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THE INFLUENCE OF PH ON QUALITY OF TOMATO (*Lycopersicon esculentum* Mill) WINE

John Owusu[1,2], *Haile Ma[1], Zhenbin, Wang[1], Ronghai, He[1]

[1]School of Food and Biological Engineering, Jiangsu University,
301 Xuefu Road, Zhenjiang 212013, China.
[2]Hospitality Department, School of Applied Science and Technology,
Koforidua Polytechnic, P. O. Box 981, Koforidua, Ghana.
*Corresponding author: Email: mhl@ujs.edu.cn,Tel: +86-511-88790958; Fax: +86-511-88780201

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ABSTRACT:

The study was carried out to assess the influence of different pH levels on tomato wine enological parameters. Tomato wine was produced at three different pH levels of 3.20 (Wine B), 3.35 (Wine A) and 4.22 (Control wine). Wine A gave the highest ethanol content, significantly higher Fermentation Efficiency but a significantly lower residual sugar than the other two wines. Wine A recorded a significantly lower pH ($p<0.05$), significantly higher titratable acidity and dry extract than Wine B and the Control wine, after fermentation and ageing. In addition, Wine A exhibited significantly lower browning index but significantly higher clarity and residual sugar content than the other two wines after ageing. Sensory evaluation of the wines showed that no significant difference existed between Wines A and B in terms of taste, aroma and colour likeness, but the panelists rated Wine B significantly higher ($p<0.05$) in overall acceptability.

Keywords: Tomato, pH, fermentation, wines, residual sugar, ageing

[I] INTRODUCTION

Among the many factors which influence the fermentation process and wine quality, pH is critical. This is probably because pH determines the effectiveness of sulphur dioxide (SO_2) as an antimicrobial agent, influences microbial and colour stability, taste and ageing potential [1]. The pH also contributes to wine astringency and affects the growth of desirable lactic acid bacteria [2]. The ability of wine to produce brown compounds increases with increase in pH [3] and also pH influences the breakdown of some fermentation by-products, typically ethyl and acetate esters [1]. Low pH enhances the hydrolysis of disaccharides, and therefore

fermentation [4]. During fermentation the level of pH, yeast strain, temperature and sulphur dioxide can influence the synthesis of glycerol [1]. Low pH increases the formation of volatile acidity by yeast but high pH can worsen the seriousness of stuck fermentation, and high acidity does not appear to enhance fermentation [5]. Under different juice and wine pH conditions, the growth rate of microbial species as well as production of sensorially important metabolites are different [6]. The effect of pH on ethanol production from the siahe sardasht grape [7] , on fermentation rate and duration [8], on fructose residue of wine [9] (Pan et al., 2011), and the effect of pH and SO_2 on yeast growth, fermentation rate and volatile acidity content of wine [10] have been reported. [11]Kunicka-Styczyńska (2009) has reported the influence of pH changes on L-malic acid consumption by yeast.

Acidity is concerned with the two interrelated concepts, pH and titratable acidity. pH is closely related with acidity of wine [1]. Whiles pH is the negative logarithm of the molar concentration of hydrogen ions, acidity is a measure of total acid concentration in food [12] (Sadler and Murphy, 2010).The pH, total acidity and volatile acidity in addition to residual sugar and alcohol contents are specified in any professional wine tasting exercise [13]. This underscores the importance attached to pH and acidity as quality parameters of wine. The acidity of must has an effect on the final acidity of wine. However, there is no clear cut way of predicting the exact wine acidity on the basis of the initial must acidity. This is as a result of acid production and consumption, as well as decreased solubility of acid salts with increasing alcoholic concentration during fermentation [13].

The pH of wine after fermentation may increase as a result of acid precipitation or yeast and bacterial metabolism. This may call for the need to readjust the post-fermentative pH. For a juice/must of pH more than 3.4 adjustments before fermentation is advisable to influence fermentation positively in order to avoid large adjustments after fermentation, which is even not permitted in some countries [1].

During fermentation yeast produces enzymes which bring about various biochemical transformations. These enzymes are protein in nature, and without the requisite pH, temperature and ionic strength may be denatured. Enzymatic activities and metabolism is very sensitive to pH changes [14].

