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Physio-chemical quality attributes of 'Italia' grapes from organic and conventional farming at harvest and during storage

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All relevant data are within the paper and its Supporting Information files.

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Abstract: This study was aimed to investigate the quality at harvest and during storage of organically and conventionally grown 'Italia' grapes, collected from 2 different locations in Southern Italy. Four vineyards were chosen in order to have an organic and a conventional farm in each location. Before harvest, six plants per vineyard were randomly selected and considered as treatment replicate. Three bunches were harvested and labelled from each plant. In laboratory each bunch was weighed and thirty berries per bunch were detached and used for initial determination which included morphological (berry weight and dimension, peel thickness) and physical (berry color and firmness) attributes, maturity indices (respiration rate, soluble solids content and titratable acidity), and nutritional composition (phenol content, antioxidant activity, sugar and organic acid composition, ascorbic acid content). Then, the bunches from each replicate were kept in individual 15-L jars at 0°C and connected to a humidified air flow throughout the whole experiment. After 7 and 14 days of storage, respiration rate, weight loss, physical and nutritional attributes were also monitored on 20 berries per bunch. Location and agricultural practices affected to a different extent several grapes quality attributes, both at harvest and during storage. Maturity stage, sugar content and berry color were significantly affected by the location, while antioxidant-related compounds were significantly higher in organic grapes. Plant production and bunch weight were significantly higher for conventionally grown grapes, which also received the highest evaluation of external appearance, in terms of stalk dehydration and berry general aspect. Differences among conventional and organic grapes were maintained, for each location, during storage at 0°C. Conventional grapes maintained a higher visual quality during storage, resulting after 14 days below the limit of marketability (score 3) but above the edibility limit (score 2); whereas in one location organic grapes were judged not edible. Results showed a higher nutritional value in grapes obtained with the organic farming system although in terms of visual quality, storability and yield, conventional fruit had a better performance.

1. Introduction

More than 403'000 hectares of organic grapes are grown worldiwide, constituting 5.7 percent of the world's grape-growing area (7.1 million hectares in 2016, according to FAOSTAT). In Europe, over 340'000 hectares (8.7 percent of the harvested grape area) are organic; Spain and Italy, cultivated more than 100'000 hectares of organic grapes, followed by France with over 78'000 hectares. The Italian National Information System on Organic Agriculture (SINAB) reported for the 2012 an increase of 6.4% of the organically cultivated land compared to the previous year, with a total of 49,709 organic operator. Regions in Southern Italy have the largest organic areas (Sicilia, Puglia and Calabria) and the largest number of organic farms with an increase of operators (20.3%) in Puglia Region, while most of the processors are located in northern Italy (especially Emilia Romagna and Lombardia). As known, grapes contain a wide range of nutritional and functional component such as vitamins, minerals, organic acids, enzymes as well as phytochemicals (Walzem, 2008), among which phenolics, particularly flavonoids, anthocyanins and resveratrol, are the most important because are held accountable for their health benefits (Yang *et al*., 2009). However, as known, both pre- and postharvest practices may affect the amount of these nutritional and functional compounds as well as many other elements of horticultural crops (Lee and Kader, 2000). Among the preharvest conditions, genotype, environmental conditions, cultural practices, and maturity at harvest influence quality attributes of grapes such as the concentration of phenolic compounds (Sellappan *et al.*, 2002). Particularly the application of organic and conventional agricultural techniques may affect the table grapes quality. Generally organic agriculture optimizes the health and productivity of interdependent communities of soil life, plants animals and humans. In fact, organic agriculture does not use synthetic pesticides and fertilizers (Briar *et al.,* 2007), but only ecological products. Several studies showed that the use of organic or conventional techniques significantly influenced the production, in terms of number of bunches on the vine stock and the average weight of the bunch (Detoni *et al.,* 2007). However, in the last years researchers focused their attention on the influence of organic cultivation on the content of secondary metabolites although no clear behaviors were observed. Higher concentration of bioactive compounds in plants grown with the organic system were reported by several authors, which were considered as the results of the plant exposure to situation that leads to an increase of natural defenses (Winter and Davis, 2006). Dani *et al.* (2007) reported that organic crop influenced the phenolic content and the antioxidant activity of white and purple grape juices, but for some study difference observed 1 month before harvest, were not observed at the harvest time (Mulero *et al*., 2010). Regarding differences observed during storage, *Thompson seedless* grapes from organic orchard showed more desirable color and lower browning index, and generally higher nutritional content than conventional grapes, with similar decay incidence (Zahedipoura *et al.,* 2019), but there is not much literature to this regard. Based on the above considerations, this paper had the principal aim of comparing the physio-chemical attributes at harvest and during storage of table grapes cultivated with organic and conventional techniques also taking into account the effect of two different production areas in Puglia Region (southern Italy).

