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# Antioxidant Activity, Chromatic Properties and Flavour Quality of Ultrasonic-Aged Tomato Wine

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**Key words:** Aromatic quality, ultrasonic treatment, phenolic content, flavonoid content, fruity flavour

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**Abstract:** Ageing has a major impact on the antioxidant activity, chromatic properties and the aromatic quality of wine and hence its consumer acceptability. However, time and space requirements of conventional wine ageing may be expensive. The antioxidant activity, chromatic properties and aromatic qualities of tomato (*Lycopersicon esculentum* Mill.) wine aged using ultrasonic frequency of 33 kHz were compared with tomato wine aged in bottles for 3 months. The aromatic qualities were determined using Solid Phase Microextraction-Gas-Chromatography-Mass Spectrometer (SPME-GC-MS) and the volatile compounds were identified using the NIST98 Library and quantified with1-propanol as internal standard. The molybdate assay was used to determine the total antioxidant activity and the chromatic properties were measured using an automatic colour difference meter. Higher values ($p<0.05$) of phenolic and flavonoid contents and hence, Total Antioxidant Activity (TAA) was recorded for the ultrasonic treated wine than the wines aged in bottles. In addition, the ultrasonic treatment improved the fruity flavour of the tomato wine and produced aged wine of the lowest browning index. Ultrasonic treatment is useful for the improvement of tomato wine qualities.

## INTRODUCTION

The application of ultrasound in food processing has gained a lot of attention in recent times. Ultrasonic processing is known to be simple, less expensive, reliable, and environmentally friendly (Bhat *et al*., 2011). Ultrasonic processing involves the use of ultrasonic wave of frequency 20 kHz and above. There have been reports of ultrasonic treatment in enzyme and microbial inactivation, meat tenderization and fruit juice processing (Tiwari *et al*., 2009). In addition homogenization of cow's milk (Bosiljkov *et al*., 2011), enhancement of

most bioactive compounds of sonicated kasturi lime (Bhat *et al*., 2011), increased Lightness (L*) and improved anthocyanin content of red grape juice upon sonication (Tiwari *et al*., 2010) were also reported.

Ageing is a very important phase in winemaking because it helps to improve the sensory, chemical and physicochemical properties of wine (Ribéreau-Gayon *et al*., 2009). However, the traditional process of ageing requires time, space and energy which may be expensive. For proper enhancement of its qualities, wine may be kept for not >3 months in containers under specified temperature and humidity conditions. All these involve cost. As a result alternative processes of ageing have been explored and reported. Among these were the use of pulsed electric field (Puértolas *et al*., 2009), irradiation (Chang, 2003), electric field intensity (Zeng *et al*., 2008), andultrasonic wave (Chang and Chen, 2002; Chang, 2004). Chemical polymers may be broken down into numerous mist particles during the ultrasonic process (Petro-Turza, 1987) and this can accelerate the ageing process of wine. The existing information on the application of ultrasound for ageing wine is very limited and in addition there is no report on the application of ultrasound to age tomato wine. This study was therefore carried out to compare the antioxidant, chromatic and aromatic qualities of tomato wine aged with the ultrasonic frequency of 33 kHz and those aged in bottles at 10 and 15°C for 3 months.

## MATERIALS AND METHODS

**Preparation of yeast culture:** This study was carried out by using dry yeast Saccharomyces bayanus, BV 818, purchased from Angel Yeast Company Limited, Hubei Province, China. In accordance with the manufacturer's instructions *S. bayanus*, BV 818 was kept in a refrigerator at 5°C. The yeast culture was prepared in a-250 mL Erlenmeyer flask using YDP (yeast extract-0.5% (w/v), peptone-1.0% (w/v) and glucose-2% (w/v)). The pH of the culture media was adjusted to 5.0 with tartaric acid and then sterilized in an autoclave at 121°C for 20 min. *S. bayanus*, BV 818 weighing 0.03 g was suspended in 100 mL sterilized media to produce yeast concentration of 0.3 g $L^{-1}$. The suspension was heated to 40°C for 20 min to rehydrate the yeast cells (Kraus *et al*., 1981). It was cooled to room temperature (25°C) for adaptation (Jackson, 2008) and then incubated (QYC 211 Incubator Shaker, Shanghai Test Equipment Co. Ltd.) at 30°C for 24 h at a speed of 160 g.

