as reduce cardiovascular diseases (Kim et al., 2003). Furthermore, phenolic compounds have a determinant role in fruit taste and aroma contributing to the astringency and bitterness of horticultural crops (Hamauzu, 2006; Veberic et al., 2009; Milivojevic et al., 2012). They are also responsible for color formation of fruits and vegetables (case of anthocyanins) (Hamauzu, 2006; Pfeiffer & Hegedus, 2011). Certain phenolic compounds are characteristic of some species or varieties (Perez-Ilzabre et al., 1991). Quantitative differences of phenolic compounds depend on fruit variety, stages of maturity, storage conditions (Spanos & Wrolstad, 1992) and the presence of the peel in fruit-based products (Garcia-Viguera et al., 1997).

Carotenoids are notable for their wide distribution, structural diversity, and of various functions (Rodriguez-Amaya & Kimura, 2004). They have been recognized with several beneficial effects on human health ranging from provitamin A activity to the enhancement of the immune response and reduction of the risk of degenerative diseases such as cancer, cardiovascular diseases, cataract, and macular degeneration (Van den Berg et al., 2000; Landrum & Bone, 2001). They are potent antioxidants and free radical scavengers (Bohm et al., 2002; Grassmann et al., 2002). Several studies have correlated the color with the pigment content of different fruits and vegetables (Arias et al., 2000). The color value could be used to express the content of β-carotene in white-fleshed sweet potatoes, and thus color measurements have been considered to be appropriate for the rapid estimation of carotenoid content (Ameny & Wilson, 1997). The daily intake of provitamin A can only be achieved by consuming 100-200 g per day of fruits and vegetables with particularly high carotenoids content (de Rigal et al., 2000).

Apricot fruit has great nutritional value because of fiber, minerals and low energy value (50 Kcal 100 g^{-1} fresh weight) that combined with the nutraceutical plus-value (vitamins, carotenoids and polyphenols) make it 'healthy and easy to eat' (Leccese et al., 2011). Various phytochemicals (vitamins, carotenoids and polyphenols) contribute significantly to the taste, color and nutritive values of its fruits (Dragovic-Uzelac et al., 2007). For this species, the antioxidant profile has been analyzed with particular focus on the total antioxidant capacity, polyphenols and /or carotenoids (Ruiz et al., 2005a; Leccese et al., 2011; Schmitzer et al., 2011). Numerous factors have been shown to influence the fruit antioxidant capacity or quantity of individual antioxidant compounds in stone fruit species, including genotype (Drogoudi et al., 2008; Hegedus et al., 2010), geographic region of cultivation (Munzuroglu et al., 2003; Dragovic-Uzelac et al., 2007), harvest year (Hegedus et al., 2010) and the length of the fruit development period (Leccese et al., 2008). In recent years, an increased demand is being recorded for fruit with high amount of phytochemicals and large antioxidant capacity (Milivojevic et al., 2012) to benefit consumer's health (Cantin et al., 2009).

Apricot is a rich source of carotenoids and vitamin C (Ruiz et al., 2005a; Akin et al., 2008; Hegedus et al., 2010). For carotenoids, β-carotene represents more than 50% of total carotenoids present in apricots (Radi et al., 2004; Sass-Kiss et al., 2005; Ali et al., 2011). Besides β-carotene, apricot fruit and its products contain smaller amounts of α-carotene, γ-carotene, zeaxantin and lutein (Fraser & Bramley, 2004). Lichou et al. (1998) signaled that depending on the carotenoid content in apricot, these compounds induce more or less intense skin and flesh colors.

Recently, it has been shown that apricot fruits provide protection against radiation and have in vivo cardio-protective activity that are associated with its antioxidant phenolic contents (Parlakpinar et al., 2009; Ugras et al., 2010). The major phenolic compounds described in apricot fruit are chlorogenic and neochlorogenic acids, (+)-catechin, (-)-epicatechin, and rutin (or quercetin-3-rutinoside), which have a positive and highly singficant relationship with the antioxidant capacity of apricots (Dragovic-Uzelac et al., 2007). For this species, no relationship was found between color and the phenolic content (Lichou et al., 1998). Likewise, Ruiz et al. (2005b) reported that no correlation between flesh color of apricot varieties and phenolic content was obtained. Similar results were observed for peaches and nectarines (Radi et al., 2004).

