ANTIOXIDANT CAPACITY, TOTAL PHENOLIC, CAROTENOID, AND VITAMIN C CONTENTS OF FIVE TABLE GRAPE VARIETIES FROM ALGERIA AND THEIR CORRELATIONS

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Abstract

Aim: The aim of this work was the determination of some antioxidants (total polyphenols (TPP), total flavonoids (TF), carotenoids, vitamin C, the antioxidant capacity (AC) (reducing power) and other physicochemical parameters, such as pH, total soluble solids (°Brix), total acidity and density, in an attempt to understand how the evaluated characteristics vary with different grape varieties.

Methods and results: Grape is currently known as a fruit that presents a very high antioxidant activity that can inhibit the harmful effects of free radicals. In this study, five Algerian table grape varieties were tested: Cardinal, Gros noir, Muscat noir, Muscat blanc and Victoria. TPP, TF, carotenoids and AC were determined by using colorimetric assays, and the physicochemical parameters (pH, °Brix, total acidity and density) were measured using classical methods. The darker varieties (Gros noir and Muscat noir) had the highest levels of polyphenols, flavonoids, carotenoids and vitamin C and possessed a good reducing power. A strong positive correlation was found, especially between TPP, TF and AC.

Conclusion: This study indicated that some Algerian grape varieties exhibit high antioxidant phenolic and carotenoid content, which can potentially be used as natural source of antioxidant.

Significance and impact of the study: This study on the AC, the TPP, carotenoid and vitamin C contents of five table grape varieties from Algeria and their correlations is very unique, as it is the first study on varieties grown in this country.

Key words: table grape, bioactive compounds, phenols, antioxidant activity, correlation

Résumé

Objectif: Le but de ce travail est la détermination de certains antioxydants (polyphénols totaux (PPT), flavonoïdes totaux (FT), caroténoïdes et vitamine C, de la capacité antioxydante (CA) (pouvoir réducteur) et d'autres paramètres physico-chimiques, tels que le pH, les solides solubles totaux (°Brix), l'acidité totale et la densité, pour comprendre la variation des caractéristiques évaluées avec différents cépages.

Méthodes et résultats: Le raisin est considéré comme un fruit présentant une activité antioxydante très élevée qui peut inhiber les effets néfastes des radicaux libres. Dans cette étude, cinq variétés algériennes de raisin de table ont été évaluées: Cardinal, Gros noir, Muscat noir, Muscat blanc et Victoria. Les PPT, les FT, les caroténoïdes et la CA ont été déterminés à l'aide de tests colorimétriques, alors que les paramètres physico-chimiques (pH, °Brix, acidité totale et densité) ont été mesurés en utilisant les méthodes classiques. Les variétés plus foncées (Gros noir et Muscat noir) présentent les concentrations les plus élevées en polyphénols, flavonoïdes, caroténoïdes et vitamine C et possèdent un pouvoir réducteur élevé. Une forte corrélation positive a été révélée, surtout entre PPT, FT et CA.

Conclusion: Cette étude a montré la présence de teneurs élevées en composés phénoliques antioxydants et en caroténoïdes dans quelques variétés algériennes de raisin pouvant potentiellement être utilisées comme source naturelle d'antioxydant.

Importance et impact de l'étude: Cette étude sur la CA, les PPT, les caroténoïdes et la vitamine C de cinq variétés de raisin de table d'Algérie et leurs corrélations est très originale du fait qu'elle est la première étude réalisée sur des variétés cultivées dans ce pays.

Mots clés: raisin de table, composés bioactifs, phénols, activité antioxydante, corrélation

