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Phenolic compounds and antioxidative properties of selected wines from the northeast of Thailand

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Abstract

The phenolic contents and antioxidative properties of selected wines, produced in the northeast of Thailand, were evaluated and compared, particularly those produced at Suranaree University of Technology (SUT) Farm as a case study. Nine wine varieties were used to evaluate their total phenolic content (TPC) by Folin–Ciocalteu method, free radical scavenging efficacy by DPPH method and reducing power by ferric reducing-antioxidant power (FRAP) method. The red wines had significantly higher ($p < 0.05$) amounts of total phenols, flavonoids and antioxidant activities (AA) compared to white wines. Capillary electrophoresis (CE) was used as a powerful and high performing tool for analysis of principal phenolic compounds in the wines. *t*-Resveratrol was found in Shiraz, Zinfandel and blended wine varieties. (+)-Catechin was found in all wine varieties, except in Chasselar Dore. (+)-Catechin was present in wines at a higher level than (−)-epicatechin. In red wine, gallic acid was the dominant phenolic acid found.

Keywords: Wines; Antioxidant property; Capillary electrophoresis; Thailand

1. Introduction

The phenolic antioxidants in red wines have been proposed as an explanation for the lower death rate from coronary heart disease in France referred to as "The French Paradox" (despite high fat intake, mortality from coronary heart disease is lower in some regions of France than in the other developed countries due to regular wine consumption) (Kannel & Ellison, 1996; Renaud & de Lorgeril, 1992; Wollin & Jones, 2001). Phenolic compounds in wine play an antioxidant role in both biological and food systems. They have many favourable effects on human health, such as inhibition of oxidation of low-density lipoprotein cholesterol, and inhibition of platelet aggregation (Frankel, Waterhouse, & Kinsella, 1993; van de Wiel, van Golde, & Hart, 2001), thereby decreasing heart disease risks. Phenolic compounds can be classified into two groups: the flavonoids and non-flavonoids. The major flavonoids in wine include conjugates of the flavonols: quercetin and myricetin; the flavan-3-ols, (+)-catechin and (−)-epicatechin; and anthocyanins. The non-flavonoids include the hydroxybenzoates: *p*-hydroxybenzoic acid and gallic acid; the hydroxycinnamates: caffeic, caftaric, and *p*-coumaric acids; and the stilbenes: *trans (t)*-resveratrol, *cis (c)*-resveratrol, and *t*-resveratrol glucoside.

The antioxidant activities of these phenolic compounds in wines as well as their individual pure chemicals have been investigated using many procedures such as the stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical method (Sanchez-Moreno, Larrauri, & Saura-Calixto, 1999), and ferric reducing-antioxidant power (FRAP) method (Katalinic, Milos, Modum, Music, & Bodan, 2004).

Capillary electrophoresis (CE) is one of the useful techniques to evaluate phenolic constituents in wines. Its high efficiency and capacity to resolve a complex of natural compounds were the reasons for choosing this technique. The successful application of CE for wine and polyphenol

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determination has been demonstrated (Frankel, Waterhouse, & Teissedre, 1995; Gu, Chu, O'Dwyer, & Zeece, 2000; Minussi et al., 2003; Sadecka & Polonsky, 2000).

The amounts of active polyphenols in wines are dependent on grape variety, geology, environment and wine processing technique (Frankel et al., 1995). Just more than 10 years ago, wine production in Thailand increased considerably; however, there is little knowledge of phenolic contents and antioxidative properties of wines produced in different regions of Thailand. Therefore, the purposes of this study were to evaluate the contents and antioxidant qualities of phenolic compounds in some selected wines produced from grapes grown in the northeast region of Thailand particularly those from Suranaree University of Technology (SUT) Farm and to obtain the phenolic profiles of such wines.

