Bioactive components of *Prunus avium* L. black gold (red cherry) and *Prunus avium* L. stark gold (white cherry) juices, wines and vinegars

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Abstract Cherries are one of the most popular fruits, characterized by attractive colour, firmness, appearance and delicious tastes. Cherries are consumed fresh as well as in jams, wine, dried, candy and other processed products. Cherries vary in antioxidant properties and phenolic substances. The aim of the study was to determine the effects of ethanol and acetic acid fermentation on total antioxidant activities and phenolic substances of cherry juice. Total investigation of solids, pH, soluble solids, phenolic substances, ORAC and TEAC of *Prunus avium* L. cherry juices, macerated cherries wine, and vinegars were analyzed. All samples had 300.1–854.79 mg GAE/L of total phenolic contents, and 6.62–17.97 $\mu\text{mol/mL}$ of ORAC values, and 1.5–5.5 mmol/mL of TEAC. Chlorogenic acid was present in the highest amount *P. avium* L. black gold vinegar.

Keywords Cherry vinegar · ORAC · TEAC · Antioxidant · Phenolic substances · Chlorogenic acid

Introduction

Fruits and vegetables are well established as protection effect against the development of human diseases such as cardiovascular disease, diabetes and cancer (He et al. 2007). Plant-based foods have a wide range of bioactive components that provide significant beneficial health effects. Fruits are also rich sources of potentially bioactive

compounds such as flavonoids, phenolic acids, stilbenes, coumarins, tannins, fiber, vitamins and phytonutrients (Crozier et al. 2009).

Vinegar is produced worldwide from a wide variety of starting materials using different production methodologies. Budak et al. (2014) reported that functional therapeutic properties of vinegar described include antibacterial activity, blood pressure reduction, antioxidant activity, reduction in the effects of diabetes, and prevention of cardiovascular disease. Grape, apple, pomegranate, cherry and other fruit juices are the primary starting materials used for vinegar production.

Cherries (*Prunus* spp.) are the smallest member of the stone fruit family. They comprise over a hundred species. The most important species is *Prunus avium* L., known as “sweet cherry”, and *Prunus cerasus* L., known as “sour cherry or tart cherry” (Ferretti et al. 2010). Sweet cherries may also be named according to their color. Red sweet cherry is “*Prunus avium* L. black gold” while white sweet cherry is “*Prunus avium* L. stark gold”. The main qualitative features of cherries are not their colour, sweetness, sourness, and firmness, but also for its nutritional and bioactive properties (Lara et al. 2016).

In cherries, as in other red fruits, the maturation process is related to changing from the initial green colour to red, as a result of accumulation of polyphenolic compounds, anthocyanins and degradation of chlorophyll. Phenolic compounds are concentrated in the skin and contribute to sensory and organoleptic qualities of fruit, such as taste and flavour. Furthermore, it has been shown that they are bioactive compounds (Serrano et al. 2005). In addition to phenol acids, hydroxycinnamates have been quantified both in sweet and sour cherries. Flavonols and flavan-3-ols such as catechin, epicatechin, quercetin 3-glucoside, quercetin 3-rutinoside, and kaempferol 3-rutinoside were

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also found both in sweet and sour cherries (Chaovanalikit and Wrolstad 2004; Gao and Mazza 1995).

The antioxidant capacity of extracts from cherries has been widely investigated using ORAC assay. It has been reported that the antioxidant capacity ranges from 1145 to 1916 μmol Trolox equivalents (TE)/100 g in *P. cerasus* L. cv Amarena Mattarello, Visciola Ninno and Visciola Sannicandro (Blando et al. 2004). It has to be emphasized that the values found in *P. cerasus* L. are comparable to those found in some other berry fruits, (for example, strawberries) and are higher than in apples and kiwi fruit (Lister et al. 2002). Extracts of *P. avium* L. are able to inhibit copper-triggered low density lipoproteins (LDL) oxidation, an atherogenic modification of this lipoprotein class (Heinonen et al. 1998). The antioxidant activity of *P. cerasus* L. and *P. avium* L. cherries were approved using neuronal PC 12 cells exposed to oxidative stress (Kim et al. 2005). Sarić et al. (2009) reported that an increased activity of the superoxide dismutase (liver, blood) and glutathione peroxidase (liver) enzymes and a decrease of lipid peroxidation were observed in an animal model fed with “*Prunus cerasus* cv. Maraska” juices obtained from an autochthonous cultivar. Studies in human subjects showed that the consumption of 280 g of cherries (about 45 *P. avium* L. cherries) increased plasma lipophilic antioxidant capacity (Prior et al. 2007).