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INTRODUCTION

In recent times, natural antioxidants have attracted considerable interest among nutritionists, food manufacturers and consumers because of their presumed safety and potential therapeutic values. It has been shown that some phytochemicals, including polyphenols, flavonoids and carotenoids in fruits and vegetables, consumed as part of our daily diet, may reduce the risk of chronic diseases such as cancer and heart disease (Keevil *et al*., 2000; Veluri *et al*., 2006; Voutilainen *et al*., 2006). Grape is one of the most important fruit commodities as an economic plant with good agricultural characteristics. It is mainly processed to juice, wine or raisins (dried grapes). Grapes are becoming increasingly popular as a fruit and are a significant source of nutritional antioxidants, such as flavonoids, phenolic acids, anthocyanins and carotenoids, as well as biologically active dietary components with high antioxidant activities such as vitamin C. Grape has been studied by many researchers (Giovanelli and Brenna, 2007; Orak, 2007; Mulero *et al*., 2010; Bunea *et al*., 2012), who found that it is among food products having the highest concentration of TPP compounds and the highest level of total AC . The phenolic profile of grapes was published by some authors (Revilla and Ryan, 2000; Rockenbach *et al*., 2011). Revilla and Ryan (2000) reported the presence of 17 different phenolic molecules with antioxidant properties (gallic acid, procyanidin B1, *trans*-caffeoyltartaric acid, (1)-catechin, *trans*-coumaroyltartaric acid, procyanidin B2, (2)-epicatechin, delphinidin-3-*O*-glucoside, cyanidin-3-*O*-glucoside, petunidin-3-*O*-glucoside, peonidin-3-*O*-glucoside, malvidin-3-*O*-glucoside, rutin, quercetin-3-*O*-glucuronoside, malvidin-3-*O*-glucoside-acetate, *trans*-resveratrol, and malvidin-3-*O*-glucoside-(*p*-coumarate)). In this context, the aim of this study was to assess the TPP, carotenoid and vitamin C contents, the AC, and their correlations of five fresh table grape varieties from Algeria, with a view to exploiting their potential as a source of natural antioxidants. In addition, some chemical characteristics were analyzed as they are important for the sensory quality of grape at ripeness.

MATERIALS AND METHODS

1. Grape samples

The work was carried out on five different varieties of table grape, namely: Cardinal (red variety), Gros noir, Muscat noir (blue-black varieties), Muscat blanc and Victoria (white varieties) (harvest year 2012) grown at four different sites (Cardinal grapes were harvested in two different sites) in the region of El-Tarf located in northern Algeria (36° 45’ 00” N; 81° 10’ 00” E). Samples were harvested at maturity (as determined by the owners of the vineyards), which was confirmed later by measuring the sugar content (°Brix). The sampling of grapes was done meticulously and berries were collected randomly from top, bottom, sun-exposed and unexposed clusters on each side of the vine. For each variety, two samples were taken, one for physicochemical analysis and the other for antioxidant analysis. Samples were placed in clean, dry, plastic boxes and quickly transported and stored until analysis.

Table 1. Characteristics of the vines and topography of the plots

Site	1	2	3	4
Culture system	Royat Cordon	Royat Cordon	Royat Cordon	Pergola
Fertilization treatment	No	No	Yes (foliar nitrogen)	Yes (nitrogen fertilizers and phosphoric plus trace elements (Ca, K) by fertigation)
Vineyard age (year)	32	32	39	5
Distance x spacing (m)	3.0 x 1.0	3.0 x 1.0	3.0 x 1.0	3.0 x 2.5
Topographical situation	Plain	Plain	Plain	Plain
Soil type	Silty sandy	Silty sandy	Silty sandy clay	Silty sandy
Irrigation	Non irrigated	Non irrigated	Noni rrigated	Dropwise
Varieties	Cardinal	Cardinal Gros noir	Muscat blanc Muscat noir	- Victoria
Sampling date	15/07/2012	15/07/2012 (Cardinal) 04/08/2012 (Gros noir)	04/08/2012	04/08/2012

Table 1 summarizes the main characteristics of the vineyards and sample plots.

2. Physicochemical analysis

Physicochemical analyses were performed on grape juice two days after sampling. The grape juice was obtained by direct pressure of grapes followed by separation of juice from pulp by filtration. The grape juice samples were analyzed for pH, soluble solid content (°Brix), total acidity and density according to Algerian Standards of the Official Algerian Journal NA 301 : Grape Juice : Specification (1989).

- pH : determined with a pH-meter (Hanna, pH-210) ;
- °Brix : determined with a refractometer (Carl Zeiss Jena) ;
- Acidity : measured by titration with 0.1N NaOH ;
- Density : determined with a pycnometer at 20 °C.

3. Estimation of ascorbic acid

The oxidation-reduction method described by Njoku *et al.* (2011) was used for the estimation of ascorbic acid content with some modifications ; it is a direct titration of 10 ml of grape juice with iodine (I_2). Results are expressed as mg of vitamin C/100 ml of juice.