2. Materials and methods

2.1. Chemical

1,1-Diphenyl-2-picrylhydrazyl (DPPH) was obtained from Sigma Chemical Co. (St. Louis, MO, USA). Tripyridyl-s-triazine was obtained from Acros Organics (Morris Plain, NJ, USA). The polyphenol standards commonly found in wines were used for CE determination: resveratrol, (+)-catechin, (−)-epicatechin, rutin, syringic acid, *p*-coumaric acid, caffeic acid, gallic acid, protocatechuic acid (Sigma Chemical Co., St Louise, MO, USA), cinnamic acid, *p*-hydroxybenzoic acid, quercetin, gentisic acid (Acros Organics, Morris Plain, NJ, USA) and salicylic acid (Asia Pacific Specialty Chemicals Ltd., Seven Hills, Australia). All other chemicals and solvents were reagent grade and purchased from Sigma and Fisher Scientific, Inc. (Pittsburgh, PA, USA).

2.2. Sample collection

Five red wines: Shiraz, Muscat Hamburg (China), Zinfandel, Barbera (vintage year 2003 and 2004), and Muscat Hamburg (vintage year 2004); three white wines: Italia, Chasselar Dore (year 2003), and Chenin Blanc (year 2004) obtained from SUT farm; and a commercial blended wine (red wine; Dong Pa Ya Yen) purchased from a local food store in Nakhon Ratchasima Province, were used for this experiment.

2.3. Determination of phenolic compounds

2.3.1. Total phenolic content

The total phenolic contents (TPC) were determined by Folin–Ciocalteu method (Matthaus, 2002). Sample solution of 0.1 ml was introduced into a test tube and then 2 ml of 2% of sodium carbonate were added. After incubation for 2 min, 0.1 ml of Folin–Ciocalteu's reagent (Folin–Ciocalteu:methanol, 1:1, v/v) was added. The absorbance was measured at 750 nm after incubation for 30 min. Gallic acid was used as chemical standard for calibration. The TPC content of the sample was expressed as mg of gallic acid equivalents per litre of sample (mgGAE/l).

2.3.2. Flavonoid content

The possible use of formaldehyde to precipitate the flavonoid phenolic compounds has been proposed for wine (Ough & Amerine, 1988). To 10 ml of wine sample, 5 ml of HCl:H_2O (1:4, v/v) solution and 5 ml of 37% formaldehyde were added, left for 24 h and filtered through 0.45 μm polyethersulphon membrane (Supor@Acrodisc®, Pall Life Sciences, Gelman Sciences Inc, Ann Arbor, MI, USA). The amount of flavonoid was calculated as the differences between total phenols and non-flavonoids in wine. The flavonoid content was expressed in mgGAE/l.

2.4. Determination of antioxidant activity

2.4.1. Free radical scavenging activity

The DPPH method (Sanchez-Moreno et al., 1999) was used to determine free radical scavenging property. For each solution, different concentrations were tested using gallic acid as a standard for calibration, and expressed as mg gallic acid equivalents per litre of sample (mgGAE/l). Sample solution of 0.1 ml was added to 3.9 ml of a 2.5×10^{-2} g/l methanolic DPPH solution. The tube was kept for 45 min in the dark, then the absorbance was measured at 515 nm. Antioxidant activity of the sample was defined as the amount of antioxidant necessary to reduce the initial DPPH concentration by 50% (Efficient concentration = EC50 mgGAE/l).

2.4.2. Ferric reducing-antioxidant power (FRAP)

Measurement of reducing ability of the antioxidative property was performed using the FRAP method (Katalinic et al., 2004). The working FRAP reagent was prepared by mixing 10 volumes of 1.0 mol/l acetate buffer, pH 3.6 with 1 volume of 10 mmol/l TPTZ (2,4,6-tripyridyl-s-triazine) in 40 mmol/l hydrochloric acid and with 1 volume of 20 mmol/l ferric chloride.

In a reaction tube, sample solution of 50 μl and 150 μl of deionized water were added into 1.5 ml of the FRAP reagent. Absorbance was measured after 8 min. A standard curve was prepared using different concentrations (100–1000 μmol/l) of $FeSO_4 \cdot 7H_2O$. The antioxidant efficiency of the sample solution was calculated with reference to the standard curve given by a Fe^{2+} solution of known concentration. Ferric reducing power of the sample was expressed in mmol Fe^{2+}/l.

2.5. Analysis of phenolic component

2.5.1. Sample preparation

For liquid/liquid extraction, 1 ml of wine was extracted twice with 1 ml of diethyl ether. The organic phase was completely dried under nitrogen gas and re-suspended with 1 ml of ethanol (50%). Wine sample was filtered through 0.45 μm polyethersulphon membrane.

