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Original article

Quality and antioxidant traits of organic apricots (*Prunus armeniaca* L.) at harvest and after storage

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Summary

In recent years, consumers are interested in low-input agricultural practices and healthy foods. The aim of this research was to assess the pomological quality and antioxidant properties of organic apricot fruits from several cultivars which have been previously evaluated under integrated cultivation. Apricot quality after cold storage (14 days at 4 ± 0.5°C, 90% relative humidity) was also tested in order to evaluate the fruit storability. Fruits from seven Italian apricot cultivars (*Prunus armeniaca* L.), grown under organic management system, were analyzed according to the main physicochemical traits, total antioxidant activity (TAC) and total phenols content (TP). Organic practices did not always have a significant influence on the major fruit quality attributes. Three out of seven genotypes positively responded to organic management showing, in particular, higher TAC and TP levels than integrated apricot fruits. Moreover, the capacity to keep unchanged the physicochemical and antioxidant properties of fruits after storage was an interesting result considering the high susceptibility of fresh apricots to conservation. The maintenance of high quality parameters could be an added-value for organic apricot productions. In conclusion, this study provides new perspectives for organically grown apricots, confirming the importance of the cultivar's choice in order to obtain the best quality performances, in agreement to researches establishing as the genotype may influence more than any other parameters the fruit quality characteristics.

Keywords

Italy, organic farming, pomological traits, *Prunus armeniaca* L., total antioxidants, total phenols

Significance of this study

What is already known on this subject?

- The growing demand for organic foods addresses researchers to pay attention on quality profile of organically produced fruits. Actually, studies on apricot fruits from organic cultivations are still scanty.

What are the new findings?

- Some apricot genotypes positively responded to organic management maintaining unchangeable physicochemical and antioxidant properties of fruits also after storage.

What is the expected impact on horticulture?

- Provide new perspectives for organically grown apricots, taking into account the importance of the cultivar's choice in order to maximize the fruit quality attributes.

Introduction

In recent years, the ever growing concerns of consumers toward health and safety foods emphasized the role of phytochemicals and antioxidant compounds able to counter noxious free radicals (Liu, 2003). Several studies have ascertained a negative association between intake of fruits and/or vegetables and risk of cancer or cardiovascular disease (Linseisen et al*.*, 2007; Dauchet et al*.*, 2009). These products, due to the considerable amount of phytochemicals which may have beneficial effects on human health, are perceived by consumers as produced by low input agricultural practices. In particular, organically grown fruits are commonly considered to be safer for themselves and the environment, cleaner, more nutritious and healthier than conventionally grown ones (Magnusson et al*.*, 2003; Lester, 2006).

The farm management can affect soil dynamics and plant metabolism, and potentially resulting in differences in plant productivity, both yield and quality attributes (Condron et al., 2000; Herencia et al., 2007). Determining the nutritional potential of organic food is not a simple task because numerous factors, including weather, specific environmental and pedological conditions, influence the quality in terms of pomological characteristics and amount of vitamins and phytochemicals, such as phenols, flavonoids, carotenoids (Crinnion, 2010; Gąstoł et al., 2011).

Many fruit species have been studied for their nutraceutical properties, and a large source of variability related to fruit quality traits has been attributed to the genotype effect, as also found in apricot culture (Scalzo et al., 2005; Leccese et al., 2012a). This fruit species (*Prunus armeniaca* L.) is characterised by a non-surplus production, with a notable richness of local genotypes which may let to valorise the cultivation in different environmental areas (Audergon et al., 2006). Fresh apricots are a good source of fibres, minerals (potassium, calcium, iron, magnesium, zinc, phosphorus and selenium) and vitamins such as vitamin A, vitamin C, thiamin, riboflavin, niacin and pantothenic acid compared to the very low energy intake per 100 g of fresh product (Lichou et al., 2003). Breeding programs, carried out at the Department of Agriculture, Food and Environment (University of Pisa, Italy), have produced new appealing apricot cultivars whose fruits have

Table 1. Parental lines, ripening time, harvest time (days before/after 'San Castrese', reference cultivar for ripening; harvest time 0 = July 1 in central Italy), fruit size (6.2.5), eating quality (6.2.15) and stress susceptibility (7) according to International Board for Plant Genetic Resources – IBPGR (1984)*.