Tomato is the most prominent source of lycopene [15], a carotenoid which is more efficient in quenching singlet oxygen than other carotenoids [16]. Epidemiological studies have established that lycopene has a protective effect against prostate cancer [17]. This makes tomato one of the most important fruit vegetables. The matured tomato fruit harvested green can be stored at 12.8-15.6 ^{o}C for several days without losing its quality significantly. However, when fresh tomato is stored in air at near optimum storage temperature and relative humidity, its shelf life is about 2-4 weeks, based on stage of ripening [18]. Tomato is a perishable commodity, and therefore to keep it stable for a reasonable time, there is need for one form of processing or the other. The well known existing processed forms of tomato are juice, paste, puree, soup, ketchup, sauce, and canned tomatoes [19].

There is the need to broaden the processing avenues to stimulate tomato production, against the backdrop of estimated fruit and vegetable postharvest losses of 20-50% [20]. Therefore in the present study winemaking was explored as a processing method for tomato as a means of adding value and extending its shelf life. Since pH plays a critical role in fermentation and final wine quality, the present study was carried out to assess the effect of pH on tomato wine quality.

[II] MATERIALS AND METHODS

2.1 Preparation of yeast culture

The yeast culture was prepared using YPD (yeast extract – 0.5% (w/v), peptone – 1.0% (w/v), and

glucose – 2% (w/v)). Tartaric acid was then used to adjust the pH of the culture medium to 5.0. The media contained in a-250 Erlenmeyer flask was sterilized in an autoclave at 121 ^{o}C for 20 min. Dry yeast (*Saccharomyces bayanus*, BV 818*)* of mass 0.03 g was then suspended in the 100 ml sterilized medium to produce yeast concentration of 0.3g/L. The suspension was then heated to 40 ^{o}C for 20 min, to activate the yeast cells. It was cooled to room temperature and incubated in an incubator shaker (QYC 211 Incubator Shaker, Shanghai Test Equipment Co. Ltd.) at 30 ^{o}C for 24 h at a speed of 160 rpm.

2.2 Preparation and inoculation of tomato must

The tomato was washed thoroughly with tap water, rinsed in distilled water and then sterilized with 2% potassium metabisulphite (KSM). The sterilized tomato was then rinsed in distilled water again. The tomatoes were cut into smaller pieces and blended using a Kenwood blender (Philips HR 2006, China). Ammonium phosphate and pectic enzyme at the rate of 0.5 g/L were added to the must. The brix of the tomato must was adjusted to 18.3 ^{o}Brix using table sugar of 200 g/L [13] (Ribereau-Gayon et al., 2006b). The pH of the must was determined and found to be 4.22±0.01 (Control). Two other tomato musts were produced by adjusting the original pH to 3.35±0.02 (Wine A) and 3.20±0.01 (Wine B) using tartaric acid [13]. The original titratable acidity (TA) of the tomato must was determined as 2.4±0.1 g/L (citric acid). However, by adjusting the original pH of the must to 3.35 and 3.20, the TA increased to 3.4±0.1 and 3.5±0.1 g/L respectively. The must was heated at 40 ^{o}C in a water bath for 1 h, allowed to cool to room temperature and inoculated with 3.3% (v/v) 24-hour yeast culture (*Saccharomyces bayanus*, BV 818), The must of volume 0.9 L, which weighed 0.974 kg with 5% dry matter content, was fermented in a 1-L Erlenmeyer flask.

2.3 Fermentation of tomato must

The tomato must was incubated at 18±2 ^{o}C for 9 days. During fermentation the weight loss of the fermentors was determined as a measure of the rate of carbon dioxide (CO_2) production [21]. After fermentation the wine was cold stabilized at 5 ^{o}C for 24 h and centrifuged at 5000 rpm for 10 min. It was then filtered and kept at 5 ^{o}C until needed for analysis. The efficiency of fermentation was calculated using the formula by [22] Gupta et al. (1990):

Fermentation efficiency (FE) =

$$\frac{\text{Actual ethanol produced x 100\%}}{\text{Theoretical ethanol from sugar consumed}}$$

Where

theoretical ethanol from sugar consumed = ^{o}Brix x 0.52 [1]