Blood levels of C-reactive protein (CRP) and nitric oxide (NO) in healthy subjects decreased with the intake of *P. avium* L. cherries (280 g/day) for 28 days (Kelley et al. 2006) as an marker for inflammation inhibitor. Ridker (2001) reported that elevated levels of serum CRP is one of the most prominent indicators of inflammation which is a significant risk factor for cardiovascular disease (CVD). Increased production of NO contributes to oxidative stress, tissue injury and plasma concentrations are implicated in a variety of rheumatic diseases, including rheumatoid arthritis (Abramson et al. 2001; Onur et al. 2001).

Kang et al. (2003) in vitro studies have demonstrated that they are able to reduce proliferation of human colon cancer cells in culture. Animal model with tumor suppressor (adenomatous polyposis coli-APC) gene mutation (APCMin mice) was used in the study. The mice were popular animal model for studies of human colon cancer. The study has shown that intake of *P. cerasus* L. extract (375–3000 mg/kg diet) inhibits tumor development (Kang et al. 2003; Bobe et al. 2006). To our knowledge, no previously published study investigating the effects of ethanol and acetic acid fermentations on the antioxidant activity of *P. avium* L. black gold and *P. avium* L. stark gold cherry juices has been addressed. The aim of the study was to determine the changes in antioxidant properties and phenolic substances of *P. avium* L. black gold and *P. avium* L. stark gold cherry juices, wine and vinegar.

Materials and methods

Chemicals and reagents

Folin-Ciocalteu reagent was supplied by Merck (Darmstadt, Germany). 2,2'-azinobis (3-ethylbenzthiazolin-6-sulfonic acid) diammonium salt (ABTS), 6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (trolox), 2,2'-Azobis (2-amidinopropane) dihydrochloride (AAPH), fluorescein disodium salt and gallic acid were purchased from Acros (New Jersey, USA). Standards (gallic acid, epicatechin, catechin, chlorogenic acid, caffeic acid, syringic acid, coumaric acid, ferulic acid, rutin) for HPLC analysis were purchased from Sigma (Milan, Italy).

Ethanol and acetic acid fermentations of *Prunus avium* L. black gold and *Prunus avium* L. stark gold cherry juices

Prunus avium L. black gold and *P. avium* L. stark gold cherries were harvested from Isparta, Turkey and immediately transported to the Department of Food Engineering, Suleyman Demirel University, Isparta, Turkey.

Saccharomyces cerevisiae was obtained as dry baker's yeast from ConFerm Uni V-Begerow, Company, Germany. Yeast strain was rehydrated aerobically at 25 °C for 6 h in a 100 mL sterilized, phosphate buffered saline solution (PBS). Rehydrated yeast strains were cultured aerobically overnight at 30–37 °C, in glucose-yeast-broth for *Saccharomyces cerevisiae*. Freshly cherry juices were immediately inoculated yeast strain (2.0%, v/v, juice base, final concentration approximately 10^6 cfu/mL).

After the completion of the ethanol fermentation, samples were appropriately taken. Acetic acid fermentation of cherry wines was initiated with the addition of two-year aged cherry vinegar (*Acetobacter pasteurianus*; 1:3 ratio) using surface technique at 25 °C. It was decided by analyzing the amount of alcohol and acidity. Flow scheme of the process is presented in Fig. 1. Sample codes and sample descriptions are shown in Table 1. Alcohol content of wine and acidity of wine vinegar was determined.