Cultivars	Parental lines	Ripening time	Harvest time	Fruit size*	Eating quality*	Stress susceptibility*
Bona	Portici × Harcot	Early-Med.	-7	Small	Excellent	Low
San Castrese	Unknown	Medium	0	Medium	Fair	Extr. Low
Ammiraglia	Boccuccia S. × Harcot	Med-Late	+6	Medium	Excellent	Low
Dulcinea	Moniqui (open pollination)	Med-Late	+5	Medium	Excellent	Low
Pisana	Precoce di Toscana (open pollination)	Late	+8	Large	Excellent	High
Silvana	Bergeron × Canino T.	Late	+11	Large	Excellent	Extr. Low
Marietta	S. Francesco × Polonais	Late	+14	Medium	Good	High

excellent organoleptic traits and nutraceutical profile. The quality attributes have been generally established using integrated agricultural practices, but the increased consumer's demand for healthier and safe-controlled fruits addressed researchers to pay attention on quality profile of organically produced apricots, as alternative to conventional agricultural practices.

Thus, the aim of this research was to assess the pomological quality and antioxidant properties of organic apricot fruits from several cultivars which have been previously evaluated under integrated cultivation. Apricot quality after cold storage was also tested in order to evaluate the fruit storability.

Materials and methods

Cultivars and fruit sampling

Seven Italian apricot cultivars ('Bona', 'San Castrese', 'Ammiraglia', 'Dulcinea', 'Pisana', 'Silvana', 'Marietta') were evaluated under organic cultivation, over two harvest seasons (2009 and 2010). The main characteristics of cultivars, such as parental lines, ripening and harvest time, fruit size, eating quality and stress susceptibility are shown in Table 1. With the exception of 'San Castrese', originated from South Italy (Campania), the other ones were obtained from breeding programs carried out at Pisa University (Department of Agriculture, Food and Environment).

Trees (15 years old), grown at 'Azienda Agricola Camillo Pacini' (Tuscany, Italy, altitude 12 m a.s.l., lat. 43°47'13.6"N, long. 10°25'19.3"E), were planted in a completely randomized experimental design, grafted onto Myrobolan 29/C rootstock, and trained as a free palmette system spaced at 4 × 4.5 m. The soil was sandy, moderately deep, of medium texture, non-calcareous and a drip irrigation system was applied. All trees received routine horticultural care (pruning, thinning, fertilization, pest and disease protection) according to organic guidelines (EU Council Regulation 834/07, Italian Directive 220/95).

The main climatic data were acquired: hourly temperatures were registered by an automatic data-logger (Tynitag Plus®, West Sussex, UK, 2003) and rainfall data were provided by the Hydrological Service of Tuscany (Sir).

Fruits, without malformations and symptoms of pest infestations or disease infections, were randomly sampled from trees with a similar crop load (about 20 kg canopy^{-1}). From June to mid-July, fruits were collected at physiological maturity stage to assess the quality traits related to the main physicochemical parameters, total antioxidant capacity, and total phenol content. The analysis were immediately carried out at harvest and after 14 days of cold storage (4 ± 0.5°C, 90% relative humidity).

Physicochemical determinations

On fruits (N = 30 at harvest and after cold storage, each), single measurements of fresh weight, skin and flesh colour, flesh firmness, and total soluble solids (TSS) were made. Moreover, titratable acidity (TA) was determined on apricot juice obtained from flesh samples of 10 fruits, in triplicate.