2.4 Enological parameters

The TA of the must/wine was determined by titrating 10 ml of must/wine against 0.1 N sodium hydroxide (NaOH) to a pink end-point using phenolphthalein indicator [12], and the results were expressed in g/L citric acid. The pH of the must/wine was measured after calibration with solutions of pH 7 and 4 respectively according to the [23] AOAC (1984) using a pH meter (PHS-2C Precision pH/mV meter, China). Hence the acid taste index (ATI) was calculated using the formula: ATI = TA (g/L) – pH [24]. The TSS was determined with the Abbe Refractometer with temperature compensation (WAY-2S, Germany) and the values expressed in degree brix (^{o}Brix). Alcoholic strength of the wine was measured using the [25] Caputi *et al.* (1968) spectrophotometric method after distillation of the alcohol, and the results expressed as % v/v. The dinitrosalicyclic (DNS) method [26] was used to determine the residual sugar content of the wine. The spectral analysis method described by [27] Somers and Ziemelis (1985) was used to determine total phenolics, where after filtration

and appropriate dilution, the absorbance was measured at 280 nm (A_{280}) using a spectrophotometer (UNICO 7200 Spectrophotometer, China). Volatile acidity was determined by distilling 10 ml of carbon dioxide-free wine and titrating 80 ml distillate against 0.1 N NaOH until a pink colour persisted for 15 s [28]. Dry extract was determined by [29] AOAC (1995) and the results expressed in g/L. Colour parameters were measured following the method of [30] Glories (1984). Absorbance was measured at 420 nm (A_{420}), 520 nm (A_{520}) and 620 nm (A_{620}) and the values used for calculating colour density, intensity, tint, and % yellow colour, % red colour and % blue colour as follows: Colour density (CD) = A_{420} +A_{520}, Colour intensity (CI) =A_{420}+ A_{520}+A_{620}, Colour tint or hue (CT) = A_{420}/A_{520}, % yellow = 100 x (A_{420}/CI), % red =100 x (A_{520}/CI), % blue =100 x ($_{A620}$/CI). The absorbance at 420 and 660 nm is a measure of browning index [1] and clarity [31] respectively.

2.5 Wine ageing

The wines produced were aged in bottles at 5±2 ^{o}C for 8 months. During this period the following parameters were monitored: pH, TA, TSS, alcoholic strength, residual sugar, volatile acidity, dry extract, acid taste index, colour intensity, tint, density, % yellow, % red, % blue, absorbance at 280 and 420 nm.

2.6 Sensory evaluation

After 8 months ageing, a 10-member semi-trained panel was used to assess the taste, aroma colour, and the overall acceptance of the three wines on a 5-point hedonic scale. On the scale 1-dislike very much, 2-dislike much, 3-neither like nor dislike, 4-like much, 5-like very much. The mean scores of the panelists were subjected to analysis of variance (ANOVA).

2.7 Statistical analysis

A one-way ANOVA was used to analyze the data, and the statistical package used for the analysis was SPSS Statistics 17.0. The Least Significance Difference (LSD) was used to determine the differences between the means.

[III] RESULTS AND DISCUSSION

3.1 Fermentation monitoring

Fermentation monitoring of the fermentors in the course of fermentation is shown in Fig. 1. During fermentation the weight loss of the fermentors was determined as a measure of the rate of carbon dioxide (CO_2) production [21]. The results indicated that the rate of fermentation from the commencement up to the 48th

***Fig. 1:**

hour, from the highest to the lowest, was in the order Control wine (produced from tomato must of pH 4.22), Wine B (produced from tomato must of pH 3.20) and then Wine A (produced from tomato must of pH 3.35). However, at the 72nd hour the trend was reversed, with the Control wine and Wine A registering the lowest and the highest rate respectively. Also at the 72nd hour after commencement of fermentation, the three wines recorded their maximum CO_2 production, with Wine A having the highest and the Control wine the lowest. The maximum CO_2 production figures obtained for the three wines were comparable to those (1.02-2.07 g/L/h) reported for raspberry wine produced at pH 4.0 from TSS 16 ^{o}Brix [32]. The fermentation of the must used for producing Wines A and B came to completion at about the 192nd hour, whiles that of the Control wine was completed in the 216th hour. The results indicated that generally the fermentation duration of the must (of pH 4.22) used to produce the Control wine was slightly longer than those for producing Wines A and B. In tomato juice of pH 4.4 and TSS 24^{o} Brix, fermented at 26 ^{o}C, using 2% (v/v) inoculum size of *Saccharomyces cerevisiae* 3282, fermentation is reported to have lasted for 120 h [33]. A slower rate and longer duration of fermentation has been reported for a defined medium of pH 2.5 compared with media of pH values 3.5, 4.5 and 5.5 [8]. Akubor [34] (1996) has reported fermentation duration of 336 h for African bush mango juice of pH 5.12 using 3% (w/v) inoculum size of *Saccharomyces cerevisiae.* Fermentation efficiency (FE) of the