Proximate analysis

pH was measured using a pH meter (WTW, Inolab, USA), titratable acidity, total solid (%) was determined gravimetrically, and total soluble solid (Brix) contents of the samples were measured using Abbe refractometer (Bellingham Stanley Limit 60/70 Refractometer, England; AOAC 1992).

Fig. 1 Flow scheme of ethanol and acetic acid fermentations of cherry juice

Total phenolic content

Total phenolic contents of fresh cherry juice, cherry juice taken after maceration, wine and vinegar samples were determined spectrophotometrically according to the Folin-Ciocalteu method using 2 N Folin reagent (Singleton et al. 1999). After addition of Folin-Ciocalteu reagent to the sample it was allowed to react for 6 min. Reaction was stopped by using 1.25 mL of 7% sodium carbonate. The color was developed for 90 min. and the absorption was determined at 760 nm using a spectrophotometer (Shimadzu Scientific Instruments, Inc., Tokyo, Japan). The measurement was compared to a standard curve of gallic acid concentrations and expressed as milligrams of gallic acid equivalents (GAE) L⁻¹.

Total antioxidant activity

Total antioxidant activity of fresh cherry juice, cherry juice taken after maceration, wine and vinegar samples were measured by Oxygen Radical Absorbance Capacity (ORAC) and 2,2'-azino bis (3-ethylbenzthiazoline)-6-sulfonic acid (ABTS) methods.

Oxygen radical absorbance capacity (ORAC) assay

ORAC assay was carried out according to the hydrophilic ORAC-Fluorescein method (Dávalos et al. 2005). The method kinetically measured the total antioxidant capacity of the samples using 2,2'-Azobis (2-amidinopropane) dihydrochloride (AAPH) damage to fluorescent compound. Briefly, 20 µL of blank, Trolox standard, appropriate dilutions of cherry juice, wine and vinegar samples in 75 mM phosphate buffer were added to triplicate wells in a

Table 1 Chemical analysis of cherry samples

Sample code	Sample description	pH	Titrateable acidity (g/100 mL)	TSS (°B)	Total solid (%)
RCJ	Cherry juice from red sweet cherry (<i>Prunus avium</i> L.)	4.07 ± 0.07 ^a	0.61 ± 0.01 ^a	14.55 ± 0.15 ^a	15.67 ± 0.10 ^a
RCM	Cherry juice taken after maceration of red sweet cherry (<i>Prunus avium</i> L.)	4.14 ± 0.12 ^a	0.37 ± 0.02 ^a	6.60 ± 0.10 ^b	7.35 ± 0.19 ^b
RCW	Cherry wine from red sweet cherry (<i>Prunus avium</i> L.)	4.18 ± 0.06 ^a	0.39 ± 0.06 ^a	5.65 ± 0.15 ^b	6.86 ± 0.05 ^{bc}
RCV	Cherry vinegar from red sweet cherry (<i>Prunus avium</i> L.)	3.74 ± 0.11 ^b	4.0 ± 0.27 ^b	2.90 ± 0.30 ^c	3.58 ± 0.01 ^c
WCJ	Cherry juice from white sweet cherry (<i>Prunus avium</i> L.)	4.16 ± 0.01 ^a	0.71 ± 0.04 ^a	17.60 ± 0.1 ^a	22.01 ± 0.08 ^a
WCM	Cherry juice taken after maceration of white sweet cherry (<i>Prunus avium</i> L.)	4.10 ± 0.01 ^a	0.70 ± 0.05 ^a	9.30 ± 0.2 ^b	10.25 ± 0.07 ^b
WCW	Cherry wine from white sweet cherry (<i>Prunus avium</i> L.)	4.19 ± 0.02 ^a	0.68 ± 0.07 ^a	7.65 ± 0.18 ^b	9.35 ± 0.15 ^b
WCV	Cherry vinegar from white sweet cherry (<i>Prunus avium</i> L.)	4.00 ± 0.01 ^a	0.33 ± 0.04 ^b	3.45 ± 0.1 ^c	5.87 ± 0.3 ^c