The present study aims to define nutritional attributes of organically grown apricots of local and introduced cultivars. Phytochemical levels will be defined for each type and quality performance between cultivars will be discussed.

MATERIALS AND METHODS

Plant material

Three local apricot cultivars ‘Oud Rhayem’, ‘Oud Hmida’ and ‘Oud Aouicha’ and two introduced ones ‘Mogador’ and ‘Ninfa’ are considered in this study. They were grown in Testour region (Northwest of Tunisia: 36° 33’ N and 09° 26’ E) which was characterized by annual temperature of 20°C, rainfall of 390 mm and humidity of 58%. Testour ranked the 4th region with 6% of annual fruit production and area, respectively. The annual production of apricot was estimated to 30 500 Tons spread over 9200 ha (GDAP, 2017).

Organic cultivation system of apricot trees is managed as the following: treated during April with organically insecticides against aphids and fertilized with compost as organic fertilizers. They are characterized by early flowering time (end of February-beginning of March) and medium-early ripening time (mid- to the end of May). The trees were 15 years old, grafted on mech-mech seedling rootstock (good vigor; relatively tolerant to chlorosis; improves productivity and size), spaced at 5 x 5 m and drip irrigated from April to October.

Fruit sampling

Thirty ripe fruits per cultivar were the subject of the different analysis. These fruits harvested during mid-end of May 2017 (22/05/2017) at the commercial stage of maturity (less than 10% green color mainly around the suture) as defined by Lichou et al. (1998). Fruits were picked from the periphery in the average height of the observer. According to Lichou et al. (1998), for the fruits developed on the tree periphery, the light and the sun exposure increase their metabolic activity and advance their maturity with important color and over color. After a first evaluation (morphological and physico-chemical evaluation), fruit samples were divided in 3 lots of 10 fruits each. Apricots were then mixed using a centrifuge-mixer (Moulinex JU350B39) and obtained juice was analyzed for phytochemical properties (carotenoids, flavonoids and anthocyanins). For these analyses, we referred to fruit quality investigations as Nagata and Ayamashita (1992), Arnous et al. (2001), Yang et al. (2009) and Lee et al. (2005).

Fruit biochemical analysis

Total carotenoids

Total carotenoids were measured by using Acetone-hexane (4:6, v/v) as described by Nagata and Ayamashita (1992). Yet, the protocol was little modified to improve carotenoids extraction from fruit samples. For each cultivar, 5g of juice/lot of 10 fruits was homogenized separately with 10 ml of solvent. After vortex shaking, the mixture was stand for few minutes until separation of the two phases. The superior phase is composed by the solvent and the extract. For apricot, if phase separation does not occur, 5ml of solvent could be added. The total carotenoids content (expressed as β-carotene) in each extract was measured by using a spectrophotometer (BioBase; BK-W 1000, China) at 4 wave lengths: 453 nm, 505 nm, 645 nm and 663 nm, successively. For apricot, the mean carotenoids content was divided by 5 (in the beginning, 5g of juice was used) and was expressed as β-carotene equivalent (mg/100g of fresh mass) which was identified as the main pigment in apricot varieties according to Ruiz et al. (2005a).

Total phenolics

According to Arnous et al. (2001), the total phenolics were estimated by using Folin-Ciocalteu method. For each apricot cultivar, 50 µl of Folin-Ciocalteu reagent and 790 µl of distilled water were added to10 µl of juice (After vortex shaking for 1 min, 150 µl of sodium carbonate (20%) was added. The mixture was shaked again and kept in the dark for 2 hours at ambient temperature. Absorbance of the extracts was measured at 750 nm. The same analysis was repeated 3 times for each cultivar. The mean phenolics content was expressed as gallic acid equivalents (GAE) (mg/100 g of fresh mass) and estimated by calibration curve obtained from measuring the absorbance of a known concentration of gallic acid standard.

Total flavonoids

Total flavonoids were extracted by using spectrophotometric method according to Yang et al. (2009). 250 µl of juice sample has been diluted with 1.25 ml distilled water. 75 µl of sodium nitrite (5%), 150 µl of aluminum chloride (2%), 500 µl of NaOH (1 M) and finally 3 ml of distilled water were added to the juice. The total flavonoids content in each extract of juice was measured by using a spectrophotometer at 510 nm. The results were expressed as catechin equivalent (mg/100 g of fresh mass) and estimated by calibration curve obtained from measuring the absorbance of a known concentration of catechin standard.