**Tomato wine production:** Tomato (Lycopersicon esculentum Mill.) was purchased from a local market in Zhenjiang, Jiangsu Province, China). The tomato was selected among the lot based on colour and size uniformity. It was washed several times with running tap water to remove dirt, sterilized with 2% potassium metabisulphite (KSM), rinsed several times with distilled water and the water dried with napkin paper. It was then cut into smaller pieces with a sterilized knife and blended with a sterilized Kenwood blender (Philips HR 2006, China). Potassium metabisulphite (0.050 g $L^{-1}$) was added to the must as an antioxidant and antimicrobial agent (Jackson, 2008). Pectic enzyme (0.5 g $L^{-1}$) was added to break down pectin to improve aroma and colour extraction (Brown and Ough, 1982)and also ammonium phosphate (0.5 g $L^{-1}$) was added as a source of ammonia and phosphorus for the growth of *S. bayanus*, BV 818 (Fugelsang and Edwards, 2006). The Total Soluble Solid (TSS) of the milled tomato was measured with the Abbe Refractometer (WAY-2S, China) as described (AOAC, 2000) and the figure obtained was 4.90 ±0.20°Brix. The original tomato must TSS was ameliorated with table sugar to 20.6±0.30°Brix. The pH of the must was determined with a pH-meter (PHS-2C Precision pH/mV meter, China) after standardization with standard buffer solutions of pH 7 and 4 in accordance with AOAC (1984) method. The must pH obtained was 4.11. Into a-5.0 L Erlenmeyer flask was placed 4.5 L (5.30 kg) of tomato must and this was inoculated with 180.0 mL ($1.3\times10^6$ cells $mL^{-1}$) of the 24 h *S. bayanus*, BV 818 inoculum to give inoculum level of 3.8%. Triplicate musts were batch fermented in an incubator at temperature 15±2°C (Jackson, 2008). Fermentation was monitored until the TSS value of the musts stabilized. After fermentation, the pomace was separated from the wine. The wine was then stored at 7°C for two months for particles to settle down.

**Ultrasonic treatment and bottle storage:** The ultrasound (Pulsed Sweeping Frequency Ultrasound Equipment, Wuxi FanBo Biological Engineering Co. Ltd., Wuxi, China) of frequency 33 KHz was used for sonication of the tomato wine. The probe of the ultrasound was immersed in an ultrasonic bath of dimensions 45 cm×36.5 cm×31 cm containing water level of 5 cm. Wine samples of volume 170 mL was put in a robust polythene bag and processed at a constant power of 600 W and varied pulsed duration of 10 sec on and 5 sec off for 30 min. During the ultrasonic processing the sample temperature rose from 10 to 19°C. After sonication pH, TSS, ethanol content, total phenolic and flavonoid contents, TAA, browning index ($A_{420}$), L*, a*, b*, C*, H* and ΔE* and volatile composition of the tomato wine were determined.

**Determination of tomato wine properties:** The pH of the tomato wine was determined according to the method of AOAC (1984), the Total Soluble Solids (TSS) was measured with the Abbe Refractometer (WAY-2S, Germany) equipped with temperature compensation mechanism, ethanol content was determined by the method described by Caputi *et al*. (1968). The browning

index ($A_{420}$) was measured as increased absorbance at 420 nm ($A_{420}$) (Jackson, 2008). An automatic colour difference meter (DC-P3, Beijing, China) with a 2 cm path length was used to determine the colour of the tomato wines. The instrument was calibrated with the black and white reference tiles. Three replicate measurements were made in each case. CIELab values $L^*$, $a^*$ and $b^*$ were measured. The coordinate, $L^*$ indicates lightness (ranging from 0-100) with 0 being black and 100 being white. The coordinates $a^*$ measures red (+) and green (-) and $b^*$ is for yellow (+) and blue (-). The change in lightness, $\Delta L^*$, change in redness/greenness, $\Delta a^*$, change in yellowness/blueness, $\Delta b^*$, were used to calculate the colour difference, $\Delta E^*$ as $\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{½}$. In addition, the results of $a^*$ and $b^*$ were used to calculate the Chroma ($C^*$) and hue angle ($H^*$) values using the equation:

$$C^* = (a^{*2} + b^{*2})^{½} \quad (1)$$

$$H^* = \tan^{-1}(b^*/a^*) \quad (2)$$

**Measurement of total phenolics and total flavonoid:** The total phenolics of the wine samples was assayed using the Folin-Ciocalteu reagent according to the method of Singleton and Rossi (1965). Gallic acid was used as a standard for plotting a calibration curve (20-100 mg $L^{-1}$), and the concentration of total phenolics was expressed in milligram gallic acid equivalent per litre (mg GAE/L). A slightly modified method of Zhishen *et al*. (1999) was used for total flavonoid determination. A 0.5 mL aliquot of wine sample or standard solution of rutin was added to a 10 mL volumetric flask containing 2 mL of distilled water, followed by the addition of 0.15 mL sodium Nitrite ($NaNO_2$) solution (0.5 g $L^{-1}$). After 5 min, 0.15 mL of a 1 g $L^{-1}$ aluminium chloride ($AlCl_3$) solution was added and 6 min later, 2 mL of 1 mol $L^{-1}$ sodium hydroxide (NaOH) solution was added to the mixture. The total volume was made up to 5 mL with distilled water, the solution was mixed and the absorbance was measured at 510 nm against water blank. Rutin was used as the standard for the construction of a calibration curve (50-250 mg $L^{-1}$) and the concentrations were expressed as milligram rutin equivalents per liter (mg RE/L). All samples were analyzed in triplicates.

**Measurement of TAA:** The TAA was determined following the molybdate assay (Prieto *et al*., 1999). An aliquot of diluted wine sample (0.30 mL) was combined in a vial with 3.00 mL of molybdate reagent solution (0.6 mol $L^{-1}$ sulphuric acid, 28 mmol $L^{-1}$ sodium phosphate and 4 mmol $L^{-1}$ ammonium molybdate). The vials were covered and heated in a water bath at 95°C for 90 min. The sample mixture was cooled with tap water to room temperature (25°C) and the absorbance was measured at 695 nm against a blank. Ascorbic acid (diluted in 13% ethanol v/v) was used to prepare a standard curve in the range 20-100 mg $L^{-1}$ and the total Antioxidant Activity was Expressed in terms of milligram per liter ascorbic acid equivalent (AAEmg $L^{-1}$).

**SPME analysis of volatile compounds:** A modified method of Solid Phase Microextraction (SPME) technique described by (Márquez *et al*., 2007) was used for extraction of volatile compounds from tomato wine. The SPME fiber used was a Stable Flex Divinylbenzene/ Carboxen/Polydime- thylsiloxane (DVB/CAR/PDMS) (Supelco, Bellefonte, PA) which is designed for flavor analysis. For each SPME analysis, 5 mL of tomato juice or wine sample was placed in a 15 mL glass vial containing a small stir magnet at 350 rpm. The sample was spiked with 50 µL water solutions of the internal standard, 1-propanol (100 µg $L^{-1}$). One gram of sodium chloride was then added to increase the volatility of the flavour compounds. The vial was sealed with a silicone septum and tightly capped. It was then put into a water-bath maintained at a constant temperature of 40°C. The SPME needle then pierced the septum and the fiber was extended through the needle to place the stationary phase in contact with the headspace of the sample. The fiber was withdrawn into the needle after 30 min. Finally, it was removed from the vial and inserted into the injection port of the gas chromatograph for 3 min. The extracted chemicals were desorbed thermally and transferred directly to the analytical column. The fiber was conditioned for 1 h at 270°C before use.