Data expressed as mean ± SE

^{a,b} Values with the same lower-case letters in the same column do not differ significantly ($P > 0.05$)

black, clear-bottom, 96-well microplate. A volume of 200 μ L of 0.96 μ M fluorescein in phosphate buffer was added to each well and incubated at 37 °C for 30 min. Then, AAPH was added to each well. To measure the decay of fluorescence a SynergyTM HT Multi-Detection Microplate Reader (Winooski, Vermont, USA) with injectors was used with a 485, 20 nm bandpass, excitation filter and a 528, 20 nm bandpass, emission filter. The Trolox[®] was used as a standard and ORAC values were kinetically calculated according to Cao and Prior (1999) using KC4TM Data Reduction Software (BioTek Instruments, Winooski, VT).

2,2'-azinobis (3-ethylbenzthiazoline)-6-sulfonic acid (ABTS) assay

2,2'-azinobis (3-ethylbenzthiazolin-6-sulfonic acid) diammonium salt radical (ABTS) inhibition against Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was spectrophotometrically measured to determine Trolox Equivalent Antioxidant Capacity (Seeram et al. 2005). A standard calibration curve was constructed for Trolox and was used as the antioxidant standard at certain concentrations. ABTS assay values were calculated from the Trolox standard curve and expressed as Trolox equivalents (in μ mol/mL).

Quantification of phenolic substances

Gallic acid, epicatechin, catechin, chlorogenic acid, caffeic acid, syringic acid, coumaric acid, ferulic acid and rutin in fresh cherry juice, cherry juice collected after maceration, wine and vinegar samples were quantified by HPLC (Shimadzu, Kyoto, Japan). Samples were diluted with distilled water and filtered through a 0.45 μ m filter before HPLC analysis. This system consisted of a model LC-20AD pump, SPD-M 20A diode array detector, a CTO-10ASVP column oven and a DGU-20A3 degasser system. Inertsil ODS-3 analytical column (250 mm $\times$ 4.6 mm I.D., 5 μ m) was used as stationary phase (GL Sciences Inc.[®], USA). The chromatographic conditions for the samples were as follows: flow rate, 0.8 mL/min, injection volume, 20 μ L, column temperature, 30 °C. All compounds were detected at 278 nm.

Statistical analysis

All data were reported as the mean $\pm$ SEM. Juice, wine and vinegar production (each fermentation) was carried out in duplicate. All analysis were repeated two times. Mean values were calculated from four experimental data.

Statistical analyses were carried out using SPSS for Windows (version 17.0, SPSS Inc.). Duncan's multiple range test was used to compare means when a significant variation was highlighted by analysis of variance. The significance was established at $P < 0.05$.

Results and discussion

Titrateable acidity and pH values, as well as total soluble solids (TSS) and total solids contents of fresh cherry juice, cherry juice taken after maceration, wine and vinegar samples are presented in Table 1. pH value of cherry wine samples had between 3.68 and 3.73 (Xiao et al. 2015). pH value of cherry samples had between 3.56 and 3.80 (Hayaloglu and Demir 2015); 3.21 and 4.76 (Picariello et al. 2016); 3.52–4.11 (Chaovanalikit and Wrolstad 2004). pH values of cherry vinegar (RCV and WCV) samples were 3.74 and 4.00, respectively ($P < 0.05$). Vinegar sample (RCV) had the lowest pH values due to high content of acetic acid and indicated that the effect of acetic acid fermentation on pH was significant ($P < 0.05$).