Total anthocyanins

Total anthocyanins were determined according to Lee et al. (2005). Three samples of juice/cultivar were analyzed. Potassium chloride (0.025 M; pH=1) and sodium acetate (0.4 M; pH=4.5) solutions were used. 3.6 ml of each solution were added to 0.4 ml of juice. The absorbance was measured at 510 nm and 700 nm by spectrophotometer. The total anthocyanins content was expressed as cyaniding-3-glucoside (mg/l of fresh mass).

Statistical analysis

For each apricot cultivar, means values and respective standard error of means were determined for each phytochemical property. General Linear Model (GLM) was performed for the analysis of variance and to establish the effect of cultivar on these cited fruit characteristics. The means values were compared by the Duncan test at 5% in order to define groups from homogenous subsets. Principal component analysis (PCA) was used to establish relationships between cultivars and to highlight cultivars with high fruit quality performance. All these analyses were performed using the SPSS 17.0 and Excel Stat softwares.

RESULTS AND DISCUSSION

Analysis of variance of phytochemical properties

Total carotenoids

The results showed a highly significant difference in β-carotene content between local and introduced apricot cultivars (Fig. 1). In fact, β-carotene levels were higher in introduced cultivars than in local ones. 'Mogador' showed the highest β-carotene level (0.050 mg/100g of fresh mass) followed by 'Ninfa' (0.042mg/100g of fresh mass) (Fig. 1). Whereas, low levels of β-carotene were obtained in local cultivars. They varied between 0.020 mg/100g of fresh mass ('Oud Rhayem' and 'Oud Hmida') and 0.034 mg/100g of fresh mass ('Oud Aouicha') (Fig. 1). Similar variation of β-carotene content among apricot varieties was obtained by many researchers (Ruiz et al., 2005a; Dragovic-Uzelac et al., 2007; Akin et al., 2008; Drogoudi et al., 2008; Ali et al., 2011). Yet, the β-carotene level was determined to be significantly different among apricot varieties and among different regions with the same variety (Munzuroglu et al., 2003; Dragovic-Uzelac et al., 2007; Erdogan & Erdemoglu, 2011). Our values of β-carotene content were close to those obtained by Kan et al. (2014) which ranged between 0.05 and 0.327 mg/100 g fresh mass in Turkish apricot cultivars grown under different farming conditions (irrigated and dry). Radi et al. (1997) found a variation of β-carotene between 0.05 and 1.16 mg/100 g fresh mass in several apricot cultivars (originated from France and Spain) grown in France. Also, similar carotenoid content expressed of β-carotene equivalents (1.01 to 1.81 mg/100 g fresh mass) were obtained in Pakistan apricot cultivars (Ali et al., 2011). While, higher levels of β-carotene (0.57 to 4.87 mg/100 g fresh mass) were observed in some Turkish apricot varieties (Akin et al., 2008). Drogoudi et al. (2008) observed the similar variation of total carotene content (0.95 to 3.78 β-carotene equivalent mg/100g fresh mass) between group of apricot cultivars (local, American and hybrids) grown in Greece. Also, Wassem et al. (2021) reported an average of 0.47-10.09 β-carotene equivalent mg/100 g fresh mass in Pakistan apricots varieties. Apricots have been described as one of the most important dietary sources of provitamin A carotenoids, which include β-carotene, β-cryptoxanthin and α-carotene (Ruiz et al., 2005a). These latter authors reported that β-carotene was the main pigment in apricot varieties and it ranged from 48% in a white flesh variety to 88% in an orange flesh apricot. Similarly, Alajil et al. (2021) reported that β-carotene was the main pigment in apricot varieties grown in India which counted 33 to 84% of the total carotenoids. However, according to Kafkaletou et al. (2019), β-carotene represented 87 to 97% of total carotenoids in apricots grown in Greece. Moreover, Ruiz et al. (2005a) signaled that in contrast with other fruits, the peel of apricot was consumed as an edible portion and is the richest portion in carotenoids (2-3 times higher than in the flesh). Variations in carotenoids are attributed to climate, variety, geographical origin, harvest and the methods of cultivation (Akinci et al., 2004).