three wines was calculated using the formula of [22] Gupta et al. (1990) and the results are shown in Table 1. The FE of Wine A was significantly higher than Wine B and the control wine ($p<0.05$). Sugar consumption was more efficient in the must used to produce Wine A than the other two musts during fermentation. Fermentation efficiency of 110% has been reported for African bush mango juice fermented at pH 5.12 and at ambient temperature [34].

3.2 Enological parameters of tomato wines

Table 1 shows the enological parameters before and after ageing. After fermentation, the ethanol content of Wines A and B was not significantly different

***Table 1:**

($p>0.05$), but was significantly higher than that of the Control wine ($p<0.05$). The differences in ethanol content of the wines may be due to the fact that the pH of the musts used to produce Wines A (produced from tomato must of pH 3.35) and B (produced from tomato must of pH 3.20) were more favourable to the growth of yeast and hence encouraged better sugar consumption in Wines A and B than the Control wine. Low pH is known to enhance the hydrolysis of disaccharides, and therefore fermentation [4]. The use of tomato juice at its original pH (4.4) adjusted to 22^o Brix is reported to produce wine of ethanol content 7.88% [33]. Maximum and minimum ethanol production is reported for siahe sardasht grapes produced by using musts of pH 4.5 and 3.5 respectively [7]. The ethanol content of all the three wines reduced significantly after ageing. In addition, Wine A recorded significantly higher ethanol content ($p<0.05$) than Wine B, after ageing, even though the difference before ageing was not significant. Reduction in ethanol content for Amla wine during ageing was reported by [35] Soni et al. (2009). The reduction in ethanol content during ageing might have been caused by oxidation of ethanol to acetaldehyde [1], and that significantly higher ($p<0.05$) oxidation might have occurred in the Control wine than Wine B, which was also higher than Wine A.

The residual sugar of Wine A, after fermentation, was significantly lower than Wine B and the Control wine ($p<0.05$). Also Wine B recorded a significantly lower residual sugar than the Control wine. A must of pH 3.2 is reported to have produced wine of statistically significant fructose residue compared to those produced from must of pH 3.35, 3.5 and 3.65 [9]. The results indicated that sugar consumption by yeast (*Saccharomyces cerevisiae*) was better at pH 3.35 than at 3.20, which was also better than at 4.22. This was confirmed by the highest ethanol production recorded at pH 3.35 than at 3.20, which was also higher than that at 4.22. After ageing the Control wine and Wine B exhibited no significant difference in residual sugar content, but these were significantly lower than that of Wine A. The residual sugar values for all the wines, after fermentation and ageing were higher than 2 g/L reported by Torija et al. [8]. Residual sugar affects the microbial stability of wines [1]. After fermentation, the TSS of Wine B and the Control wine were not significantly different, but Wine A recorded a significantly higher value ($p<0.05$) than the other two wines (Table 1). Wine of TSS 7^o Brix is reported to have been produced from tomato juice of 22^o Brix [33]. Even though Wine A had a significantly higher TSS than the other wines, its reducing residual sugar was significantly lower than the rest. This may be due to more efficient fermentation which occurred in Wine A than the rest.