2.5.2. Capillary electrophoresis procedure

Capillary electrophoresis analyses were performed using an Agilent Technologies (Santa Clara, CA, USA) model

G1600AX, equipped with a diode-array detector. An extended light path capillary tube of 50 μm i.d. (Agilent) with effective and total lengths of 56 and 64.5 cm, respectively, was used. Electrophoretic analyses were performed at an applied voltage of 15 kV at 25 °C.

The sample was hydrodynamically injected at 5.10^3 Pa pressure for 7 s. Between analysis, the column was flushed with 0.1 M sodium hydroxide for 1 min (1.75 μl), deionized water for 2 min (3.5 μl) and electrophoretic buffer for 3 min (5.25 μl). Electrophoretic buffer was a mixture of phosphate 25 mmol/l and borate 10 mmol/l, pH 8.5. Detectable wavelengths were from 190 to 400 nm. The wavelength for *t*-resveratrol was at the maximum wavelength of 206 nm. The wavelengths for other phenolic compounds were taken from the work of Minussi et al. (2003). All CE analyses were performed in duplicate. Before being used, all solutions were filtered through a 0.45 μm polyethersulphon membrane.

2.6. Statistical analysis

Two replicates of each wine variety were experimented. Each replicate was chemically analyzed in duplicate samples. Statistical analysis was evaluated in a completely randomized design (CRD) with Statistical Analysis System (1993) and means comparison by Duncan's Multiple Range Tests (DMRT) were analyzed. A $p < 0.05$ was considered statistically significant.

3. Results and discussion

3.1. Total phenolic content and antioxidant activity of wines

The TPC contents of red and white wines ranged from 1498 to 2432 mgGAE/l and 306 to 846 mgGAE/l, respectively (Table 1). The contents of phenolic compounds were similar to those presented by Waterhouse and Teissedre (1997) who reported the variability in the levels of total phenolic content (TPC) ranging from 1850 to 2200 mg/l for red and 220 to 250 mg/l for white wines and mentioned that grape skins and seeds had long contact time during fermentation process for red wines giving high amounts of these compounds. Different vintage years gave differences in phenolic composition. The average TPC of Shiraz and Zinfandel wine produced in vintage year 2004 were significantly higher than those wine varieties produced in year 2003. However, Muscat Hamburg (China) red wine in vintage year 2003 contained TPC twice as much of the one produced in year 2004. These were in agreement with Waterhouse and Teissedre (1997) that TPC and individual compounds varied depending on vintage year. The red wines had significantly higher amounts of total phenols and flavonoids compared to white wines, except in Italia white wine variety. The amounts of flavonoids ranged between 74.27% and 91.74% of TPC for red wines and 29.35% and 67.46% for white wines, while the non-flavonoid phenols in wines ranged between 195 and 576 mgGAE/l for red wines and 159 and 275 mgGAE/l for white wines. There was no significant difference of non-flavonoids between red and white wines.

The free radical scavenging activities, EC50s, determined by DPPH method of red and white wines were not significantly different, ranging from 3.1 to 6.8 mgGAE/l except in wine produced from Chasselar Dore with the EC50 of 13.8 mgGAE/l. Moreover, red wines also had higher ferric reducing-antioxidant power (FRAP) than white wines. Chasselar Dore variety had significantly lowest antioxidant property (highest EC50 and lowest FRAP value) because of its low TPC and flavonoid content.