**GC-MS parameters and analyses:** The SPME fiber was desorbed at 250°C for 3 min in the injection port of an Agilent 6890/5973 GC-MS (Agilent, USA ) with a DB-1701 (cross linked [14%-Cyanopropyl -phenyl)-methylpolysiloxane, Agilent] column (30 m, 0.25 mm i.d., 25 µm film thickness) for 31 min runs. The injection port was operated in splitless mode and the flow rate of ultrahigh-purity helium (99.9995%) as carrier gas was 1 mL $min^{-1}$. The initial oven temperature was 50°C, held for 10 min, ramped at 6°C $min^{-1}$ to 150°C and then at 8°C $min^{-1}$ to 200°C and held for 3 min. The total run time was 35.92 min. The Agilent 5973 quadrupole mass spectrometer was operated in the electron ionization mode at 70 eV, a source temperature of 230°C, quadrupole at 150°C with a continuous scan from m/z 33-330.Data were collected with HP ChemStation software (D.00.00) and searched against the NIST98 libraries. Compounds were preliminarily identified by library search and then the identities of most were confirmed by GC Retention Time (RT), MS ion spectra, authentic compounds or a homologous series and a Retention Index (RI). The RIs from a series of straight-chain alkanes (C5-C19) were

used to calculate RIs for all identified compounds. The qualitative and quantitative identification of the volatile compounds was based on the comparison of retention times and peak surface area read from sample and standard chromatograms. All tests were carried out in triplicates.

**Statistical analysis**: The SPSS was used to analyze the results and the means were separated using the Duncan's Multiple Range Test. Differences were considered significant with the $p \leq 0.05$.

## RESULTS AND DISCUSSION

**pH, Total soluble solids, ethanol content of tomato wine:** After 3 months bottle ageing, the pH of the tomato wines stored at both 10 and 15°C as well as the ultrasonic treated wine were not significantly different from that of the one before ageing (Fig. 1a), though the value recorded by the ultrasonic treated wine was slightly higher.

These results are in agreement with those reported earlier (Chang and Chen, 2002; Tiwari *et al*., 2008; Adenkunte *et al*., 2010; Tiwari *et al*., 2009). The TSS of the ultrasonic treated wine and the one stored at 15°C were similar to the untreated (Fig. 1b). Similar results were reported where sonication did not significantly influence the TSS of orange juice (Tiwari *et al*., 2009) and tomato juice (Adenkunte *et al*., 2010). The ethanol content of the ultrasonic treated and the bottle aged wines were not different ($p>0.05$) even though the untreated one was slightly higher (Fig. 1c). The present results are in consonance with those reported elsewhere (Chang, 2003; Zeng *et al*., 2008).

**Chromatic property of tomato wines:** The colour properties of the aged and un-aged wines are shown in Table 1. The ultrasonic treated wine recorded the lowest ($p<0.05$) $L^*$ value. This agrees with the results reported for sonicated tomato juice (Adekunte *et al*., 2010). Higher $a^*$ value ($p<0.05$) was found for the ultrasonic treated wine and this agrees with the results of a reported study on sonication (Fonteles *et al*., 2012). However, the ultrasonic treated wine gave lowest ($p<0.05$) $b^*$ value (Tiwari *et al*., 2009). In addition, highest $\Delta E^*$, lowest $C^*$, and highest $H^*$ ($p<0.05$) were recorded for the ultrasonic treated wine. The $\Delta E^*$ values of the ultrasonic treated and all bottle aged wines were >3 units which conforms with the results obtained for wines aged for 66 weeks (García-Puente Rivas *et al*., 2006) and this gives an indication that the wines could be differentiated from the untreated wines visually in terms of colour