2. Materials and Methods

In this experiment two organic farms were chosen in 2 different locations of the Puglia Region, one at Castellaneta (78 m above sea level) in province of Taranto (LOC1) and one in Adelfia (151 m on sea level) in province of Bari (LOC2). The climate for both locations is Mediterranean semi-arid, characterized by hot and dry summers and moderately cold and rainy winter seasons, with annual mean temperature of 14-15°C and mean annual rainfall within 450-500 mm. For each location a conventional farm, with similar characteristics, and in the same area (within 1 km) was chosen as control, resulting in a comparison among 2 different organic with 2 conventional farms. In each location, 6 plants were used as replicate, and 3 bunches for each replicate were collected in the same day, at the commercial maturity stage, with a total of 18 bunches per field. Soils were composed by 63.2% sand; 22.1% clay; and 14.7% silt for Bari location and 69.8% sand; 15.1% silt and 15.1% clay for Taranto. The conventional vineyard was managed according to common viticultural practices for the growing area, including winter mineral nutrition, spring-summer fertigation, and irrigation with seasonal volume of about 2000 m3/ha by drip irrigation. The organic farming was managed according (EC) Reg. 834/07 and Reg. 889/08.

At harvest bunches were weighed, closed in a sealed container to measure respiration rate, before to detach 30 berries per bunch. On these 30 berries per bunch biometrical attributes were evaluated, including berry weight and dimensions (major and minor axes), and peel thickness. Following, bunches from each replicate were kept in individual 15-L jars at 0°C and connected to a humidified flow of air for the entire duration of the experiment. After 7 and 14 days of storage, respiration rate, weight loss, physical and nutritional attributes were also monitored on 20 berries per bunch. After berry detachment stalks were protected by excessive dehydration by using adhesive tape around the berry abscission zone.

Quality indexes

Initially and after 6 and 14 days, bunches were individually scored using a 5 to 1 subjective scale, with 5 = excellent, no defects, 4 = very good, minor defects, 3 = fair, moderate defects, 2 = poor, major defects, 1 = inedible. A score of 3 was considered as the limit of marketability and a score of 2 as the limit of edibility.

Then 20 berries for each bunch were used the following quality assessment:

- peel color using a spectrophotometer (Konica Minolta CM 2600d, Japan) in the CIE L*a*b* mode, and then calculating Hue Angle and Chroma values;
- flesh firmness with a manual firmness tester by measuring force required by a 2-mm probe to penetrate the tissue for 5 mm in two opposite locations;
- titratable acidity on 4g of grape juice for each replicate, using an automatic titrator (Crison, Titromatic 1S, Barcelona, Spain) with 0.1 N NaOH solution to pH 8.1 and reported as percent of tartaric acid;
- soluble solids content (SSC) using a refractometer (Atago, PR-32; Tokyo, Japan);

For respiration rate 3 bunches of each plant were closed in a sealed container to let CO_2 accumulate. Samples of gas (0.1 mL) were collected through a rubber septum and injected into a gas chromatograph (Shimadzu, model 17A, Kyoto, Japan) equipped with a thermal conductivity detector (230°C). Separation of CO_2 was achieved on a Carboxen 1006 plot (30 m X 0.53 mm, Supelco, Bellefonte, PA USA), with a column flow of 7 mL min^{-1}, and oven temperature of 180 °C; the difference in concentration was then referred to the sample weight, to the elapsed time, and to the head space volume. The sample weight at each storage time was also used to calculate weight loss.

Nutritional quality

After previous determinations, part of the berries were peeled, and the skin was frozen for the analysis of phenols and antioxidant activity whereas the juice was used for sugars composition and Vitamin C.