The size of fruits by weight was defined according to International Board for Plant Genetic Resources – IBPGR (1984). The skin colour of the un-blushed side was evaluated using a colour chart for apricot fruit which provides 10 shades from 1 (green) to 10 (red-orange) by different categories: 1–4: yellow-green; 5–8: yellow-orange; 9–10 red-orange (Lichou et al., 2003). The skin colour of the blushed side was evaluated visually according to the following classes: <35% (class 1), 35–65% (class 2), >65% (class 3). Firmness was evaluated with a digital penetrometer (Model 53205, TR-Turoni & C. Inc., Forlì, Italy) at the equatorial region of the apricot, using an 8-mm-wide plunger. TSS were measured using a refractometer (Model 53015C TR, TR-Turoni & C. Inc., Forlì, Italy) and expressed in °Brix at room temperature. TSS was classified according to the following classes: <11.0 °Brix (class 1), 11.0–13.5 °Brix (class 2), 13.6–16.0 °Brix (class 3), >16 °Brix (class 4). Titratable acidity (TA) was determined on a known volume of juice titrated with 0.1 N sodium hydroxide (NaOH) to an end point of neutral pH (8.1). TA, expressed as milli-equivalents per 100 g of fresh weight (meq 100 g^{-1} FW), was classified as follows: <20 meq 100 g^{-1} FW (class 1), 20–30 meq 100 g^{-1} FW (class 2), >30 meq 100 g^{-1} FW (class 3).

Total Antioxidant Capacity (TAC) and Total Phenols (TP) analysis

The Total Antioxidant Capacity (TAC) and Total Phenols (TP) analyses were carried out on the same fruits previously subjected to the physicochemical determinations. Fresh samples of 3 g were homogenized using an ultra-Turrax T25 (Ika, Staufen, Germany) at 4°C to avoid oxidation, for three independent extractions per each cultivar. The extraction was performed in 80% ethanol for 1 h in a shaker in the dark and subsequently centrifuged at 2,600g for 10 min at 2–4°C.

TAC assay

Total antioxidant capacity was evaluated using the improved Trolox Equivalent Antioxidant Capacity (TEAC) method (Arts et al., 2004). The TEAC value was calculated in relation to the reactivity of Trolox, a water-soluble vitamin

E analogue, which was used as an antioxidant standard. In the assay, 40 µL of the diluted samples, blanks, were added to 1,960 µL ABTS•+ solution, which resulted in a 20–80% inhibition of the absorbance. The decrease in absorbance at 734 nm was recorded at 6 min after an initial mixing, and plotted against a dose-response curve calculated for Trolox (0–30 µM). Antioxidant activity was expressed as micromoles of Trolox equivalents per gram of fresh fruit weight (µmol TE g^{-1} FW). Trolox was purchased from Sigma Chemical Co. (St. Louis, MO, USA).

TP assay

Total phenolic content was determined according to the improved Folin-Ciocalteu (F-C) method (Waterhouse, 2001). The assay provides a rapid and useful indication of the antioxidant status of the studied material and has been widely applied to different food samples. Gallic acid (GA; Sigma Chemical Co., St. Louis, MO, USA) was used as a standard compound for the calibration curve. Total phenol content was calculated as mg of GA equivalent (GAE) per g of fresh fruit weight (mg GAE g^{-1} FW). The absorbance of the blue colored solutions was read at 765 nm after incubation for 2 h at room temperature.

Statistical analysis

Data were reported as means ± standard errors of the means (SEM). Student's *t*-test procedure, variance (ANOVA) and regression analysis were performed using the package GraphPad Prism 5 (GraphPad Software, Inc.).

Results and discussion

The climate of the experimental site is characterized as Mediterranean, with the rainy season occurring primarily during autumn and winter months, while the summer is moderately dry. The climatic conditions occurred during the period of fruit growth and ripening of the years 2009–2010 were very similar, both for temperatures and rainfall events (Table 2).

The average daily temperatures ranged from 13 to 21°C from April to June. No relevant temperature variations were recorded with respect to the seasonal averages of the considered climatic area (Guerriero et al., 2010). In the same period the cumulative amount of rainfall ranged from 131 to 137 mm in 2009 and 2010, respectively.