4. Determination of total carotenoids

Carotenoids were extracted by the method described by Sass-Kiss *et al.* (2005). Briefly, 20 ml of mixed extraction solvents (hexane/acetone/ethanol, 2:1:1) was added to 10 g of fresh crushed grapes. After stirring for 30 min, the upper phase was recovered. 10 ml of hexane was added for a second extraction. The mixture of the two hexane phases was used for the determination of total carotenoids by spectrophotometry at 420 nm. Concentrations of carotenoids are estimated by reference to the calibration curve using β-carotene as standard and the results are expressed as µg/g of fresh weight (µg/g FW).

5. Sample preparation and extraction for phenolic and antioxidant analysis

Frozen grapes were washed with distilled water, dried with a cloth and crushed in a domestic mixer. A mixture of 10 g of crushed grapes, 20 ml of extraction solvent (methanol 80 %) and 0.1 ml/10 ml of solvent (v/v) of concentrated HCl (to avoid oxidation of the phenolic compounds) was placed in a water bath with stirring. After agitation, the liquid extract was separated from the solid residues by centrifugation at 3000 rpm/15 min ; the extraction procedure was repeated three times. The final extract, which consisted of a mixture of three supernatants, was transferred into opaque vials and stored in a fridge (4 °C) until further analysis. The extraction procedure was performed twice.

6. Determination of total polyphenols (TPP)

Total phenolic content in the extract was determined using Folin-Ciocalteu (FC) reagent according to the method described by Nickavar *et al.* (2008) with some modifications. Briefly, 50 µl of freshly prepared extracts was mixed with 2.5 ml of Folin-Ciocalteu reagent (diluted 1/10) and incubated at room temperature. After 10 min, 2 ml of sodium carbonate solution (7.5 %) was added. The final solution was mixed thoroughly and allowed to remain in the dark for 30 min. The absorbance was measured at 765 nm with a spectrophotometer. Gallic acid was used as standard phenolic compound (0.1 - 0.9 mg/ml) and the results were expressed as mg of gallic acid equivalent (GAE)/g FW. The assay was performed in two replicates for each extract.

7. Determination of total flavonoids (TF)

TF were measured by a colorimetric assay developed by Kim *et al.* (2003), with modifications. Briefly, 250 µl of extract or standard solution of catechin at different concentration (20 - 260 µg/ml) and 1 ml of distilled water were mixed in a 10 ml test tube. The following were successively added : at zero time, 75 µl of 5 % $NaNO_2$; at 5 min, 75 µl of 10 % $AlCl_3$; and at 6 minutes, 500 µl of 1N NaOH. The solution was then immediately diluted by adding 2.5 ml of distilled water and mixed thoroughly. The absorbance of the mixture, pink in color, was directly measured in a spectrophotometer at 510 nm against a blank sample and the results were expressed as catechin equivalents (mg CE/g FW). Samples were analyzed in two replicates for each extract.

8. Antioxidant assay

The antioxidant activity of the whole grape extracts was determined using reducing power according to the method described by Jayaprakasha *et al.* (2001). Briefly, 1 ml of grape extract, 2.5 ml of phosphate buffer (0.2 M, pH 6.6) and 2.5 ml of potassium ferricyanide solution (1 % w/v) were mixed in a test tube and reacted for 20 min at 50 °C. At the end of incubation, the tubes were immediately cooled and 2.5 ml of trichloracetic acid (TCA) (10 %) was added. After, 2.5 ml of mixture was mixed with 2.5 ml of distilled water and 500 µl of ferric chloride (0.1 % w/v) and reacted for 10 min. The absorbance was then measured at 700 nm against a blank sample. Ascorbic acid was used as standard (0.1 - 0.9 mg/ml) and the