Table 1
Total phenolic content and antioxidant activity of selected SUT wine

Wine variety[A]	TPC (mgGAE/l)	Flavonoid (mgGAE/l)	Non-flavonoid (mgGAE/l)	DPPH (EC50) (mgGAE/l)	FRAP (mmol Fe^{2+}/l)
Red wine					
Shiraz (03)	$1687.5 \pm 109.6^{b,c}$	$1253.3 \pm 9.2^{c,d}$	$434.2 \pm 9.2^{a,b}$	$4.6 \pm 0.1^{b,c,d}$	$10.5 \pm 2.5^{c,d}$
Shiraz_K1V (04)	2843.6 ± 235.9^{a}	$2268.0 \pm 105.7^{a,b}$	575.6 ± 341.6^{a}	2.7 ± 0.5^{d}	$19.5 \pm 0.2^{a,b}$
Shiraz_EC1 (04)	2938.2 ± 57.9^{a}	2647.1 ± 40.7^{a}	$291.1 \pm 17.2^{b,c}$	$4.1 \pm 0.8^{b,c,d}$	$19.3 \pm 3.0^{a,b}$
Muscat (China) (03)	$2365.9 \pm 19.6^{a,b}$	$2170.6 \pm 3.7^{a,b}$	$195.3 \pm 3.7^{b,c}$	3.1 ± 0.0^{d}	$17.1 \pm 0.7^{a,b,c}$
Muscat (China) (04)	$1458.4 \pm 382.1^{c,d}$	$1190.2 \pm 280.7^{c,d}$	$268.1 \pm 101.4^{b,c}$	$3.6 \pm 0.0^{b,c,d}$	$10.6 \pm 2.9^{c,d}$
Muscat (04)	$2184.4 \pm 12.9^{a,b,c}$	$1901.0 \pm 4.0^{a,b,c}$	$283.4 \pm 8.9^{b,c}$	$3.8 \pm 0.3^{b,c,d}$	$15.6 \pm 1.5^{a,b,c}$
Zinfandel (03)	$1856.3 \pm 133.4^{b,c}$	$1516.4 \pm 41.2^{b,c}$	$339.9 \pm 41.2^{b,c}$	$3.8 \pm 0.1^{b,c,d}$	$12.8 \pm 0.1^{b,c,d}$
Zinfandel (04)	2750.9 ± 623.6^{a}	2449.3 ± 619.4^{a}	$301.6 \pm 4.2^{b,c}$	$3.3 \pm 1.5^{c,d}$	20.6 ± 7.2^{a}
Barbera (03)	$2431.5 \pm 398.1^{a,b}$	$2077.4 \pm 15.8^{a,b}$	$354.1 \pm 15.8^{a,b,c}$	$6.1 \pm 0.0^{b,c,d}$	$16.4 \pm 3.8^{a,b,c}$
Barbera (04)	$2479.7 \pm 1029.2^{a,b}$	$2117.4 \pm 999.9^{a,b}$	$362.3 \pm 29.3^{a,b,c}$	$4.8 \pm 0.3^{b,c,d}$	$15.9 \pm 6.2^{a,b,c}$
Blended (02)	$1498.1 \pm 84.9^{c,d}$	$1184.0 \pm 7.4^{c,d}$	$314.1 \pm 7.4^{b,c}$	$6.7 \pm 0.7^{b,c}$	$10.8 \pm 0.0^{c,d}$
White wine					
Italia (03)	$845.7 \pm 9.5^{d,e}$	$570.5 \pm 35.4^{d,e}$	$275.2 \pm 35.4^{b,c}$	$5.7 \pm 0.1^{b,c,d}$	$6.4 \pm 0.1^{d,e}$
Chasselar Dore (03)	306.0 ± 22.6^{e}	89.8 ± 26.4^{e}	$216.2 \pm 26.4^{b,c}$	13.8 ± 3.0^{a}	1.9 ± 0.0^{e}
Chenin Blanc (04)	311.2 ± 9.7^{e}	151.6 ± 58.7^{e}	159.6 ± 68.4^{c}	6.8 ± 3.8^{b}	2.2 ± 0.6^{e}

Each value is the mean ± standard deviation, $n = 4$.
SUT, Suranaree University of Technology.
Numbers with different letters within the same column are significantly different ($P \leqslant 0.05$).
[A] Muscat, Muscat Hamberg, (02), (03) and (04) mean vintage year 2002, 2003, and 2004, respectively, K1V = K1V1116 yeast strain, EC1 = EC1118 yeast strain.