The main physicochemical traits of apricots from organic cultivation, at harvest and after 14 days at 4°C cold storage, are shown in Table 3. Data are referred as mean values of 2009 and 2010 harvest seasons.

The analysed cultivars were characterized by mean fruit weight ranging from about 55 to 95 g. The smallest and the biggest fruit sizes were found in 'Bona' and 'Dulcinea', and 'Ammiraglia' and 'Pisana', respectively. Concerning the fruit skin colour, pomological trait impacting on consumer's apricot quality perception (Ruiz and Egea, 2008), the unblushed area was generally orange (shade 6–8), apart from 'Dulcinea' characterized by yellow-green skin ground colour (shade 4). This latter cultivar showed a low rate of overcolour (<35%) like 'Bona', 'San Castrese' and 'Marietta', while 'Pisana' and 'Silvana' exhibited attractive fruits due to an extensive bright

Table 2. Monthly mean maximum and minimum temperatures (°C), relative average (Avg), and cumulative rainfall (mm) from April to June over a 2-year period (2009–2010).

	2009				2010			
	T max	T min	Avg	Rainfall	T max	T min	Avg	Rainfall
April	18.5	10.1	13.9	86.9	18.4	8.0	13.2	85.0
May	24.3	12.4	18.4	14.7	20.3	11.6	15.6	18.6
June	26.2	16.0	21.2	29.9	25.1	15.7	20.6	33.4
Total amount				131.5				137.0

Table 3. Main physicochemical traits from organically produced apricot fruits at harvest (H) and after 14 days of cold storage (*S*): skin colour of the un-blushed side (SC-ub), skin colour of the blushed side (SC-b), fruit weight (g), fruit weight (FW) loss (%), flesh firmness (kg 0.5 cm^{-2}), total soluble sugars (TSS, °Brix), titratable acidity (TA, meq 100 g^{-1} FW), sugars/acids ratio (TSS/TA). Mean of a 2-year period ± SEM. Significant differences between M and *S*, denoted by asterisks (*), were tested by Student *t*-test ($P \leq 0.05$).

Cultivar	Fruit	SC-ub	SC-b	Fruit weight	FW loss	Firmness	TSS	TA	TSS/TA
Bona	H	7	<35%	54.9 ± 2.86		2.3 ± 0.19	13.2 ± 0.55	15.5 ± 0.62 *	0.85 ± 0.01 *
	S				*7.0 ± 0.32*	*2.2 ± 0.26*	*13.1 ± 0.96*	*13.4 ± 0.64*	*0.98 ± 0.01*
San Castrese	H	7-8	<35%	67.6 ± 0.53		2.2 ± 0.05	11.1 ± 0.07	19.5 ± 0.89	0.56 ± 0.01
	S				*6.1 ± 0.29*	*2.0 ± 0.02*	*11.3 ± 0.07*	*20.5 ± 0.25*	*0.55 ± 0.01*
Ammiraglia	H	7-8	35-65%	95.2 ± 6.68		2.6 ± 0.21	14.6 ± 0.37	12.1 ± 0.21 *	1.01 ± 0.04 *
	S				*11.3 ± 0.20*	*2.5 ± 0.19*	*14.4 ± 0.42*	*10.4 ± 0.44*	*1.38 ± 0.02*
Dulcinea	H	4	<35%	55.8 ± 2.67		2.4 ± 0.18	12.1 ± 0.57 *	8.8 ± 0.51 *	1.35 ± 0.02 *
	S				*0*	*2.5 ± 0.25*	*13.9 ± 0.49*	*11.0 ± 0.25*	*1.26 ± 0.01*
Pisana	H	7	>65%	85.7 ± 0.58		2.1 ± 0.02	13.6 ± 0.08 *	10.2 ± 0.40	1.34 ± 0.03 *
	S				*15.0 ± 1.11*	*2.5 ± 0.24*	*12.0 ± 0.19*	*10.3 ± 0.03*	*1.05 ± 0.04*
Silvana	H	7	>65%	64.0 ± 1.29		2.1 ± 0.11	15.1 ± 0.33	20.2 ± 0.14	0.75 ± 0.02
	S				*15.2 ± 0.90*	*2.3 ± 0.16*	*14.5 ± 0.32*	*19.6 ± 0.96*	*0.74 ± 0.01*
Marietta	H	6	<35%	60.8 ± 3.61		2.0 ± 0.07	14.3 ± 0.25 *	6.5 ± 0.12	2.20 ± 0.11
	S				*3.3 ± 0.20*	*2.4 ± 0.28*	*13.0 ± 0.42*	*6.2 ± 0.15*	*2.10 ± 0.12*