Many investigations signaled a relationship between the carotenoids content and the color of fruit (Arias et al., 2000; Ruiz et al., 2005a; Carbone et al., 2018). For our studied apricot cultivars, the ground color of skin and the color of flesh of the fruit have been characterized previously (Lachkar et al., 2021). In fact, the two introduced cultivars 'Mogador' and 'Ninfa' were characterized by medium orange as the ground color of skin and light orange as the color of flesh (Fig. 2) as reported by Lachkar et al. (2021). The local cultivar 'Oud Aouicha, was identified by light orange as the color of flesh (like the introduced cultivars) and also as the ground color of skin. This latter was respectively, yellowish and medium orange for 'Oud Hmida' and 'Oud Rhayem'. These cultivars were characterized by cream and medium orange color of flesh (Fig. 2), respectively as signaled by Lachkar et al. (2021). Ruiz et al. (2005a) reported that the color parameters [a*, b*, hue angle: H°= arctangent (b*/a*) and chroma:

$(a^{*2}+ b^{*2})^{1/2}$] showed good correlations with individual and total carotenoids in both flesh and peel of apricot. The hue angle has been described as a suitable color index and quality criterion to select new varieties with higher carotenoid contents. It decreased from the yellow to the orange stage due to carotenoid accumulation (Ruiz et al., 2005a). Indeed, Ayour et al. (2016) signaled that apricot genotypes with the lowest h values may be defined as a carotenoids-rich source.

Total phenolics

A wide variability of total phenolics was obtained among organic apricot cultivars. The values varied between 93 ('Ninfa': introduced cultivar) and 163 mg GAE/100g fresh mass ('Oud Hmida': local cultivar) (Table 1). Similarly, Kafkaletou et al. (2019) signaled that total phenolics in various apricot genotypes cultivated in Greece ranged from 33.5 to 113.4 mg GAE/100 g fresh mass. However, Alajil et al. (2021) and Wassem et al. (2021) reported a spectrum of total phenolics contents ranging from 25.31 to 89.95 mg GAE/100 g fresh mass in apricot genotypes cultivated in India and from 209.64 to 641.15 mg GAE/100 g fresh mass in Pakistan apricot varieties. In our study, the phenolics levels of fruit of 'Oud Hmida', 'Oud Aouicha' and 'Mogador' were statistically similar and they were the highest ones (154,33; 159,79 and 162,62 mg GAE/100g fresh mass, respectively) (Table 1). While, 'Ninfa' showed the lowest level of phenolics (93.48 mg GAE/100g fresh mass). These results were similar to those obtained by Ruiz et al. (2005b) (32.6 to 160 mg/100g fresh mass of edible portion) and by Miloševic et al. (2012) (100 to 130 mg/100 g fresh mass). High total phenolic compounds were obtained in Turkish apricot varieties (423.37 to 818.05 mg GAE /100 g fresh mass) (Akin et al., 2008) and in Pakistan ones (459.1 to 731.0 mg GAE /100 g fresh mass) (Ali et al. 2011). Similarly, in Greece, a remarkable variation was observed in the total phenol content (30 to 740 mg GAE/100 g fresh mass) between Greece, American and hybrids apricot cultivars (Drogoudi et al., 2008). Whereas, in Italy, small amounts of phenolics (20.78 to 75.76 mg GAE/100 g fresh mass) were obtained by Leccese et al., (2007). The different findings of total phenolics content may be related to the origin of cultivars (Kalyoncu et al., 2009), environmental conditions, length of fruit development period, maturity levels of fruits (Dragovic-Uzelac et al., 2007; Hegedűs et al., 2010) and fruit location on the tree (Dragovic-Uzelac et al., 2007). Moreover, their types and their concentrations changed according to the different cultivars (Kan & Bostan, 2010). Otherwise, analytical methods can make up differences and amounts on phenolic compounds (Hegedűs et al., 2010; Leccese et al., 2011). Considering their ripening calendar, the highest phenol content has been recorded in later ripening cultivars (Leccese et al., 2007) and the polyphenol quantities in apricot decreased with ripening (Dragovic-Uzelac et al., 2007).