Table 2. Physicochemical analysis of grape juice samples

		pH	°Brix (%)	Acidity (%)	Density (20°C)
Site 1	Cardinal	3.81 ± 0.01[f]	17.65 ± 0.07[b,c]	0.406 ± 0.00[b]	1.077
Site 2	Cardinal	3.58 ± 0.01[c]	17.30 ± 0.14[a,b]	0.448 ± 0.04[b]	1.074
	Gros noir	3.64 ± 0.01[d]	17.05 ± 0.07[a]	0.420 ± 0.02[b]	1.062
Site 3	Muscat blanc	3.39 ± 0.01[a]	17.75 ± 0.35[c]	0.413 ± 0.01[b]	1.073
	Muscat noir	3.50 ± 0.001[b]	21.01 ± 0.01[d]	0.518 ± 0.02[c]	1.087
Site 4	Victoria	3.74 ± 0.01[e]	17.85 ± 0.07[c]	0.217 ± 0.01[a]	1.076

Values marked by different letters are significantly different ($p<0.05$)

results were expressed as ascorbic acid equivalent antioxidant (mg AAEA/g FW). The assay was performed in two replicates for each extract.

9. Statistical analysis

All data are reported as mean ± standard error of two replicates. The statistical comparison of data was performed by a one way analysis of variance (ANOVA) at $p<0.05$ with STATISTICA 5.5 (StatSoft Inc., Oklahoma, USA) in order to determine significant differences between the results. The LSD (Least Significant Difference) test was applied to reveal significant differences for each parameter among the studied grape varieties. To determine whether the bioactive compounds contributed to the (AC), Pearson's correlation coefficients were calculated at 5 %.

RESULTS AND DISCUSSION

1. Physicochemical analysis

The results for the physicochemical analysis of the grape juices are shown in Table 2 as mean ± standard deviation.

Acidity varied significantly ($p<0.05$) and ranged from 0.217 ± 0.01 % (Victoria) to 0.518 ± 0.02 % (Muscat noir), and pH varied between 3.81 ± 0.01 (Cardinal) and 3.39 ± 0.01 (Muscat blanc). Muscat noir showed the second lowest pH and the highest acidity, which explains the characteristic taste of this variety. pH data are in agreement with the grape juices (pH 3.30 - 3.51) studied by Burin *et al.* (2010).

Total soluble solids (°Brix) of the different grape juices showed significant differences ($p<0.05$) and ranged from 17.05 ± 0.07 % (Gros noir) to 21.01 ± 0.01 % (Muscat noir), and density varied between 1.062 and 1.087 for the same variety, respectively. According to the CODEX STAN 247 (2005), the minimal °Brix value of grape juice is 16 %. All grape juices analyzed in this study present value higher than 16 %, indicating that the samples are in accordance with the legislation and are a good source of sugars. The Muscat noir variety contains the highest total soluble solid content, which gives it a relatively sweet taste. The differences in the chemical composition of juices can be attributed to genetic differences among varieties and physiological factors (Del Caro *et al.*, 2004). The chemical composition (total soluble solids, sugar, acids,…) of Flame grapefruit significantly varies with the fertilization treatment (Dou *et al.*, 2005).

2. Ascorbic acid and total carotenoid contents

The ascorbic acid and total carotenoid contents of the six grape samples are shown in Table 3.

2.1 Ascorbic acid content

Grapes are known to be a nutrient source of vitamin C in dietary intake. Here, the ascorbic acid content ranged from 12.33 ± 0.01 (Victoria) to 30.80 ± 4.98 mg/100 ml of grape juice (Gros noir). The ascorbic acid content varies between 27.7 and 40.0 mg/100 ml among grapefruit juices (Dou *et al.*, 2005), whereas it ranges from 4.4 to 57.2 mg (%) in organic and conventional grape juices (Dani *et al.*, 2007). Several factors influence the ascorbic acid content, including preharvest factors, such as climatic conditions (sunlight exposure and weather) and farming practices (fertilizers), maturity at harvest, harvesting method, postharvest handling conditions (storage), species, cultivars and tissues (Lee and Kader, 2000), as well as genotype (Sharique and Beigh, 2009). All these factors are responsible for the wide variation in vitamin C content of fruits and vegetables.

2.2 Carotenoid content

Levels of carotenoids were very different among the five grape varieties studied ($p<0.05$). With regard to their concentrations (Table 3), we detected significant amounts of carotenoids in all grape varieties at harvest, in both red and white ones. The results ranged from 5.99 ± 0.12 (Victoria) to 16.11 ± 0.34 µg/g (Muscat noir). As climatic conditions were uniform for all the cultivars, this trend could be due to the differences in varieties and viticultural conditions (soil characteristics, irrigation and fertilization treatment), which vary from one site to another. The Victoria variety showed the lowest carotenoid content in comparison with the other varieties studied. This may be due to the fact that this variety was treated for powdery mildew caused by *Erysiphe necator* and received intensive treatment every 4 days.