Ascorbic and dehydroascorbic acid were analysed on fresh samples by high performance liquid chromatography (HPLC Agilent 1200 Series, Waldbronn, Germany) equipped with a binary pump, an autosampler, and a photodiode array detector (DAD) (Zapata and Dufour, 1992).

The following determinations were performed on the frozen samples:

- organic acid and sugar composition by using the HPLC equipped with the (DAD) array and a refractometric detector (Pérez *et al.,* 1997).
- total phenolics of grape skins by the Folin-Ciocalteu reagent (Singleton and Rossi, 1965), dilutions were carried out in duplicate and calculated using a calibration curve obtained with gallic acid, reading the absorbance at 575 nm.
- antioxidant activity by spectrophotometer using the DPPH (2,2 diphenyl1-1-picrylhydrazil) method (Brand-Williams *et al*., 1995).
- Phenolic composition using the same extract for total phenolics analysed with HPLC procedure (Bonilla *et al.,* 1999).

Statistical analysis

On the data collected after harvest, a split plot design for the location and treatment was run, whereas on the whole data set a split plot with location as main plot, treatment as subplot, and time as third plot was assessed. Finally, due to the presence of significant 3th order interaction, a split plot for each location (for treatment and time of storage) was run.

3. Results and Discussion

The effect of location (LOC1 and LOC2), and cultivation system (organic and conventional) on quality attributes is shown in Tables 1 (physical and physiological attributes including productivity) and 2 (chemical composition) at harvest. Both area of cultivation and cultivation system showed a significant effect ($p<0.05$) on most of physical attributes (Table 1), with significant interaction only in the case of firmness, and chroma, but generally the effect of the cultivation system was the same in both locations. Particularly conventionally grown grapes showed higher visual quality, firmness, and production per plant, which in turn induced lower dimensions of the berries. At the same time LOC2 (Bari) also induced higher productivity, higher visual quality and firmness compared to LOC1 (Taranto). Respiration rate was higher in organic grown grapes than in conventional grapes and in LOC2 compared to LOC1, indicating a higher metabolic activity for these fruit.

As shown in Table 2, total phenolics, flavonols and antioxidant activity were higher in organic grapes and in LOC1, compared to respectively conventional grapes and LOC2. For soluble solids content and titratable acidity there was a significant interaction, but looking to sugar and acid composition (data not shown), no significant differences due to the cultivation system were found for total organic acids, with significant highest amount of tartaric acid and glucose, among sugars, in organically grown grapes and in LOC1.

Differences among conventional and organic grapes were maintained, for each location, during storage at 0°C. Conventional grapes maintained a higher visual quality during storage, resulting below the limit of marketability (score 3) but above the edibility limit (score 2) at 14 days, whereas in LOC1 (Taranto) at that time organic grapes were judged not edible (data not shown). These results may be explained with the higher metabolic activity of organic table grapes, which reduce their storability. Firmness was higher in conventional grapes than in organic grapes for samples grown in Taranto area while no differences were observed for grapes grown in Bari. Also in another study the authors reported higher firmness for conventionally grown grapes than for organic, being related to the higher thickness of

Table 1 - Productivity, morphological indexes, physical and physiological quality attributes at harvest of organic and conventional grapes grown in the locations of Taranto (LOC1) and Bari (LOC2) in the Apulia region (Italy)

	Treatment		Location		Location x treatment
	Organic	Conventional	LOC1	LOC2	
Production per plant (kg)	23.5 b	31 a	25 b	29 a	NS
Visual Score	4.1 b	4.5 a	3.9 b	4.7 a	NS
					*
Hue Angle	102.3 NS	103.7 NS	102.4 NS	103.7 NS	NS
Chroma	7.5 NS	7.4 NS	8.1 a	6.9 b	*
Respiratory activity	3.8 a	2.6 b	1.1 b	5.3 a	NS
Morphological indexes					
Berry lenght (mm)	29.6 a	27.4 b	27.8 b	29.3 a	NS
Berry width (mm)	24 a	22.4 b	27.9 b	23.7 a	*
Berry weight (g)	10.9 a	9.5 b	27.10 b	10.8 a	NS
Peel thickness	0.99 NS	1.04 NS	27.11 NS	1.13 NS	NS

Different letters indicate significant differences among mean values according to Tukey's test (*P* value≤0.05).
NS= not significant.