Total acidity of cherry samples had 0.71–1.01 g/100 g (Hayaloglu and Demir 2015); 9.74–11.02 g/L (Lara et al. 2016); 0.89–0.93% (Wang and Long 2015); 0.49–1.11% (Cao et al. 2015) while total acid of cherry wine samples had 7.59–7.90 g/L (Xiao et al. 2015). In this research, titration acidity of RCV sample was 4.00 g/100 mL while the titration acidity of WCV sample was 0.33 g/100 mL, RCV sample was the highest in other samples ($P < 0.05$). Acidity of wine vinegar is not less than 60 g/L (Codex alimentarius commission, 2000). TSS and titrateable acidity are used as indicators of the eating quality and harvest maturity (Serradilla et al. 2012). It was made cherry wine from *P. avium* L. stark gold cherry juice. But WCV did not turn into vinegar product which was made from *P. avium* L. stark gold cherry. pH and titrateable acidity of the WCV sample did not show vinegar criteria. Regulations in the United States require vinegar to contain at least 4% acetic acid resulting from acetic acid fermentation of ethanol containing substrates. Besides, WCV vinegar had a very bad organoleptic characteristics in terms of taste, aroma and acidity while RCV vinegar had a very good characteristics in terms of those of them.

It has begun to ethanol fermentation with 14.55 and 17.60 Brix in the study. In other studies, Brix values of cherry samples ranged between 14.43 and 18.38 in four different cherry juice samples (Chaovanalikit and Wrolstad 2004); 14.70–19.07 in “New Star” and “Sweet Heart” cherry samples (Lara et al. 2016); 15.0–18.0 in five different cherry types (Picariello et al. 2016); 14.66–18.94 in nine different cherry juices (Schüller et al. 2015); 13.26–19.55 in twelve different cherry type (Hayaloglu and

Demir 2015); 19.5–21.2 in two cherry type (Wang and Long 2015); 10.07–16.90 in four different cherry type (Cao et al. 2015). TSS was gradually decreased during alcohol fermentation. Alcohol value is also significant parameter for acetic acid fermentation (Treck and Teuber 2002).

Total phenolic contents, antioxidant activity (ORAC and TEAC (ABTS-)) values of cherry samples are presented in Fig. 2a, b, respectively. Total phenolic content of RCJ was found to higher than RCM, RCW, RCV in this study ($P < 0.05$). The same tendency was also observed in the WCJ, WCM, WCW, WCV samples ($P < 0.05$). In other study, the total phenol content had between 84.96 and 162.21 mg GAE/100 g (Ballistreri et al. 2013); 60–155 mg GAE/100 g (Serrano et al. 2005); 235.53 and 736.54 mg GAE/L (Xiao et al. 2015); 58.31–115.41 mg GAE/100 g (Hayaloglu and Demir 2015); 28.3–218.0 mg GAE/100 g (Picariello et al. 2016) in different cherry samples. Total phenolic content of cherries from the Campania Region ranged between 20.2 and 362.4 mg GAE/100 g (Pacifico et al. 2014). Cao et al. (2015) determined that the total phenolic content was found at 161.99 mg/100 g and 832.70 mg/100 g. Total phenolic content values of RCJ and WCJ in our results were consistent with the literature. Yoo et al. (2010) reported that total phenolic content of cherry fruit had 188–221 mg GAE/100 g while that of cherry wine had 79.4–149 mg GAE/100 mL. Total antioxidant activities of RCV and WCV had lower than that of RCW and WCW. Budak and Güzel-Seydim (2010) stated that antioxidant activity of wine samples had higher than vinegar samples.

Cherry juice samples had the highest ORAC antioxidant activity among all the samples ($*P < 0.05$). ORAC antioxidant activity of RCJ and WCJ samples were 17.97 and 15.14 $\mu\text{mol/mL}$, respectively. In a study conducted by Blando et al. (2004) antioxidant activity by ORAC assay of sour cherry fruits was found to range from 1.145 to 1.916 $\mu\text{mol TE}/100\text{ g}$. Another study stated that antioxidant activity of four cherry samples showed a range of 4.62–15.00 $\mu\text{mol TE/g}$ by ORAC assay (Chaovanalikit and Wrolstad 2004). Schüller et al. (2015) indicated that antioxidant capacity of cherry juices had 3.45–9.64 $\mu\text{mol TE/mL}$. In other study, antioxidant activity value was identified between 9.1 $\mu\text{mol TE/g}$ and 38.9 $\mu\text{mol TE/g}$ (Picariello et al. 2016). ORAC results were consistent with our results. However, the ORAC values of RCV and WCV were significantly higher than the RCW and WCW, respectively. Moreover, antioxidant activity of *P. avium* L. black gold samples had higher than *P. avium* L. stark gold in the study. Davalos et al. (2005) reported that antioxidant activities of red wines had higher than for rose or white wines due to polyphenols and phenolic compositions.