Table 2
Calibration and recovery data of 14 standard phenolic compounds by capillary electrophoresis

Peak no./compound	Regression equation[a]	Abs	Correlation coefficient	Recovery (%)[b]	Extraction recovery (%)[c]
1. *trans*-Resveratrol	$y = 5.31018x - 1.26761$	206	0.99679	102.27	90.81
2. (−)-Epicatechin	$y = 13.75689x - 7.01988$	206	0.99236	67.4	76.33
3. (+)-Catechin	$y = 18.1251x - 8.90925$	206	0.99536	76.96	104.81
4. Rutin	$y = 4.2446x - 1.7062$	206	0.99677	79.13	52.45
5. Syringic	$y = 6.59337x - 3.6545$	206	0.98815	74.03	92.49
6. Cinnamic	$y = 9.05151x - 0.0192$	217	0.99916	85.53	98.46
7. *p*-Coumaric	$y = 7.33965x - 2.17302$	206	0.99751	88.74	95.81
8. Gentisic	$y = 14.02428x - 3.15387$	206	0.99041	99.34	113.52
9. *p*-Hydroxybenzoic acid	$y = 12.68154x + 1.09211$	206	0.9984	96.86	93.72
10. Quercetin	$y = 8.80158x - 1.35929$	206	0.99934	99.41	109.21
11. Salicylic acid	$y = 22.40915x - 5.99405$	206	0.95843	85.57	83.37
12. Caffeic acid	$y = 12.66657x - 4.3738$	217	0.998	88.1	102.78
13. Gallic acid	$y = 17.80169x - 8.85641$	217	0.99568	85.09	96.53
14. Protocatechuic acid	$y = 45.78436x - 13.50042$	206	0.9982	82.62	91.17

[a] x is concentration in mg/l and y is peak area.
[b] Recovery due to the performance of capillary electrophoresis instrument, $n = 7$.
[c] Recovery due to extraction process, $n = 7$.

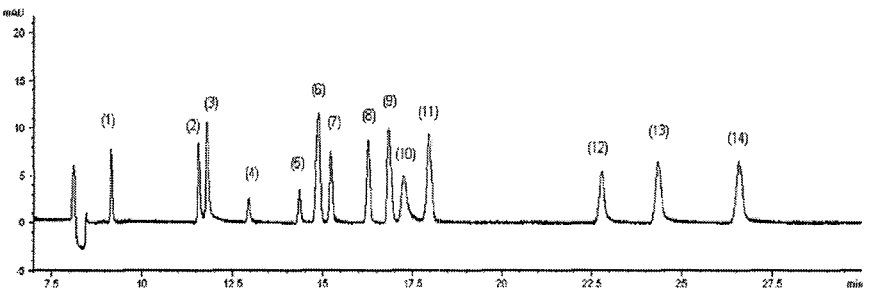

Fig. 1. Electropherogram of 14 standard phenolic compounds. Detectable wavelengths were from 190 to 400 nm; identification of peak numbers as in Table 2.

Table 3
The bioactive phenolic component (mg/l) of the selected SUT wines

Wine variety[A]	Phenolic composition of wine (mg/l)				
	Resveratrol	Epicatechin	Catechin	Rutin	Quercetin
Red wine					
Shiraz (03)	2.76 ± 0.84^{a}	$2.32 \pm 0.16^{a,b}$	$3.56 \pm 0.04^{c,d}$	5.33 ± 0.27^{a}	ND
Shiraz_K1V (04)	1.31 ± 0.75^{b}	$4.09 \pm 3.18^{a,b}$	$6.20 \pm 4.94^{a,b,c,d}$	ND	$2.42 \pm 0.62^{a,b}$
Shiraz_EC1 (04)	1.53 ± 0.50^{b}	$4.14 \pm 1.71^{a,b}$	$9.29 \pm 1.33^{a,b,c,d}$	ND	3.74 ± 2.47^{a}
Muscat (China) (03)	ND	$3.93 \pm 0.13^{a,b}$	$13.17 \pm 0.09^{a,b}$	2.50 ± 0.05^{c}	ND
Muscat (China) (04)	ND	$1.44 \pm 0.26^{a,b}$	$3.59 \pm 1.33^{c,d}$	ND	$1.69 \pm 0.49^{b,c,d}$
Muscat (04)	ND	$3.11 \pm 1.14^{a,b}$	$9.97 \pm 4.79^{a,b,c}$	ND	$2.28 \pm 0.81^{a,b,c}$
Zinfandel (03)	ND	$3.56 \pm 0.16^{a,b}$	$4.15 \pm 0.25^{b,c,d}$	ND	ND
Zinfandel (04)	1.38 ± 1.02^{b}	6.84 ± 5.50^{a}	14.46 ± 11.60^{a}	ND	$2.07 \pm 0.90^{a,b,c}$
Barbera (03)	ND	ND	$0.72 \pm 0.10^{c,d}$	ND	$0.52 \pm 0.08^{c,d}$
Barbera (04)	ND	$3.59 \pm 2.79^{a,b}$	$6.15 \pm 4.91^{a,b,c,d}$	ND	$1.28 \pm 0.28^{b,c,d}$
Blended (02)	1.21 ± 0.03^{b}	$2.69 \pm 0.27^{a,b}$	$6.26 \pm 0.46^{a,b,c,d}$	ND	ND
White wine					
Italia (03)	ND	ND	$0.92 \pm 0.03^{c,d}$	3.46 ± 0.36^{b}	ND
Chasselar Dore (03)	ND	ND	ND	ND	ND
Chenin Blanc (04)	ND	ND	$1.70 \pm 0.11^{c,d}$	ND	$2.12 \pm 0.10^{a,b,c}$