There are relatively few studies regarding grape carotenoid composition. The quantitative carotenoid data obtained were not in agreement with the literature data. Crupi *et al.* (2010) studied the carotenoid concentration in some wine grapes and obtained values for total carotenoids in the range of 720 - 2052 µg/kg depending on grape variety. In their study on three Italian grape varieties (Erbaluce, Barbera and Nebbiolo) at harvest, Giovanelli and Brenna (2007) found amounts of 1.1, 9.1 and 4 µg/g of dry weight, respectively, which approach those found here for Cardinal (8.72 µg/g ± 0.20) and Victoria (5.99 µg/g ± 0.12). In their work on the skin of nine wine and table grape varieties cultivated in organic and conventional agriculture, Bunea *et al.* (2012) found that white grape varieties have a higher carotenoid content compared with the blue-black cultivars. However, in their work on the skin of three grape varieties (white, red and black), Lancaster *et al.* (1997) reported a concentration of 0.005 mg/g (on fresh mass basis) for these three varieties. The profile and the amount of grape carotenoids could be influenced by several factors, such as: plant variety, climatic conditions, stage of maturation, soil features (Kamffer *et al.*, 2010), and extraction methods, especially the extraction solvent, time and pH (Kamffer *et al.*, 2010). There are studies showing that soil irrigation has less influence on carotenoid profile compared with the type of soil and its water holding capacity. Soil with a low water holding capacity can lead to an increase in carotenoid concentration (Lee *et al.*, 2007).

3. Determination of total polyphenols (TPP)

The TPP content of grape cultivars are shown in Figure 1. TPP per g of fresh grape ranged from 3.35 ± 0.21 mg GAE in Gros noir to 1.21 ± 0.04 mg GAE in Cardinal 1. The phenolic concentrations of the other grape varieties were as follows: Muscat noir (3.04 ± 0.06 mg GAE), Cardinal 2 (1.85 ± 0.04 mg GAE), Victoria (1.82 ± 0.13 mg GAE) and Muscat blanc (1.58 ± 0.11 mg GAE).

Based on the TPP, the five grape cultivars studied may be classified into two groups: one exhibiting clearly higher phenolic contents (berries with a strong purple color, i.e., Gros noir and Muscat noir), which is due to the maximal accumulation of anthocyanins and flavonols during the last ripening stage, thus contributing to high polyphenol contents (Marinova *et al.*, 2005), and one exhibiting low levels (i.e., Victoria, Muscat blanc, Cardinal 1 and Cardinal 2). These results are in agreement with those found by Dani *et al.* (2007), who reported higher polyphenol contents in red grape juices from *Vitis labrusca* compared with white ones.

The TPP content of Gros noir and Muscat noir was about 2.8- and 2.5-fold higher than that of Cardinal 1,

Table 3. Ascorbic acid and total carotenoid contents in different grape cultivars

		Ascorbic acid (mg/100 ml)*	Total carotenoids (µg/g)**
Site 1	Cardinal	22.44 ± 0.62[a]	08.72 ± 0.20[b]
Site 2	Cardinal	13.20 ± 3.73[a]	13.61 ± 0.07[c]
	Gros noir	30.80 ± 4.98[a]	14.93 ± 0.03[d]
Site 3	Muscat blanc	14.08 ± 2.49[a]	14.70 ± 0.11[d]
	Muscat noir	26.84 ± 5.60[a]	16.11 ± 0.34[e]
Site 4	Victoria	12.33 ± 0.01[a]	05.99 ± 0.12[a]

Values marked by different letters are significantly different ($p<0.05$);
*Expressed as mg vitamin C/100 ml of grape juice;
**Expressed as µg/g of fresh weight.