Fig. 2 a Total phenolic substances of cherry samples. b Antioxidant activity of cherry samples

TEAC values of RCV and WCV of cherry vinegar samples were 3.05 and 1.50 mmol/mL ($P < 0.05$). The ABTS⁺ antioxidant activity may be determined by conversion of blue color to colorless in presence of antioxidant substances (phenolics, thiols, Vit. C etc.; Re et al. 1999). Hayaloglu and Demir (2015) reported that TEAC values of the twelve *P. avium* L. samples found between 4.49 and 6.15 mg TE/g. In a research stated that antioxidant activity of five cherry samples showed a range of 5.8–16.9 $\mu\text{mol TE/g}$ by ABTS assay. TEAC values of cherry juice samples were consistent with our results. Tesfaye et al. (2002) reported that vinegars included different antioxidant compounds, and their final quality depends to the raw material used as substrate, the acetification system used, and the ageing procedure used during their production. Vinegar is an important product in terms of antioxidant activity.

The beneficial health effects of fruit vinegars may in part be related to the process-induced changes of their phenolics and generation of new antioxidative phenolics during fermentation (Shahidi et al. 2008).

Gallic acid, catechin, epicatechin, chlorogenic acid, caffeic acid, syringic acid, ferulic, rutin and coumaric acid

Table 2 Phenolics substances of cherry samples

Samples	Gallic acid (mg/L)	Chlorogenic acid (mg/L)	Catechin (mg/L)	Caffeic (mg/L)	Syringic (mg/L)	Epicatechin (mg/L)	Coumaric (mg/L)	Ferulic (mg/L)	Rutin (mg/L)
RCJ	nd	24.77 ± 2.50 ^e	0.38 ± 0.50 ^a	3.74 ± 0.01 ^a	6.64 ± 0.50 ^a	1.17 ± 0.03 ^{ab}	0.04 ± 0.01 ^a	1.01 ± 0.02 ^a	nd
RCM	nd	37.78 ± 3.20 ^d	1.00 ± 0.11 ^{ab}	4.00 ± 0.05 ^{ab}	14.46 ± 1.50 ^b	1.48 ± 0.05 ^b	nd	5.19 ± 0.70 ^{bc}	4.74 ± 0.50 ^{bc}
RCW	19.17 ± 2.20 ^b	14.84 ± 1.20 ^b	1.15 ± 0.10 ^b	4.55 ± 0.06 ^b	12.25 ± 2.50 ^b	0.81 ± 0.01 ^a	nd	5.60 ± 0.65 ^{bc}	1.95 ± 0.02 ^a
RCV	5.23 ± 0.50 ^a	7.23 ± 0.80 ^a	2.26 ± 0.25 ^c	3.63 ± 0.07 ^a	5.48 ± 0.80 ^a	0.64 ± 0.02 ^a	0.02 ± 0.01 ^a	3.10 ± 0.50 ^b	2.94 ± 0.42 ^b
WCJ	5.94 ± 0.15 ^a	nd	0.79 ± 0.30 ^a	nd	9.48 ± 0.59 ^a	0.84 ± 0.01 ^a	nd	2.76 ± 0.20 ^a	1.31 ± 0.50 ^a
WCM	6.55 ± 0.20 ^a	nd	1.44 ± 0.70 ^b	nd	11.46 ± 1.09 ^b	1.54 ± 0.20 ^b	0.15 ± 0.01 ^b	6.35 ± 0.30 ^c	3.25 ± 0.08 ^b
WCW	6.84 ± 0.50 ^a	nd	1.64 ± 1.30 ^b	nd	10.30 ± 2.30 ^b	1.75 ± 0.15 ^b	0.16 ± 0.02 ^b	7.78 ± 0.60 ^c	3.97 ± 0.09 ^b
WCV	4.72 ± 0.60 ^a	nd	2.89 ± 0.50 ^c	nd	6.48 ± 0.90 ^a	1.24 ± 0.25 ^{ab}	0.05 ± 0.01 ^a	4.60 ± 0.40 ^c	2.75 ± 0.10 ^b