red skin colour (> 65%). Overall the genotypes showed a flesh firmness from 2 to 2.78 kg 0.5 cm^{-2}, suitable range for fresh apricot fruits (Mratinić et al., 2011). The total soluble sugars (TSS) varied from 11.1 to 15.1 °Brix, in agreement with the minimum threshold for apricot consumer acceptance (Biondi et al., 1991; Kader, 1999). 'Dulcinea' and 'San Castrese' had the lowest TSS degree while the highest values were recorded in 'Ammiraglia', 'Silvana' and 'Marietta'. The titratable acidity (TA) values, all comprised in the low-medium class, ranged from 6.5 to 20.2 meq 100 g^{-1} FW. Consequently, the TSS/TA ratio, one of the major analytical measures for fruit quality affecting the perception of sweetness and flavour (Cemagref, 1981; Bassi and Selli, 1990; Badenes et al., 1998), was from 0.56 to 2.2. The highest TSS/TA ratio was observed in the medium-late ripening genotypes, with the exception of 'Silvana' characterized by an elevated acidity level. Several authors reported that TSS values higher than 13° Brix were positively related with an increase of TSS/TA ratio, improving the fruit eating quality, and thus consumer acceptance (Bassi and Audergon, 2006; Ruiz and Egea, 2008).

To assess the storability of apricot fruits the physicochemical performances were tested after 14 days cold storage (Table 3). A general fruit-weight loss from about 3 to 15% was recorded, with the exception of 'Dulcinea' which, characterized by a small fruit size, showed an unchangeable weight. The lowest decreases were observed in 'Marietta', 'San Castrese' and 'Bona', as recorded in previous studies carried out on a wide number of apricot genotypes (Leccese et al., 2012b). The flesh firmness did not show significant changes, while the chemical parameters were affected by storage but only in few cases, such as 'Dulcinea' where an increase in TSS and TA values was observed.

In general, the physicochemical results allow the studied genotypes to be defined as good source of quality organic apricots, confirming findings obtained over years on the same cultivars under integrated management systems (Leccese et al., 2012b). It is important to underline that agricultural practices (tree age, training system, rootstock) as well as pedoclimatic conditions (temperatures, precipitations, soil type) were similar in integrated and organic farms. In Table 4 the TSS and TA classes recorded in fruits at harvest, from organic and integrated systems are shown, taking into account that these analytical measures are the main parameters of apricot quality which may influence the organoleptic properties linked to intrinsic varietal traits (Biondi et al., 1991). In most cultivars, differences between fruits grown under the two agricultural practices were not found, as reported for other fruit species (Lombardi-Boccia et al., 2004; Peck et al., 2006; Roussos and Gasparatos, 2009). However, 'Dulcinea' and 'Marietta' apricots from integrated management showed higher TSS content.

Antioxidant properties, expressed by the total antioxidant capacity (TAC) and total polyphenol content (TP), showed a similar trend with a significant variability related to the cultivar (Figures 1A and B).

TABLE 4. Total soluble sugars (TSS), titratable acidity (TA) classes and TEAC score of fruits at harvest of several apricot cultivars from organic and integrated orchard management systems. Integrated values were taken from Leccese et al. (2012b).