Table 1. Some phytochemical properties of local and introduced apricot cultivars grown under organic cultivation system

Cultivars	TP (mg GAE/100g fresh mass)	TA (mg cyaniding-3-glucoside /100g fresh mass)	TF (mg catechin/100g fresh mass)
'Mogador'	154.33 ± 8.30 a	39.41 ± 15.34 bc	27.15 ± 1.08 a
'Ninfa'	93.48 ± 9.69 c	62.56 ± 12.45 ab	3.70 ± 1.77 c
'Oud Aouicha'	159.79 ± 5.43 a	71.36 ± 20.26 a	14.41 ± 2.50 b
'Oud Hmida'	162.62 ± 6.96 a	13.92 ± 3.21 d	13.31 ± 2.20 b
'Oud Rhayem'	116.03 ± 2.52 b	18.70 ± 6.90 cd	13.41 ± 2.12 b

TP: Total phenolics; TA: Total anthocyanins; TF: Total flavonoids.

For each phytochemical property: all the values are means of three replications ± standard deviation and means with the same letter are not statistically different by Duncan test at $p \leq 0.05$.

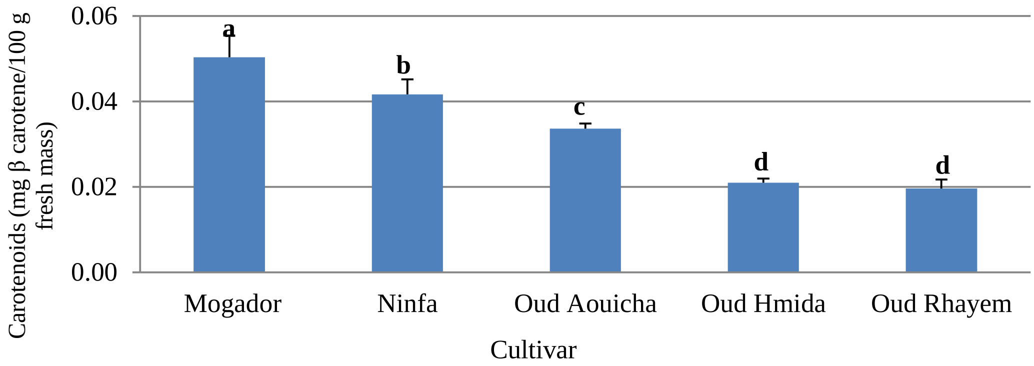

Fig. 1. Total carotenoids (mg β-carotene equivalent/100 g fresh mass) in local and introduced apricot cultivars grown under organic cultivation system

All the values are means of three replications ± standard deviation. Means with the different letter are statistically different by Duncan test at $p \leq 0.05$.

'Mogador'

'Ninfa'

'Oud Rhayem'

'Oud Hmida'

'Oud Aouicha'

Fig. 2. The ground color of skin and the color of flesh of apricots for the introduced and local studied cultivars.

In our study, the apricot cultivars were grown in same location under similar cultural practices like to the study of Miloševic et al. (2012). The variability of phenolics levels obtained was in accordance with that showed by many researchers for several groups of apricot cultivars (Dragovic-Uzelac et al., 2007; Leccese et al., 2007; Akin et al., 2008; Drogoudi et al., 2008; Pedryc et al., 2009; Schmitzer et al., 2011; Ali et al., 2011; Miloševic et al., 2012).

Total flavonoids

Total flavonoids were significantly different between studied apricot cultivars (Table 1). Introduced cultivar 'Mogador' showed the highest concentrations of total flavonoids (27.15 mg/100 g fresh mass). While, the second one 'Ninfa' had the lowest amount (3.70 mg/100 g fresh mass). The content of these compounds was statistically similar between three local cultivars (Table 1). Our values of total flavonoids were close to those obtained by many researchers (Ruiz et al., 2005b; Carbone et al., 2018; Alajil et al., 2021). Ruiz et al. (2005b) reported that flavonoids content ranged significantly from 5.7 mg/100 g fresh mass (Yellow flesh apricot varieties) to 9.2 mg/100 g fresh mass (White flesh apricot varieties) showing that white flesh varieties had higher levels than yellow, light orange, and orange varieties. In contrast, other researchers found higher flavonoids values in fruit apricot (Miloševic et al., 2012; Wani et al., 2017; Kafkaletou et al., 2019). Previous works have revealed the importance of genotype for the production of flavonoids (Ruiz et al., 2005b; Miloševic et al., 2012). Furthermore, the apricot cultivar is the crucial factor in determining the fruit total phenolic content, total flavonoid content and also antioxidant capacity (Dragovic-Uzelac et al., 2007; Drogoudi et al., 2008; Hegedűs et al., 2010; Schmitzer et al., 2011; Miloševic et al., 2012;2013). Likewise, the cultivation conditions of the plant (environmental and cultivation techniques) can affect these concentrations (Hegedűs et al., 2010).