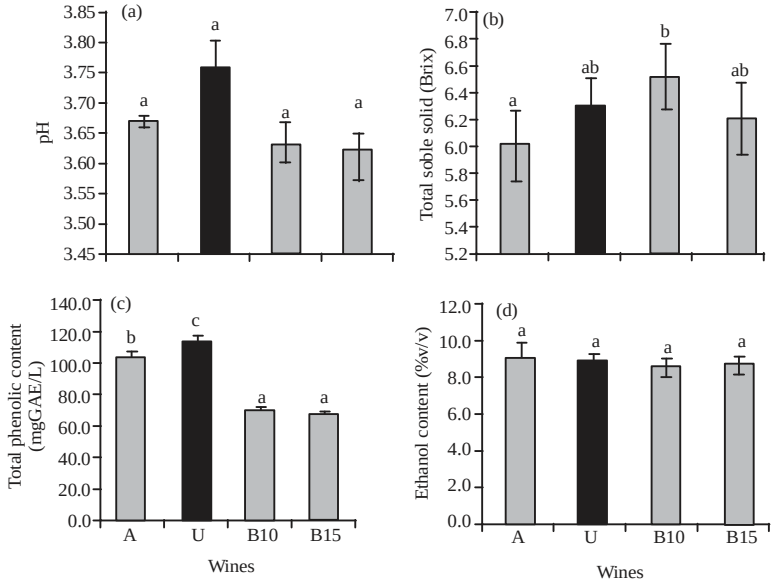


Fig. 1: a) pH; b) TSS; c) Ethanol content and (d) Total phenolic content of tomato wine before and after ageing

Table 1: Chromatic property of tomato wines

| Wines | $L^*$ | $a^*$ | $b^*$ | $\Delta E^*$ | $C^*$ | $H^*$ | $A_{420}$ |
|---|---|---|---|---|---|---|---|
| A | $59.1^{c}\pm3.4$ | $5.2^{c}\pm1.0$ | $14.2^{b}\pm2.1$ | - | $15.3^{b}\pm1.3$ | $70.2^{b}\pm5.6$ | $0.180^{a}\pm0.003$ |
| U | $55.2^{a}\pm5.3$ | $13.1^{d}\pm2.1$ | $-6.5^{a}\pm1.1$ | $22.1^{b}\pm3.1$ | $14.2^{a}\pm1.4$ | $160.1^{d}\pm4.3$ | $0.220^{b}\pm0.005$ |
| B10 | $57.5^{b}\pm4.2$ | $-3.4^{b}\pm0.3$ | $17.2^{c}\pm2.3$ | $10.3^{a}\pm1.2$ | $17.1^{c}\pm2.1$ | $100.3^{c}\pm5.5$ | $0.250^{d}\pm0.006$ |
| B15 | $60.3^{d}\pm3.6$ | $-2.2^{a}\pm0.6$ | $20.1^{d}\pm3.1$ | $9.6^{a}\pm1.0$ | $20.1^{d}\pm1.5$ | $9.5^{a}\pm1.1$ | $0.240^{c}\pm0.003$ |

A is tomato wine before ageing, B and C are tomato wines aged at 10 and 15°C and U is tomato wine treated with ultrasonic frequency 33 Hz for 30 min. *Means±standard deviation were obtained from triplicate measurements. Means with the same alphabets in a row are not significant ($p<0.05$). Values in brackets are standard deviations

Table 2: Volatile compounds concentration (mg/L) of tomato wine aged at 10 and 15°C*