Each value is the mean ± standard deviation, $n = 4$.
SUT, Suranaree University of Technology.
Numbers with different letters within the same column are statistically different ($P \leqslant 0.05$).
[A] Muscat, Muscat Hamberg, (02), (03) and (04) mean vintage year 2002, 2003, and 2004, respectively, K1V = K1V1116 yeast strain, EC1 = EC1118 yeast strain.

3.2. Phenolic component of selected wines

Fourteen pure chemicals of individual phenolic compounds were used as references to determine their presence in selected wines from SUT Farm and that available locally. The calibration and recovery data of 14 phenolic compounds used for capillary electrophoresis (CE) analysis are presented in Table 2 and electropherogram is shown in Fig. 1. Except for rutin and (−)-epicatechin, extraction recoveries were higher than 80%.

t-Resveratrol was found only in Shiraz, Zinfandel and blended wine ranging from 1.21 to 2.76 mg/l (Table 3). These results were similar to those of Gu, Creasey, Kester, and Zeece (1999) who reported low concentrations of *t*-resveratrol of 6.78 and 3.26 μM in Shiraz wine from Australia and Zinfandel wine from California, respectively. In our studies, Shiraz wine produced from vintage year 2003 had significantly higher amount of resveratrol than those produced from year 2004. However, resveratrol contents in Shiraz wines of the same vintage (2004) were not affected by yeast strains, K1V1116 and EC1118. There was no resveratrol present in Muscat and Barbara wines. Resveratrol is a phytoalexin produced by higher plants upon environmental stress such as fungal infection, injury or UV light exposure. Therefore, it is mostly located in the berry skin. Fremont (2000) reported the large variations in ranges of resveratrol concentrations of red wine originating from various countries. The concentration was dependent on grape variety, environmental conditions during cultivation, wine processing techniques and alcohol contents. Soleas, Diamandis, and Goldberg (1997) reported that grape varieties, which have a thin skin renders them sensitive to traumatic damage, Botrytis infection and UV light; for example Pinot Noir produced high resveratrol content. Thick skin berries such as those from Cabernet Sauvignon could generate low amounts of this compound. In addition, it was detected in low amounts in California wine in the range of 0.4–2 mg/l (Chu, O'Dwyer, & Zeece, 1998), 0.99–1.9 μM (Gu et al., 1999), 0.53–2.78 ppm (McMurtrey, 1997) and lower than 0.09 mg/l (Lamuela-Raventos & Waterhouse, 1999). Soleas et al. (1997) also reported that the concentration of resveratrol was climate dependent. In warm and dry climates where fungal attack is low, resveratrol production is also low. The resveratrol content of SUT wines produced from grapes grown in warm and dry climates, was also detected in low concentration. Wine processing conditions have much influence on the amount of resveratrol. Higher resveratrol contents are usually present in red wines in which there has been prolonged contact between the must and skins, whereas lower contents or amounts below the limit of detection are usually present in white wines, which are not macerated with skins and seeds (Soleas et al., 1997). In addition, Seraini, Maiani, and Ferro-Luzzi (1998) noted that alcohol was a natural stabilizing agent for polyphenolic compounds. Resveratrol, is an amphipatic molecule and requires sufficient of alcohol content to dissolve.