nd: not detected

Data expressed as mean ± SE

a,b,c Values with the same lower-case letters in the same column do not differ significantly ($P > 0.05$)

were quantified in samples (Table 2). Figure 3a, b shows a standards chromatogram and a sample chromatogram, respectively.

Gallic acid and rutin were not detected in RCJ while chlorogenic acid, caffeic and coumaric were not detected in WCJ. Chlorogenic acid is known as a significant bioactive component (Ancos et al. 2000). Chlorogenic acid was an effective protector against cardiovascular diseases with inhibition of LDL oxidation (Laranjinha et al. 1994). Ballistreri et al. (2013) stated that a total of seven phenolic compounds were characterised as hydroxycinnamic acid derivatives (neochlorogenic acid, p-coumaroylquinic acid and chlorogenic acid) and anthocyanins (cyanidin 3-glucoside, cyanidin 3-rutinoside, pelargonidin 3-rutinoside and peonidin 3-rutinoside) in *P. avium* L. cultivars.

RCJ and RCM samples had the highest contents of chlorogenic acid, between 24.77 and 37.78 mg/L, respectively. Phenolic compounds vary according to the cherry variety. Chlorogenic acid and caffeic were not found WCJ and WCV samples. However, gallic acid, syringic and ferulic were significant phenolic compounds in WCJ and WCV samples. Cao et al. (2015) showed that chlorogenic acid was 2.41–7.35 mg/100 g, catechin 1.42–1.61 mg/100 g in four different cherry species from China.

Phenols range from simple, low molecular weight, single aromatic-ring compounds to the large and complex tannins, which are derived polyphenols. They are usually conjugated to sugars and organic acids (Crozier et al. 2009). Gallic acid is the most common phenolic acid, and occurs widely as complex sugar esters in gallotannins such as 2-O-digalloyltetra-O-galloyl-glucose (Tanaka et al. 2005). However, the amount of gallic acid in RCW and WCW had increased due to conversion of sugar to alcohol during the ethanol fermentation. Phenolic substances are found to sugar and organic acid. These substances were released by the alcohol fermentation (Crozier et al. 2009). Vinegar samples were detected significant amounts of gallic acid.

Contents of gallic acid, chlorogenic acid, caffeic, syringic, epicatechin and ferulic of RCV decreased in wine samples ($P < 0.05$). Some phenolic substances may have been lost during resettling and racking during vinegar production. Budak and Güzel-Seydim (2010) stated that the content of epicatechin decreased in grape wine vinegar samples. Chlorogenic acid was found between 0.13 mg/100 g and 0.65 mg/100 g, coumaric acid ranged between 1.00 mg/100 g and 6.84 mg/100 g in cherry samples (Kim et al. 2005).

Tomas-Barberan and Espin (2001) stated that phenolic compounds contribute to the fruit quality and nutritional value in terms of modifying color, taste, aroma, and flavor and also in providing health benefits.

Fig. 3 **a** A chromatogram of standard and **b** a sample chromatogram

Conclusion

Cherries had different antioxidant properties and different profiles of phenolic substances. Cherries must be converted into new products because of a short shelf life. Cherry vinegar produced from *P. avium* L. black gold was a nice alternative to a new product. When compared to *P. avium* L. stark gold. Antioxidant

activity of wine samples was higher than vinegar samples. RCV had different phenolic compounds. RCJ, RCW and RCV samples showed the presence of chlorogenic acid while WCJ, WCW and WCV did not show the same.

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