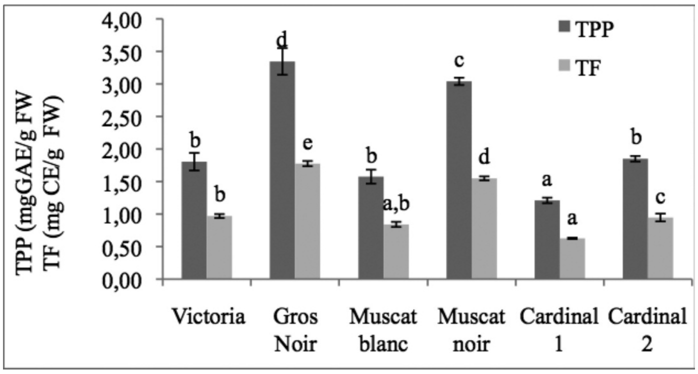

Figure 1. Contents of total polyphenols (TPP) and total flavonoids (TF) in various grape cultivars. The data are displayed with mean ± standard deviation (bars). Values marked by different letters are significantly different ($p<0.05$). TPP and TF are expressed as mg of gallic acid equivalents (GAE)/g and mg of catechin equivalents (CE)/g of fresh weight, respectively.

respectively. Our observation is lower than the 3.7-fold reported by Orak (2007) in red grapes. The averages of TPP of grape were significantly different at a level of $p<0.05$. The highest content of TPP in the grape extracts might account for the better results found for their antioxidant activity. In fact, it had been reported that the antioxidant activity of plant materials is well correlated with the content of phenolic compounds (Barros *et al.*, 2007).

Mulero *et al.* (2010) found in their study on the red grape variety Monastrell 982.0 ± 58.97 mg TPP/kg fresh weight of total grape berry, and Marinova *et al.* (2005) found 184.1 and 213.3 mg/100 g of fresh mass from white and black grapes (*Vitis vinifera*), respectively, which is close to or lower than our results. However, Yang *et al.* (2009) found TPP ranges between 201.1 and 424.6 mg GAE/100 g of fresh grape for 14 different varieties of wine grapes, which is higher than the results found in this study. Several factors such as genetic differences among different cultivars and species (Du *et al.*, 2012 ; Orak, 2007), geographical origin and clones (Stefanovits-Bányai *et al.*, 2003), tissue analyzed, extraction time, temperature and solvent (Bucić-Kojić *et al.*, 2011), developmental stage (Prvulović *et al.*, 2011), soil component (Imre *et al.*, 2012) and vegetative rootstocks (Jakobek *et al.*, 2009) could influence the phenolic content.

4. Determination of total flavonoids (TF)

The range of TF per g of fresh weight in all tested grapes varied between 0.40 ± 0.01 and 1.09 ± 0.04 mg CE (Figure 1). Gros noir exhibited the highest flavonoid content (1.09 ± 0.04 mg CE), followed by Muscat noir (0.84 ± 0.03 mg CE), Victoria (0.46 ± 0.03 mg CE), Cardinal 2 (0.46 ± 0.06 mg CE), Muscat blanc (0.45 ± 0.04 mg CE) and Cardinal 1 (0.40 ± 0.01 mg CE). The TF contents of the grape cultivars were significantly different at a significance level of $p<0.05$.

Marinova *et al.* (2005) found 36.5 and 77.1 mg/100 g of fresh mass from white and black grapes (*Vitis vinifera*), respectively, which is higher than our results. Here, the TF levels are much lower than those found by Du *et al.* (2012) (228.7 and 607.7 mg of rutin equivalents/100 g of fresh grapes of eight different grape varieties) and lower than those found by Yang *et al.* (2009). Grape flavonoid composition appears to vary greatly among tested fruits depending on their genetic origin, the time of fruit collection, and the fruit parts used (peel and edible parts) (Lu *et al.*, 2006). The presence and/or concentration of flavonoids can be affected by differences among cultivars, agricultural practices, assay protocols (Kim *et al.*, 2003) as well as sunlight and temperature exposure (Makris *et al.*, 2006).

5. Antioxidant capacity (AC) / Reducing power

Figure 2 shows the reducing power of grape methanolic extracts. In this assay, the yellow color of the test solution changes to various shades of green and blue depending on the reducing power of each compound. The presence of reducers (i.e., antioxidants) causes the conversion of the Fe^{3+}/ferricyanide complex used in this method to the ferrous form. Therefore, by measuring the formation of Perl's Prussian blue at 700 nm, we can monitor the Fe^{2+} concentration ; a higher absorbance at 700 nm indicates a higher reducing power. The total AC per g of fresh grape varied between 3.69 ± 0.13 mg AAEA in Cardinal 1 and 16.58 ± 0.07 mg AAEA in Gros noir, with intermediate values for the other four varieties: 11.85 ± 0.36, 9.19 ± 0.12, 6.26 ± 0.09 and 5.04 ± 0.23 mg AAEA in Muscat noir, Muscat blanc, Cardinal 2 and Victoria, respectively.