Total anthocyanins

The results showed a great variability of total anthocyanins content among apricot cultivars. These contents varied from 13.92 to 71.36 mg/100 g fresh mass (Table 1). In fact, the local apricot cultivar 'Oud Aouicha' showed the highest total anthocyanins content (71.36 mg/100 g fresh mass) (Table 1). Statistically, the introduced cultivar 'Ninfa' had close total anthocyanins content (62.56 mg/100 g fresh mass) as 'Oud Aouicha'. Total anthocyanin content was the lowest in the local apricot cultivar 'Oud Hmida' (13.92 mg/100 g fresh mass) (Table 1). Moreover, 'Oud Rhayem' was characterized by similar total anthocyanins content (18.70 mg/100 g fresh mass). However, Ruiz et al. (2005b) did not find a significant difference of total anthocyanins content between some apricot varieties with different flesh colors (white, yellow, light orange and orange). These pigments were detected in small amounts (0.4 to 6.2 mg/100 g fresh weight of peel) but they had a clear impact on apricot skin color, providing a red blush. In our previous study, according to apricot descriptors (UPOV, 2007), the hue of over color (blush) was purple with dark intensity for all organic apricots of local and introduced studied cultivars (Lachkar et al., 2021).

Unlike to the findings of Ruiz et al. (2005b), Toma's-Barberan et al. (2001) reported that anthocyanins content was higher in peaches and nectarines (3 to 31 mg/100 g fresh weight of peel). Variation exists from crops to crops as well within different varieties of same species. This variation in anthocyanin concentrations may be due to genetic distinctions (Wassem et al., 2021).

Table 2. PCA analysis performed on phytochemical properties of fruit among local and introduced apricot cultivars as explained by the 3 first principal components (Proportion of cumulative variability; Component loading for phytochemical properties of fruit)

Percent of variance	Component loading PC1, λ=44.07	PC2, λ=40.23	PC3, λ=13.55
Phytochemical properties of fruit	44.07	84.30	97.84
β-carotene	-0.14	0.93	-0.29
Total phenolics	0.86	0.18	0.47
Total flavonoids	0.84	0.44	-0.26
Total anthocyanins	-0.55	0.72	0.41

Principal component analysis (PCA)

The three first components (PC1, PC2 and PC3) of PCA analysis performed on phytochemical properties of organic apricot among five cultivars (local and introduced) explained 97.84% of the total variability. PC1, PC2 and PC3 marked 44.07%, 40.23% and 13.55% of the variability, respectively (Table 2). Previously, PCA analysis has been used to establish the relationships among genotypes, i.e. cultivars, and to study the correlations between fruit physical and chemical traits and other characteristics within sets of apricot genotypes (Ruiz & Egea 2008b; Mratinić et al., 2011). In our study, high positive correlation was found between PC1 component and total phenolics and also total flavonoids (Table 2). Accordingly, positive values of PC1 correspond to the two cultivars: introduced one ‘Mogador’ and local one ‘Oud Hmida’ with higher phenolics and flavonoids contents (Table 1) (Fig. 3). Previously, Lachkar et al. (2021) reported that ‘Mogador’ was characterized by lower ratios of ripening index (Total soluble solids/ Titratable acidity) and sweetness index (Total sugars/Titratable acidity) unlike to ‘Oud Hmida’ with opposite characters. While, these 2 cultivars exhibited lower values of pH and juice percentage (Lachkar et al., 2021). PCA analysis showed that the highest negative value of PC1 corresponds to the introduced cultivar ‘Ninfa’ and the local one ‘Oud Aouicha’ with higher total anthocyanins content (Table 1) (Fig. 3). These latter figures showed a high positive correlation between PC2 component and β-carotene and also total anthocyanins contents. According to this component, ‘Mogador’, ‘Ninfa’ and ‘Oud Aouicha’ were characterized by higher values of total carotenoids expressed as β-carotene equivalent and total anthocyanins (Table 1) (Fig. 3). Unlike to ‘Ninfa’, ‘Oud Aouicha’ is distinguished by the highest values of: physical characteristics of fruit, juice percentage and titratable acidity. It showed also higher total sugars and lower value of pH (Lachkar et al., 2021).