Table 4
Phenolic acids concentration (mg/l) of selected SUT wines

Wine variety[A]	Phenolic composition of wine (mg/l)								
	Syringic	Cinnamic	*p*-Coumaric	Gentisic	*p*-Hydroxy benzoic	Salicylic	Caffeic	Gallic	Proto catechuic
Red wine									
Shiraz (03)	7.32 ± 0.03^{a}	3.71 ± 0.04^{a}	18.33 ± 0.27^{b}	0.96 ± 0.85^{a}	$1.82 \pm 0.95^{a,b}$	0.62 ± 0.13^{b}	8.45 ± 0.37^{c}	$15.38 \pm 1.31^{c,d}$	$0.89 \pm 0.21^{c,d,e}$
Shiraz_K1V (04)	$6.58 \pm 0.69^{a,b}$	ND	25.90 ± 0.51^{a}	ND	$1.12 \pm 0.15^{a,b,c}$	ND	9.83 ± 1.28^{b}	$14.44 \pm 0.49^{c,d,e}$	2.04 ± 0.22^{b}
Shiraz_EC1 (04)	7.84 ± 4.76^{a}	ND	14.10 ± 5.06^{c}	ND	1.99 ± 1.10^{a}	1.30 ± 0.88^{a}	13.74 ± 0.43^{a}	20.99 ± 2.94^{b}	3.13 ± 1.34^{a}
Muscat (China) (03)	$4.97 \pm 0.05^{a,b,c}$	2.16 ± 0.50^{b}	$1.72 \pm 0.56^{d,e}$	0.72 ± 0.11^{a}	$1.39 \pm 0.05^{a,b,c}$	ND	5.73 ± 0.32^{d}	$15.11 \pm 0.28^{c,d}$	$0.54 \pm 0.05^{d,e}$
Muscat (China) (04)	$2.52 \pm 2.09^{c,d}$	ND	$3.10 \pm 2.20^{d,e}$	ND	$0.77 \pm 0.11^{c,d}$	ND	13.28 ± 0.60^{a}	10.56 ± 1.73^{e}	$1.71 \pm 0.80^{b,c}$
Muscat (04)	ND	ND	ND	ND	$0.85 \pm 0.08^{b,c,d}$	ND	2.16 ± 0.01^{f}	10.30 ± 0.15^{e}	2.10 ± 0.02^{b}
Zinfandel (03)	$5.35 \pm 1.04^{a,b,c}$	1.36 ± 0.29^{c}	$3.19 \pm 0.28^{d,e}$	ND	$0.84 \pm 0.01^{b,c,d}$	0.63 ± 0.12^{b}	8.18 ± 0.85^{c}	$13.93 \pm 1.03^{c,d,e}$	$0.58 \pm 0.08^{d,e}$
Zinfandel (04)	$5.17 \pm 1.68^{a,b,c}$	ND	4.76 ± 1.16^{d}	ND	$1.18 \pm 0.27^{a,b,c}$	$0.85 \pm 0.09^{a,b}$	2.78 ± 0.13^{f}	$17.48 \pm 0.56^{b,c}$	$1.54 \pm 0.26^{b,c,d}$
Barbera (03)	$6.05 \pm 0.06^{a,b,c}$	ND	$0.91 \pm 0.03^{d,e}$	ND	ND	$0.57 \pm 0.10^{b,c}$	$1.58 \pm 0.33^{f,g}$	25.69 ± 5.01^{a}	$0.81 \pm 0.16^{c,d,e}$
Barbera (04)	$5.50 \pm 2.10^{a,b,c}$	ND	4.57 ± 0.13^{d}	ND	$1.28 \pm 0.32^{a,b,c}$	$0.76 \pm 0.01^{a,b}$	2.45 ± 0.01^{f}	20.92 ± 1.19^{b}	2.17 ± 0.11^{b}
Blended (02)	$5.47 \pm 0.14^{a,b,c}$	0.89 ± 0.20^{d}	$3.20 \pm 1.92^{d,e}$	0.60 ± 0.16^{a}	$0.51 \pm 0.02^{c,d}$	ND	ND	$11.91 \pm 1.46^{d,e}$	$0.57 \pm 0.04^{d,e}$
White wine									
Italia (03)	$6.09 \pm 1.32^{a,b,c}$	0.49 ± 0.04^{e}	ND	ND	ND	0.60 ± 0.01^{b}	ND	ND	ND
Chasselar Dore (03)	$4.27 \pm 0.48^{a,b,c}$	1.54 ± 0.27^{c}	$1.15 \pm 0.37^{d,e}$	ND	$0.75 \pm 0.12^{c,d}$	$0.50 \pm 0.89^{b,c}$	$0.64 \pm 0.42^{g,h}$	ND	$0.60 \pm 0.05^{d,e}$
Chenin Blanc (04)	$2.64 \pm 0.28^{b,c,d}$	ND	$1.33 \pm 0.40^{d,e}$	ND	$0.73 \pm 0.04^{c,d}$	ND	4.28 ± 1.17^{e}	1.25 ± 0.33^{f}	$0.94 \pm 0.13^{c,d,e}$