After fermentation, the respective pH of the Control wine, Wines A, and B were 3.71±0.01, 3.11±0.01, and 3.40±0.00. The pH of Wines A and B were within the favourable pH range for white wines (3.1-3.4), and that of red wines (3.3-3.6) [1,33] Mathapati et al. (2010) have reported the production of tomato wine of pH 3.3 from tomato juice of pH 4.4. The pH values reported for *Syzygium malaccensis* and *Eugenia owariensis* apple wines were 3.68 and 3.79

respectively [36]. The pH range reported for kiwifruit wine samples after fermentation was 3.67-3.49 [37]. The differences in pH, for the three wines were significant ($p<0.05$). After fermentation, the pH of Wine B increased by 6.3%, but Wine A and the Control wine showed a decrease of 12.1 and 7.2% respectively. The striking feature about the pH changes was that whereas the Control wine and Wine A recorded decreases, Wine B registered an increment. Even though the musts of the two wines were adjusted with tartaric acid, it was only Wine B which showed an increment in pH after fermentation. The increase in pH after fermentation, in the case of Wine B, may be as a result of induction of tartrate crystallization and precipitation [1]. Even though the must used to produce Wine A was also adjusted with tartaric acid, the wine's pH did not reduce, probably as a result of greater amount of phenols it contained compared to Wine B (Table 1). Phenols are known to inhibit the precipitation of potassium bitartrate [13]. After ageing, all the three wines recorded pH values which were significantly lower than those before ageing. In addition, after ageing, the pH value of Wine B was significantly lower than the other two wines ($p<0.05$).The results indicated that Wine B would be more microbial and colour stable compared to the others [1].

The TA of Wine A, before ageing, was significantly higher than that of Wine B, which was also significantly higher than that of the Control wine ($p<0.05$). The original TA of the tomato must was 2.4±0.1 g/L, and after pH adjustment gave 3.4±0.1 and 3.5±0.1 g/L for the musts used to produce Wines A and B respectively. Even though after pH adjustment, Wine B recorded a higher TA than Wine A, the trend after fermentation was otherwise. The increase in TA after fermentation for Wines A and B, and the Control wine were 3.3, 2.2 and 2.0 g/L. Acid production by yeast in the course of fermentation was higher in Wine A than Wine B, and that was the probable reason for the differences in the TA values [13]. Increase in TA after fermentation was reported for tomato wine [33] and Jamun wine [38].

The acid taste index (ATI) value of Wine A was significantly higher than Wine B, which was also higher than the Control wine after fermentation and ageing (Table1). After fermentation the ATI of Wine A was in the range for dry white wines (2.7-3.7), but the value for Wine B was a bit lower, and the Control wine had a value far below. Values too far below the range for dry white wines make wine flabby [39]. However, after ageing the ATI of Wine B fell in the range for dry white wines, that of Wine A was far above the range, and the Control wine was still far below. The ATI values which are too far above those for dry white wines tend to make the wine sharp and acidic [39]. The results indicated that, after fermentation, the Control wine was more flabbier, and was still flabby after ageing, but Wine A became sharp and acidic.

The Control wine recorded a significantly lower dry extract than Wine B, which was also lower than Wine A, after fermentation (Table 1). These values were however, less than 25 g/L, the dry extract value for dry white wines [13]. The differences in ethanol content [40] and the TSS of the three wines may account for the differences in the dry extract values. Dry extract ranges of 12.90-13.40 g/L are reported for Godello white wines [41]. Dry extract is an important measure of a wine's body, therefore Wine A may have a higher body than the other two wines. After ageing, the dry extract of the Control wine showed a significant reduction, whiles those of Wines A and B indicated significant increases. [42] Martinez De la ossa et al. (1987) have reported a reduction in dry extract for sherry wine during biological ageing. Though the Control wine exhibited reduced ethanol content and TSS with reduced dry extract, reduction in ethanol contents and TSS for Wines A and B rather led to increase in dry extract. This means other factors

may be contributory to the differences in dry extract values recorded for the wines after ageing.

The volatile acidity value of Wine B was lower than both Wine A and the Control wine after fermentation. After ageing, the volatile acidity of the Control wine remained the same, but that of Wine A went down a bit, whilst that of Wine B went up a bit. The values recorded for all the three wines (Table 1) were far below the range 0.56-1.5 g/L reported by [43], after both fermentation and ageing. Volatile acidity gives an indication of possible microbial spoilage, and is used as an indicator of wine quality [13].