Table 2 - Chemical composition at harvest of organic and conventional grapes grown in the locations of Taranto (LOC1) and Bari (LOC2) in the Puglia region (Italy)

	Treatment		Location		Location x treatment
	Organic	Conventional	LOC1	LOC2	
Titratable acidity (TA)	0.4 b	0.5 a	0.5 a	0.4 b	*
Soluble solids content (SSC)	1.70 NS	16.7 NS	16.9 NS	16.8 NS	*
SSC/TA ratio	41.4 a	37.6 b	38 NS	41 NS	*
Flavan-3-oli	47.4 NS	48.5 NS	42.5 b	53.5 a	*
Hydrocinammic deriv.	4.3 NS	4.6 NS	4.9 a	3.9 b	NS
Flavonols	0.015 a	0.005 b	0.014 a	0.006 b	NS
Total phenols	387.6 a	307.3 b	437.7 a	257.2 b	NS
Antioxidant activity	940 a	641 b	987 a	594 b	NS
Ascorbic acid	0.4 NS	0.4 NS	0.2 b	0.6 a	NS
Dehydroascorbic acid	2.8 NS	2.8 NS	2.8 NS	2.8 NS	NS

Different letters indicate significant differences among mean values according to Tukey's test (*P* value≤0.05).
NS= not significant.

the epicuticular layer (Zahedipoura *et al.,* 2019). Similar results were also observed for organic kiwifruits (Amodio *et al.*, 2007), where firmness was not related to the thickness of the skin, being conventional fruit firmer despite the thin skin and the more advanced maturity stage. In the present study, the slight differences in skin thickness resulted not significant, and difference observed for one location could be due to berry dimensions and water turgor. Moreover, firmness of fruit can be affected by several agricultural practices such as sunlight exposure and (Sams, 1999) fertilization. Mineral content of soil and plant was not assessed in this experiment, but Amodio *et al*. (2007) shown a possible effect of different mineral composition of organic and conventional fruit.

Figures 1 and 2 show the changes of phenolic content and antioxidant activity of grape samples as a function of storage time for both conventional and organic production obtained in Taranto and Bari.

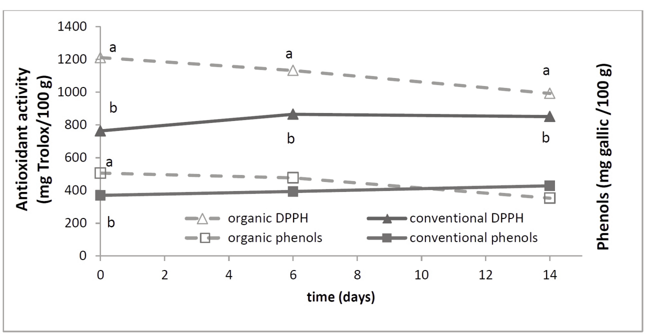

Fig. 1 - Evolution of the antioxidant activity and phenol content during storage of organic and conventional table grapes grown in LOC1 (Taranto). Different letters indicate significant differences among mean values according to Tukey's test (P value ≤0.05).

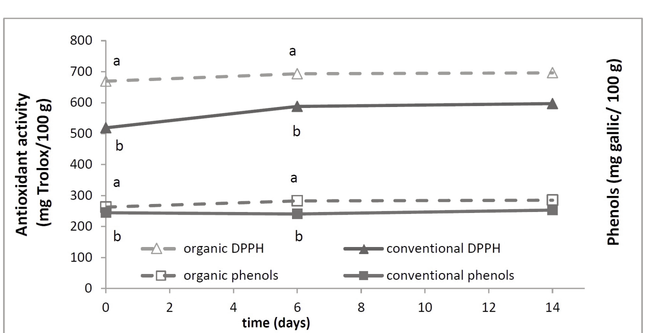

Fig. 2 - Evolution of the antioxidant activity and phenol content during storage in organic and conventional table grape grown in LOC2 (Bari). Different letters indicate significant differences among mean values according to Tukey's test (P value ≤0.05).