| Compounds | A | U | B10 | B15 | Threshold | Description |
|---|---|---|---|---|---|---|
| **Esters** | | | | | | |
| Ethyl acetate | 14.13$^{a}$±0.03 | 25.91$^{d}$±0.02 | 15.86$^{b}$±0.04 | 16.89$^{c}$±0.06 | 7.5 | Fruity, sweet |
| Ethyl butanoate (Ethyl butyrate) | 2.71$^{a}$±0.02 | 5.39$^{d}$±0.01 | 2.98$^{b}$±0.03 | 3.55$^{c}$±0.04 | 0.02 | Floral, fruity |
| Ethyl hexanoate | 71.54$^{a}$±0.43 | 69.39$^{a}$±0.13 | 81.09$^{b}$±0.27 | 104.34$^{c}$±0.43 | 0.014 | Apple, fruity, sweetish |
| Ethyl heptanoate | 1.08$^{a}$±0.03 | 1.02$^{a}$±0.02 | 1.67$^{b}$±0.03 | 1.87$^{c}$±0.04 | - | Wine-like, fruity |
| Ethyl octanoate | 346.63$^{b}$±1.13 | 152.02$^{a}$±1.17 | 367.90$^{c}$±0.97 | 366.63$^{c}$±1.21 | 0.02 | Sweet, fruity and fresh |
| Ethyl decanoate | 30.44$^{b}$±1.01 | 27.84$^{a}$±1.27 | 100.09$^{d}$±1.04 | 75.39$^{c}$±0.43 | 1.5 | Flowery, fruity |
| Ethyl-9-decenoate | 5.50 $^{b}$±0.06 | 3.63$^{a}$±0.07 | 16.66$^{d}$±0.08 | 12.50$^{c}$±0.05 | - | Fatty, fruity |
| Diethyl succinate | 1.73$^{b}$±0.03 | 1.47$^{a}$±0.01 | 2.82$^{d}$±0.02 | 2.21$^{c}$±0.01 | 0.07 | Light fruity |
| Isoamyl acetate | 17.32$^{b}$±0.02 | 30.37$^{d}$±0.03 | 15.76$^{a}$±0.05 | 18.58$^{c}$±0.02 | 0.03 | Banana, pear |
| Methyl acetate | ND | 0.23±0.01$^{b}$ | 0.11±0.01$^{a}$ | ND | - | Ethereal, estery, fruity |
| Total | 491.08$^{b}$±2.76 | 317.27$^{a}$±2.74 | 604.94$^{d}$±2.54 | 601.96$^{c}$±2.29 | | |
| **Carbonyls** | | | | | | |
| Acetaldehyde | 0.80$^{a}$±0.07 | 0.94$^{b}$±0.02 | 1.45$^{c}$±0.05 | 1.36$^{c}$±0.05 | 100 | sherry, nutty, bruised apple |
| 6-Methyl-5-Hepten-2-one | 3.33$^{c}$±0.07 | 3.23$^{c}$±0.08 | 1.61$^{a}$±0.11 | 2.23$^{b}$±0.05 | - | - |
| 2,3-butanediol | 0.46$^{a}$±0.06 | 1.17$^{b}$±0.04 | ND | 0.52$^{a}$±0.03 | 150 | Floral, waxy, fruity, herbal |
| 2,3-dihydrobenzofuran | 4.23$^{b}$±0.04 | 1.28$^{a}$±0.03 | ND | ND | - | |
| Total | 8.02±0.17 | 5.68±0.15 | 1.61±0.11 | 2.75±0.08 | | |
| **Alcohols** | | | | | | |
| Benzyl alcohol | 0.40 $^{a}$±0.05 | 0.57$^{b}$±0.01 | 0.41$^{a}$±0.05 | 0.33$^{a}$±0.10 | 200 | Citrusy, sweet |
| 3-Methyl-1-butanol (isoamyl alcohol) | 151.35$^{d}$±1.01 | 141.05$^{c}$±1.02 | 88.50$^{a}$±1.02 | 98.81$^{b}$±0.01 | 60.0 | Solvent, sweet, nail polish |
| 2-Methyl-1-propanol (isobutyl alcohol) | ND | 5.56$^{b}$±0.01 | 3.58$^{a}$±0.02 | ND | 0.55 | Malty |
| Total | 151.75$^{d}$±1.06 | 147.18$^{c}$±1.02 | 92.49$^{a}$±1.09 | 99.14$^{b}$±0.11 | | |
| **Fatty Acids** | | | | | | |
| Acetic acid | 2.29$^{a}$±0.24 | 3.06$^{b}$±0.13 | 3.23$^{c}$±0.15 | ND | 200.0 | Acid, fatty |
| Hexanoic acid | 12.40$^{c}$±0.12 | 16.10$^{d}$±0.32 | 10.80$^{b}$±0.43 | 8.70$^{a}$±0.20 | 3.0 | Cheese, rancid, fatty, fruity |
| Octanoic acid | 41.75$^{d}$±0.22 | 33.98$^{b}$±0.43 | 4.44$^{a}$±0.52 | 36.78$^{c}$±0.22 | 10 | Rancid, fatty acid, dairy |
| 3-Methylbutanoic acid | 0.93$^{b}$±0.01 | 1.49$^{c}$±0.02 | ND | 0.66$^{a}$±0.00 | 3.0 | Cheese, rancid |
| Total | 57.37$^{d}$±0.59 | 54.63$^{c}$±0.90 | 18.47$^{a}$±0.14 | 46.14$^{b}$±0.45 | | |
| **Terpene** | | | | | | |
| Linalool | 2.11$^{a}$±0.25 | 2.26$^{a}$±0.16 | 2.39$^{a}$±0.14 | 3.23 $^{b}$±0.45 | 0.025 | |