Cultivars	System	TSS Class[a]	TA Class[b]	TEAC Score[c]
Bona	Org	2	1	3
	Int	*2*	1	*4*
San Castrese	Org	2	1	4
	Int	*2*	1	*3*
Ammiraglia	Org	3	1	3
	Int	*2*	1	*4*
Dulcinea	Org	2	1	1
	Int	*4*	1	*2*
Pisana	Org	3	1	3
	Int	*3*	1	*4*
Silvana	Org	3	2	4
	Int	*3*	2	*4*
Marietta	Org	2	1	2
	Int	3	1	*1*

TSS Class[a]: class 1 (< 11.0°Brix); class 2 (11.0–13.5); class 3 (13.6–16.0); class 4 (> 16).
TA Class[b]: class 1 (< 20 meq 100 g^{-1} FW); class 2 (20–30); class 3 (> 30).
TEAC Score[c]: class 1 (≤ 1.51 μmol TE g^{-1} FW); class 2 (1.52–3.02); class 3 (3.03–4.53); class 4 (> 4.53).

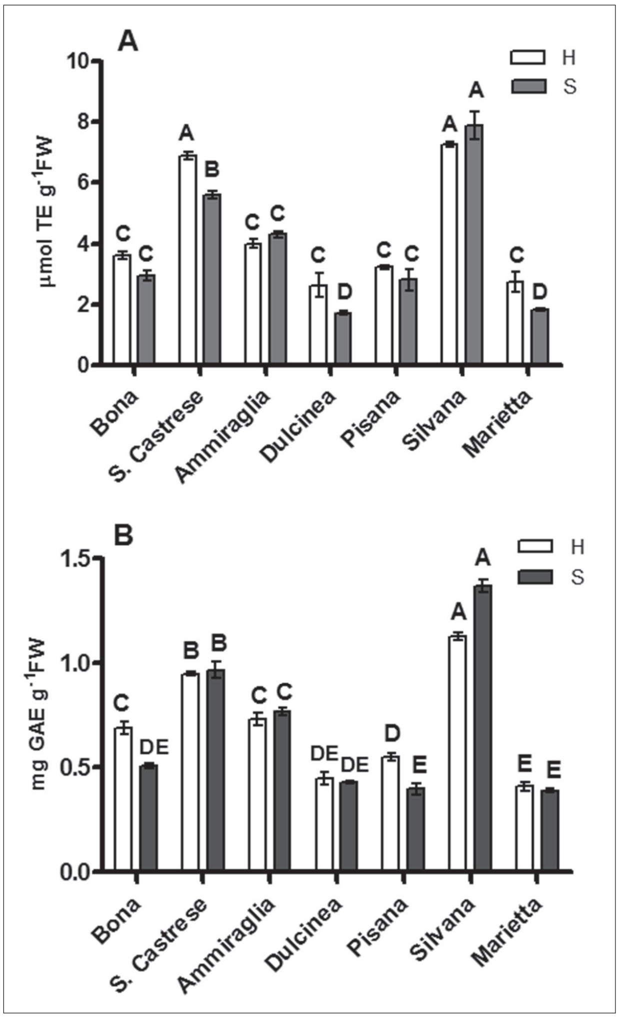

FIGURE 1. Antioxidant properties of fruits at harvest (H) and after 14 days of cold storage (S) in several apricot cultivars grown under organic system, over a 2-year period. A) Total antioxidant capacity (TAC) expressed as micromoles of Trolox equivalent per gram of fresh weight (μmol TE g^{-1} FW); B) Total phenols (TP) expressed as milligrams of gallic acid equivalents per gram of fresh weight (mg GAE g^{-1} FW). Means ± SEM. Means with different letters are significantly different ($P \leq 0.01$) according to Tukey's test.