As shown by many researchers, PCA study may help to select a set of apricot genotypes with better fruit quality performances (Azodanlou et al., 2003). In this investigation, the introduced cultivar ‘Mogador’ might be the best cultivar with highest phenolics, flavonoids and β-carotene contents. In the other hand, ‘Ninfa’ and ‘Oud Aouicha’ might be selected as performing apricot cultivars due to high contents of total carotenoids and anthocyanins. Likewise, the local cultivar ‘Oud Hmida’ was characterized by high phenolics and flavonoids contents. While, regarding the morphological and physico-chemical attributes of organic apricots, the 3 local cultivars (‘Oud Aouicha’, ‘Oud Hmida’ and ‘Oud Rhayem’) are distinguished by their fruit quality performances compared to the introduced commercial cultivars (Lachkar et al., 2021).

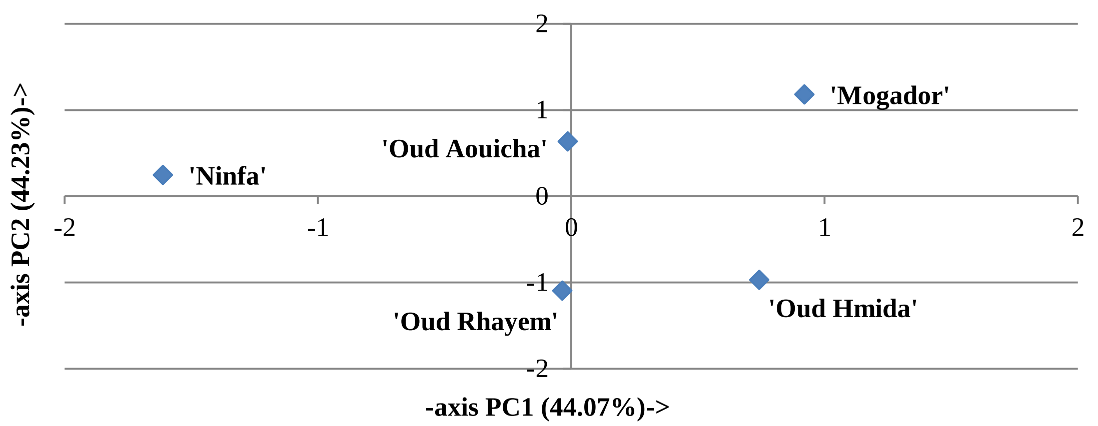

Fig. 3. PCA analysis among local and introduced apricot cultivars grown under the same organic cultivation system as explained by the 2 first principal components

CONCLUSION

The results of this comparative study between local and introduced apricot cultivars grown under organic cultivation system, showed a wide variability in phytochemical composition and properties. The introduced cultivar 'Mogador' was found to be superior compared to other cultivars, for most phytochemical compounds (β-carotene, phenolics and flavonoids). It exhibited a good antioxidant activity for human health. Even though, the introduced cultivar 'Ninfa' was characterized by high contents of β-carotene and anthocyanins. Regarding the nutritional values of the local apricot cultivars, PCA analysis permitted to identify 2 cultivars: 'Oud Hmida' with higher phenolics and flavonoids contents and 'Oud Aouicha' with higher anthocyanins and carotenoids (expressed as β-carotene equivalent) contents.

Finally, we can conclude that 'Mogador', was the performing apricot cultivar for most phytochemical compounds. Except 'Oud Rhayem', the other studied cultivars ('Ninfa', 'Oud Aouicha' and 'Oud Hmida') exhibited important accumulation of many phytochemical properties and in addition large antioxidant capacity. These local and introduced cultivars are principally intended for fresh market but they might be oriented towards other sectors (drying or processing) and might be used in breeding program as genitors with high amount of phytochemicals and moreover with a large antioxidant ability.

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Conflict of interest
The authors have no conflict of interest to report.

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