A is tomato wine before ageing, B and C are tomato wines aged at 10 and 15°C and U is tomato wine treated with ultrasonic frequency 33 Hz for 30 min. *Means±standard deviation were obtained from triplicate measurements. Means with the same alphabets in a row are not significant ($p<0.05$). Values in brackets are standard deviations. ND-not detected, Dash-no data/information

(Martínez *et al*., 2002). Similar results where high hydrostatic pressure processing lowered the $C^*$ value of a red wine was found(Tao *et al*., 2012). Reduction in $C^*$ value after 18 weeks storage of wine was also reported (García-Puente Rivas *et al*., 2005). Oxidative browning influences the colour, flavour and consumer acceptability of wine. The extent of browning of the tomato wines was assessed as increase in $A_{420}$ (Jackson, 2008). The ultrasonic treated tomato wine and those aged in bottles gave higher$A_{420}$ values than the untreated wines (Table 1). Generally the ultrasonic treated wines recorded lower $A_{420}$ values than the samples aged in bottles. In normal ageing, the $A_{420}$ value of wine increases throughout the process (Jackson, 1994). During ultrasonic treatment of samples, cavitation formation removes oxygen and this may account for the reduced browning experienced in ultrasonic treated samples than those aged in bottles (Knorr *et al*., 2004).

**Total phenolic and flavonoid content and Total Antioxidant Activity (TAA) of tomato wine:** The ultrasonic treated wine recorded higher ($p<0.05$) total phenolic and flavonoid contents than the untreated and the bottle aged wines (Fig. 1d and 2a). These results are similar to those reported for pulsed electric field-treated wines (Puértolas *et al*. 2009; Puértolas *et al*., 2010). Reduced phenolic content of wine with ageing was reported earlier (Ivanova et al., 2012). The TAA of the ultrasonic treated wine was also the highest ($p<0.05$) and this may be due to its high total phenolic and flavonoid contents ($p<0.05$). In addition, the attachment of $OH^-$ radical generated by sonication to the para or ortho position of the aromatic ring of phenolic compounds might have increased the TAA of the wines after sonication.

**Flavour qualities of tomato wine:** The flavour qualities of the wines are shown in Table 2. For the esters of known flavour characteristics, the total ester content of the ultrasonic treated wine was lower ($p<0.05$) than the un-aged and the bottle aged wines. However, ethyl acetate, isoamyl acetate, ethyl butanoate and methyl acetate content of the ultrasonic treated wine was higher ($p<0.05$) than the others. Ultrasonic treated rice wine also showed an increase in ethyl acetate content (Chang and Chen, 2002). Ethyl acetate, isoamyl acetate and ethyl

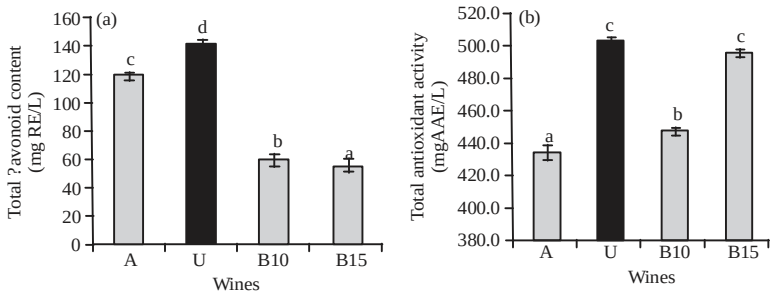


Fig. 2(a-b): a) Total flavonoid content and (b) Total antioxidant activity of tomato wine before and after ageing

butanoate which have pleasant flavour characteristics (Rocha *et al*., 2004) were present in all the wines beyond their flavour threshold (Table 2).