At harvest, TAC and TP values ranged from 2.63 ± 0.39 to 7.26 ± 0.01 μmol TE g^{-1} FW and from 0.41 ± 0.02 to 1.13 ± 0.02 mg GAE g^{-1} FW, respectively. In particular, 'San Castrese' and 'Silvana' had the greatest antioxidant values, 2–3 fold higher than the lowest ones measured in 'Dulcinea' and 'Marietta'. In order to verify the relation between TAC and TP, a regression analysis was carried out. A positive and significant relationship was found ($R^2 = 0.9281$, $P \leq 0.01$), showing polyphenols as important bioactive compounds contributing to the antioxidant properties of apricots, in agreement with previous studies (Leccese et al., 2008).

For classifying the cultivars in relation to their antioxidant level (AOX), a 'TEAC score' has been adopted according to Leccese et al. (2008): class 1 (≤ 1.51 μmol TE g^{-1} FW) very low AOX status; class 2 (1.52–3.02 μmol TE g^{-1} FW) low AOX status; class 3 (3.03–4.53 μmol TE g^{-1} FW) medium AOX status and class 4 (> 4.53 μmol TE g^{-1} FW) high AOX status. The TEAC scores of apricot fruits obtained from organically and integrated grown trees, under comparable cultivation sites, are shown in Table 4. Between the two orchard managements, some differences were observed. 'Silvana' was the only cultivar with the highest AOX status, both in organic and integrated fruits; 'Marietta' and 'San Castrese' proved to have a greater antioxidant level in organic fruits; the other four cultivars, instead, showed a lower level in organic apricots. 'San Castrese' confirmed previous results in which organic apricots always achieved TAC and TP values higher than those obtained by integrated systems (Leccese et al., 2010). As found in several studies, the antioxidant activity is strongly cultivar-dependent: results often showed inconsistent differences between organic and conventional produce (Woese et al., 1997; Roussos and Gasparatos, 2009; Cardoso et al., 2011). Thus, the nutritional quality of food between the two agronomical practices is a current topic that continues to attract interest and generate discussion (Gastoł et al., 2011).

After 14 days of cold storage a decrease in TAC levels was recorded in most cultivars (Figure 1A), with the exception of 'Ammiraglia' and 'Silvana' whose values were similar or higher (about 8%) than those found at harvest. In these cultivars, the above trend was also maintained for TP contents, and in 'Silvana' a postharvest increase of about 20% was recorded (Figure 1B). TAC and TP raises were probably due to the fruit water loss (11–15%) after storage, as found in other apricot cultivars (Leccese et al., 2010). The high apricot phenolic content, a positive attribute for healthier fruits, might be detrimental during storage because they may induce enzymatic browning phenomenon, responsible of quality loss in fruits and vegetables (Rocha and Morais, 2001). In the experiment presented here, all cultivars showed negligible rates of browning symptoms in fruits; however, to better evaluate this aspect, specific studies have been carrying out in the latest years.

Conclusions

The tested cultivars, characterized by different pomological and antioxidant properties of fruits, confirmed their quality traits which were previously described considering the integrated cultivation. Organic practices did not always have a significant influence on the major fruit quality attributes. Three out seven genotypes positively responded to organic management which could improve the antioxidant system of the plant's defence-response mechanism (Carbonaro and Mattera, 2001). In particular, 'Marietta', 'San Castrese' and 'Silvana' showed interesting properties of organic fruits, mainly due to similar ('Marietta') or higher TAC and TP levels than integrated ones. 'San Castrese', well known for a wide adaptability to different environmental conditions, established its suitability towards organic cultivations. 'Silvana', showing the highest TAC and TP contents, was also interesting since, after storage, it kept unchanged the physicochemical and antioxidant properties of fruits. Considering the high susceptibility of fresh apricots to conservation, the stability of antioxidants and other chemical parameters, such as TSS and TA, could be an added-value for organic apricot production.

In conclusion, this study provides new perspectives for organically grown apricots, confirming the importance of the cultivar's choice in order to maximize the fruit quality attributes, meeting the increasing consumer demand for healthier fruits.

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