Methanolic extracts from Gros noir, Muscat noir and Muscat blanc showed higher reducing power values than those from Victoria and Cardinal 1 and 2 (Figure 2). There was no clear trend in terms of AC and phenolic content between white and red grape cultivar as a group. It is the individual cultivar that matters. For example, Muscat blanc (white grape) had a lower TPP content than Cardinal 2 (red grape) but a higher reducing power. This can be explained by the fact that Muscat blanc had high carotenoid levels. In this case, it is not possible to rank white and red grape cultivars as a group in terms of AC, as this activity is more related to individual cultivar. This is in accordance with the results found by Gil *et al.* (2002) on five different cultivars of white-flesh nectarines and yellow-flesh nectarines from California. It was reported that the reducing properties are generally associated with the presence of reductones, which have been shown to exert antioxidant action by breaking the free radical chain by donating a hydrogen atom. Grape varieties with high reducing power might contain higher amounts of reductones, which could react with free radicals to stabilize and block radical chain reactions (Barros *et al.*, 2007). Thus, the AC of an extract cannot be predicted on the basis of its total phenolic content.

6. Correlation

The TPP content of the different varieties studied followed the same order as that of TF (Gros noir > Muscat noir > Cardinal 2 > Victoria > Muscat blanc > Cardinal 1), resulting in a high positive correlation coefficient (r^2 = 0.937; Figure 3a). A similar relation was found by Kim *et al.* (2003) in six cultivars of plums (r^2 = 0.934). Total AC was strongly correlated with total phenolics (r^2 = 0.820; Figure 3b). A similar relation was found in 16 red grape cultivars (r^2 = 0.756; Orak, 2007), in nectarine, peach and plum cultivars from California (r^2 > 0.90; Gil *et al.*, 2002), and in some plum cultivars (r^2 = 0.938; Kim *et al.*, 2003). Dani *et al.* (2007) also observed a positive correlation between TPP (Folin-Ciocalteu) and AC (DPPH) in different red grape juices. The same authors have shown that for grape juices made from *Vitis labrusca* grapes, considered an antioxidant source, the biological activity is influenced not only by the phenolic levels but also by the agricultural method used.

AC was also correlated with TF content (r^2 = 0.881; Figure 3c); Kim *et al.* (2003) also found good

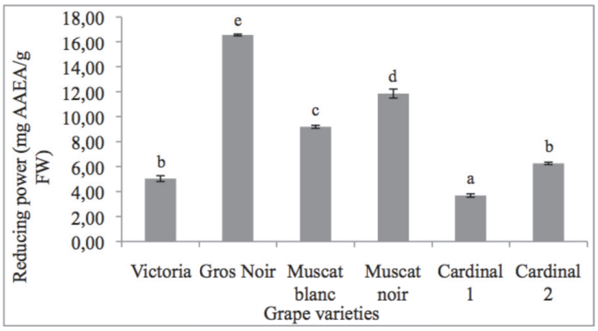

Figure 2. Reducing power of grape methanolic extract. The data are displayed with mean ± standard deviation (bars). Values marked by different letters are significantly different (p<0.05). Reducing power is expressed as mg of ascorbic acid equivalent antioxidant/g of fresh weight.

correlation (r^2 = 0.942) between TF and AC of plums and apples with a high significance level ($p<0.001$).

These results imply that polyphenols and flavonoids may play an important role in free radical scavenging activity, thus contributing significantly to the AC of the grape extracts.