Higher alcohols identified in the study and which are of known flavour characteristics were benzyl alcohol, 3-methyl-1-butanol (isoamyl alcohol) and 2-methyl-1-propanol (isobutyl alcohol). The ultrasonic-treated and the bottle aged wines gave reduced values of higher alcohols ($p<0.01$). This is similar to the results reported for AC electric field treated wines (Zeng *et al*., 2008). The flavour characteristic of isobutyl alcohol is malty and that of benzyl alcohol is citrusy and sweet (Ugliano and Henschke, 2009). The benzyl alcohol in the ultrasonic treated wine though higher ($p<0.05$) than that of the un-aged and the bottle aged wines was below the flavour threshold. Isobutyl alcohol was not detected in the un-aged wine and the wine aged at 15°C but was higher ($p<0.05$) in the ultrasonic treated wine than the wine aged in bottles at 10°C. These values were beyond the flavour threshold of isobutyl alcohol.

The major carbonyls found in the wines were 2, 3-dihydrobenzofuran, 6-methyl-5-hepten-2-one acetaldehyde, and 2, 3-butanediol. 2, 3-dihydrobenzofuran is a bioactive phytochemical which is known to possess antiangiogenic properties (Dharmalingam and Nazni, 2013). The ultrasonic treated wine recorded a reduced content ($p<0.05$) of 2, 3-dihydrobenzofuran but was not detected in the bottle aged wines. Thus only the ultrasonic treated wine may exhibit antiangiogenic properties after ageing. About 6-Methyl-5-Hepten-2-one is one of the main flavour compounds responsible for the tomato flavour (Petro-Turza, 1987). After ultrasonic treatment the value of 6-Methyl-5-Hepten-2-one was not different from that of the un-aged wine but bottle ageing led to its reduction ($p<0.05$). Thus the tomato flavour was detected much more in the ultrasonic treated wine than the bottle aged wines. Acetaldehyde which has the flavour characteristics sherry, nutty, bruised apple (Swiegers and Pretorius, 2005) was present in the wine below its threshold and the value for the ultrasonic treated wine was higher ($p<0.05$) than the untreated but lower than those aged in bottles. All the values, however were below the threshold and thus will not contribute significantly to the flavour of the wines. Higher ($p<0.05$) values of 2, 3-butanediol was recorded for the ultrasonic treated wine than the un-aged and the wine aged at 15°C. Thus with the pleasant flavour characteristics shown by 2, 3 butanediol (Table 2), it will contribute much more to the overall aroma of the ultrasound treated wine than the bottle aged ones. The fatty acids which generally have rancid flavour was reduced ($p<0.05$) after the ultrasonic treatment, though was higher ($p<0.05$) than what was recorded by the bottle aged wines. Thus the ultrasonic treatment significantly reduced the rancid flavour of the wine. The only terpene detected in the wine was linalool. The linalool content of the ultrasonic treated wine, the un-aged wine and the wine aged at 10°C were not different ($p>0.05$).

All the wines recorded linalool contents which were greater than the flavour threshold and therefore with flavour characteristics of linalool as fruity and citric (Bartowsky and Pretorius, 2009), it is expected to contribute pleasant flavours to the overall aroma of the wines.

## CONCLUSION

The ultrasonic treatment enhanced the total phenolic and total flavonoid contents of the wine and hence, the TAA. The fruity characteristics of the wine were improved by the ultrasonic treatment. Finally, the ultrasonic treatment gave the aged wine of the best browning index value. Therefore the ultrasonic treatment has the potential to enhance tomato wine quality.

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