Each value is the mean ± standard deviation, $n = 4$.
SUT, Suranaree University of Technology.
Numbers with different letters within the same column are significantly different ($P \leqslant 0.05$).
[A] Muscat, Muscat Hamburg, (02), (03) and (04) mean vintage year 2002, 2003, and 2004, respectively. K1 = K1V1116 yeast, strain, EC = EC1118 yeast strain.

(−)-Epicatechin was found only in red wine and there were no significant difference in its content. The amount of (−)-epicatechin found ranged between none detected to 6.84 mg/l in all red wines which was lower than the (+)-catechin. This was in agreement with Minussi et al. (2003) who found higher amounts of catechin than epicatechin in Italian wines. Quercetin is a free form of flavonol group and rutin is a glucoside of this compound. The amounts of quercetin ranged from 0.52 to 3.74 mg/l. Rutin was found in some wines in low amounts or was not detected. Due to its fairly high polar property, extraction and recovery by extraction solvent (diethyl ether) and buffer used for CE analysis were limited (Table 2). The blended wine from a local food store was predominantly Shiraz with a mixture of other red grape varieties. Therefore, the blended wine and Shiraz wine variety contained similar components and amounts of phenolic compounds. In addition, the white Chasselar Dore wine contained no bioactive phenolic components (Table 3), therefore, it had the lowest antioxidant activity with the highest EC50 of 13.8 mgGAE/l and lowest FRAP value of 1.9 mmol Fe^{2+}/l (Table 1).

Phenolic acids contents were found in all wines at moderate concentrations (Table 4). These compounds have been said to be the principal compounds constituted in all plants (Harborne, 1998). Cinnamic acid plays the key role in the biosynthesis pathway of phenolic compounds as it is converted to *p*-coumaric acid, which is a substrate for the formation of flavonoid and some of non-flavonoid family (Soleas et al., 1997). In red wines, gallic acid was the highest of the polyphenols presented while it was detected in very low amount or not detected in white wines. The presence of high amounts of gallic acid in red wines would be expected, since this phenolic acid is principally formed by hydrolysis of flavonoid gallate esters, which are largely absent in white wine due to lack of skin extraction (Frankel et al., 1995). This finding was in agreement with the work of Minussi et al. (2003) who reported that gallic acid was the highest polyphenol in red wine.

4. Conclusions

Antioxidant activities of red wines were significantly higher ($p < 0.05$) than those of the white ones. There were no significant differences in antioxidant activities of the red wines. Health promoting *t*-resveratrol was found only in Shiraz and Zinfandel wine varieties. *t*-Resveratrol was also found in the commercially blended wine in similar amount to those of Shiraz wine produced in year 2004 and Zinfandel wine produced in the same year. Gallic acid was the main component in red wines, while it was absent in white wines. These investigations provided information on some of the potential health benefits of some selected wines produced in the northeast region of Thailand particularly those from the SUT Farm during the vintage years of 2003 and 2004, that the red wines had a better potential health benefit than white wines.

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