In our investigation, another correlation was found between AC and carotenoid content (r^2 = 0.541, r = 0.74; Figure 3d) and between AC and vitamin C content (r^2 = 0.514, r = 0.72; Figure 3e), which indicates that these compounds also contribute to the AC of grape. In contrast, Gil *et al.* (2002) did not find a correlation between vitamin C or carotenoids and AC in their study, while Rufino *et al.* (2010), in their work on 18 non-traditional tropical fruits from Brazil, did find a positive correlation between vitamin C content and AC (ABTS, r = 0.70 and FRAP, r = 0.70). A similar result was found by Jabłońska-Ryś *et al.* (2009) in their study on seven wild fruits from the Lublin region (Poland) (ABTS, r^2 = 0.925 and FRAP, r^2 = 0.984).

CONCLUSION

Five grape varieties cultivated in Algeria were compared regarding TPP, TF, carotenoids, vitamin C and antioxidant activity. The white grape varieties have a high carotenoid content (except Victoria), as high as the blue-black varieties, while the blue-black varieties have a higher TPP content and a higher AC than the white grape varieties. *Vitis vinifera* grapes originating from table grape varieties can be used as a potential source of natural antioxidants, which can be attributed to their content of phenolic compounds. In turn, they may provide health-promoting effects to consumers, since it has been suggested that a higher consumption of fruits and vegetables with high phytochemical content can inhibit, prevent or retard

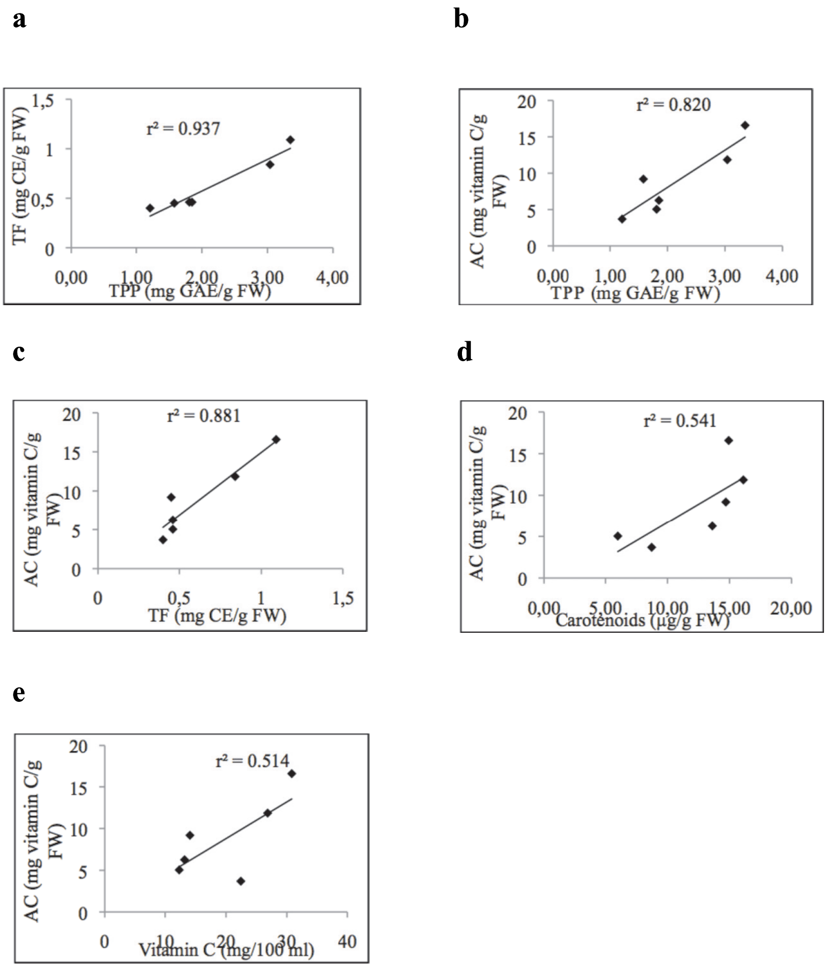

Figure 3. Simple linear regression analysis. Correlations between TPP and TF (a); TPP and AC (b); TF and AC (c); carotenoids and AC (d); vitamin C and AC (e). TPP: total polyphenols; TF: total flavonoids; AC: antioxidant capacity (reducing power); FW, fresh weight.

chronic diseases. The grapes in our study showed substantial antioxidant activity. An increased consumption of these fruits is therefore recommended in our diet. The extension of this work to future vintages should refine these conclusions and further studies on individual phenolic compounds are needed to elucidate the different antioxidant mechanisms and possible synergism.

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