Phenolic content of organic table grapes was, in general, higher than that of conventional samples probably because the conventional growing practices utilize levels of pesticides that can result in a disruption of phenolic metabolites in the plant that have a protective role in plant defense mechanisms (Macheix *et al.,* 1990). Particularly, in the moment of harvest a phenolic content of 505.1±52.4 mg gallic acid 100 g^{-1} for organic sample and 369.8±57.8 mg gallic acid 100 g^{-1} for conventional table grapes grown in Taranto were observed ($p<0.05$) (Fig. 1); nevertheless, during storage this difference was progressively reduced becoming not significant after 6 days of storage. At harvest significantly higher values for antioxidant activity were observed for organic grapes (1210.7±134.3 mg Trolox 100 g^{-1} fw) than in conventional ones (763.4±97.6 mg Trolox 100 g^{-1} fw) (Fig. 1) as well as after 6 and 14 days of storage at which organic samples showed an antioxidant activity of 992.5 mg Trolox 100 g^{-1} fw and conventional samples of 850.9 mg Trolox 100 g^{-1} fw.

For samples grown in Bari area significant differences were maintained between the phenolic content and antioxidant activity of organic and conventional up to 6 days of storage (Fig. 2) although, in this case antioxidant activity was much lower than in LOC1.

Phenolic content of 'Italia' grapes was higher compared with those reported in literature studying the antioxidant and phenolic composition of different grape cultivars grown with conventional system ranged between 148.5 mg gallic acid 100 g^{-1} for 'Chasselas Dorè' and 123.1 mg gallic acid 100 g^{-1} for 'Nepoca' grapes (Mulero *et al*., 2010). Similar differences were observed in some diffferent harvests (Macheix *et al.,* 1990). On the other hand, other authors pointed out that the concentration of phenolic compounds of the skin changes greatly depending on the variety and also on the grape ripening stage (Riu-Aumatell *et al.*, 2002). Also in the case of antioxidant activity values were higher in comparison with the results of reported on literature. Values in the range of 55.7-274.2 µg g^{-1} extract in grape skins on four varieties are reported (Anastasiadi *et al.,* 2010), while the antioxidant activity was higher for organic grapes (5.70 mM Trolox g^{-1}) compared with conventional grapes (4.40 mM Trolox g^{-1}) (Mulero *et al*., 2010). As reported from several authors, high variability of phenols content in grapes may be caused by many factors including genotype, ripening stage, environmental and growing condition. Among these organic farming have shown in different studies on grapes (Zahedipour *et al.*, 2019) and other fruit as kiwifruits (Amodio *et al*., 2007), and raspberry (Ponder and Hallmann, 2019) to positively affect antioxidant compounds, and particularly phenolics, representing a defense mechanism released from plant cells in response to biotic and abiotic environmental stress (Macheix *et al*., 1990; Zhang *et al*., 2011). In organic farming, synthetic pesticides are banned, therefore, plants need to create their own defence mechanisms against pests and diseases (Young *et al*., 2005). An increase of vitamin C and antioxidant enzymes activity was also observed in passion fruit (De Oliveira *et al*., 2017). In terms of vitamin C content at harvest and during storage organic and conventional table grapes presented almost the same values without any significant differences. Particularly, when the organic system was applied the vitamin C values were in the range of 1.46-3.12 mg 100 g^{-1} in Taranto and 2.18-3.36 mg 100 g^{-1} in Bari while for conventional samples vitamin C values were between 1.01-2.94 mg 100 g^{-1} in Taranto and 1.90-3.22 mg 100 g^{-1} in Bari (data not shown). Many factors are responsible for the wide variation in vitamin C content of fruits and vegetables at harvest. Maturity at harvest, harvesting method, and postharvest handling conditions also affect the vitamin C content of fruits and vegetable (Lee and Kader, 2000).

4. Conclusions

Results showed a higher phenolic content and antioxidant activity for grapes obtained with the organic farming system although in terms of visual quality, and yield performance conventional fruit had a better performance, resulting in a higher storability. These results confirmed previous finding on different antioxidant properties of organic fruit, but pointed out to the necessity of increasing their shelf-life in order to allow a better distribution, also considering international request of organic grapes.

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