A measure of a wine's absorbance at 280 nm is taken as total phenols [5, 27]. The total phenol of Wine A after fermentation was significantly higher than Wine A, which was also significantly higher ($p<0.05$) than the Control wine. Ethanol is known to dissolve phenols from pomace during fermentation [13]. The differences in alcoholic content of the three wines might have contributed to the variation in their total phenols content (Table 1). However, after ageing the trend in total phenol content of the wines changed. Wine B recorded a significantly higher total phenol value than Wine A.

Browning index, a measure of absorbance at 420 nm (A_{420}) with a higher value indicating more browning [1] was significantly higher in the Control wine than Wine A, which was also higher than Wine B (Table 1). [3] Ribereau-Gayon et al. (1977) have found out that brown compounds formation in wine increases with increasing pH. Colour density is a measure of colour depth, i.e. how dark it is, colour tint shows a mixture of colour with white, which increases lightness, and colour intensity gives an idea about the brightness or dullness of a colour. After fermentation the Control wine which recorded significantly highest colour density also had significantly lowest colour tint, and Wine B which showed significantly lowest colour density gave significantly highest colour tint (Table 1). The trend may be attributed to the variation in browning incidence in the three wines [1]. Also after ageing, the Control wine recorded the highest colour density and the lowest colour tint. However, Wine A rather than Wine B, showed the lowest colour density and the highest colour tint. The trend in browning which occurred in the wines after ageing could probably account for the trend in colour density and tint.

The clarity of the wines was measured as absorbance at 660 nm (A_{660}), with a wine of higher A_{660} value indicating lower clarity and vice versa [31]. After fermentation the clarity of the Control wine was significantly lower than that of Wine A, which was also lower than Wine B (Table 1). After ageing, the control wine exhibited a significantly far lower clarity, but Wine B rather had a significantly lower clarity than wine A, a clear trend reversal. Flocculated proteins are one of the main causes of reduced clarity in bottled white wines [13, 44]. The different pH of the wines might have influenced protein solubility in the wines differently, thereby leading to the variation in the observed clarity values [45].

3.3 Sensory evaluation

After 8 months bottle ageing, the flavour, colour and the overall acceptance of the three wines were assessed by a-10 member semi-trained panel, and the results are shown in Table 1. The mean taste, aroma, and colour scores of Wines A and B were not significantly different ($p<0.05$), but were significantly higher than those of the Control wine. Wine B ranked significantly higher than the other two wines in terms of overall acceptance.

[IV] CONCLUSION

Tomato wine was produced at three different pH, 3.20 (Wine B), 3.35 (Wine A) and 4.22 (Control wine) after amelioration of the total soluble solid to 18.3^{o} Brix, and incubation of the tomato must at 18±2 ^{o}C. The results of the study indicated that most enological parameters of Wine A were better than Wine B, after both fermentation and ageing. Sensory evaluation of the wines showed

that no significant difference existed between Wines A and B in terms of taste, aroma and colour likeness, but the panelists rated Wine B significantly higher ($p<0.05$) in overall acceptability. In spite of the fact that most enological parameters of Wine A were better than Wine B, the sensory evaluation panel rated the latter better on overall acceptance.

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Figure and table:

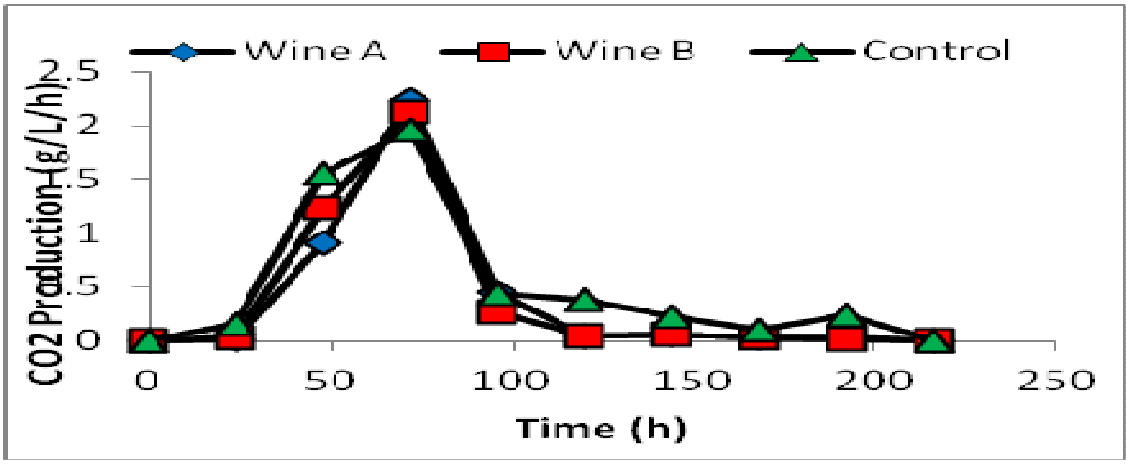

Fig. 1: Carbon dioxide production during tomato must fermentation

Parameter	Before Ageing			After Ageing		
	Control	Wine A	Wine B	Control	Wine A	Wine B
TSS (°B)	5.8±0.0[a]	6.1±0.1[b]	5.9±0.0[a]	3.9±0.1[c]	5.4±0.2[d]	5.6±0.1[d]
pH	3.71±0.01[a]	3.11±0.00[b]	3.40±0.01[c]	3.63±0.00[d]	3.03±0.01[e]	3.29±0.01[f]
TA (g/L citric acid)	4.4±0.1[a]	6.7±0.0[b]	5.7±0.0[c]	4.9±0.2[d]	8.8±0.2[e]	6.4±0.0[f]
Acid Taste Index (ATI)	0.69±0.09[a]	3.59±0.00[b]	2.3± 0.01[c]	1.27±0.2[d]	5.77±0.19[e]	3.11±0.01[f]
Ethanol content (%v/v)	10.1±0.5[a]	11.2±0.5[b]	11.1±0.5[b]	6.0±0.5[c]	9.2±0.1[d]	7.6±0.8[e]
FE (%)	155.4±0.5[a]	176.5±0.5[b]	172.1±0.5[c]	-	-	-
Reducing residual sugar (g/L)	3.27±0.06[a]	2.36±0.12[b]	3.08±0.05[c]	2.87±0.34[c]	3.41±0.13[a]	2.99±0.05[c]
Volatile acidity (g/L)	0.06±0.00	0.06±0.00	0.03±0.00	0.06±0.00	0.03±0.001	0.06±0.00
Dry extract (g/L)	16.0±0.3[a]	18.1±0.1[b]	16.8±0.0[c]	13.42±0.02[d]	18.99±0.01[e]	18.07±0.01[b]
A420	0.208±0.000[a]	0.191±0.002[b]	0.170±0.000[c]	0.493±0.0.001[d]	0.197±0.001[e]	0.215±0.001[f]
A660 (Clarity)	0.041±0.001[a]	0.014±0.000[b]	0.008±0.000[c]	0.392±0.000[d]	0.017±0.000[e]	0.038±0.000[f]
A280 (AU)	1.72±0.02[a]	4.48±0.01[b]	2.59±0.01[c]	0.94±0.02[d]	1.16±0.01[e]	1.23±0.02[f]
CI ($A_{420}+A_{520}+A_{620}$)	0.345±0.000[a]	0.275±0.001[b]	0.227±0.000[c]	1.306±0.001[d]	0.25±0.001[e]	0.309±0.001[f]
CT (A_{420}/A_{520})	2.486±0.017[a]	3.173±0.079[b]	3.864±0.000[c]	1.152±0.002[d]	5.784±0.017[e]	3.845±0.010[c]
CD ($A_{420}+A_{520}$)	0.292±0.000[a]	0.252±0.001[b]	0.214±0.001[c]	0.921±0.001[d]	0.231±0.001[e]	0.271±0.001[f]
% Yellow colour	60.3±0.0[a]	69.6±0.5[b]	73.1±2.9[c]	37.7±0.1[d]	78.3±0.1[e]	69.6±0.1[b]
% Red colour	24.2±0.1[a]	21.9±0.4[b]	19.4±0.1[c]	32.8±0.0[d]	13.5±0.1[e]	18.1±0.0[f]
% Blue colour	15.5±0.1[a]	8.5±0.1[b]	7.5±3.0[b]	29.5±0.1[c]	8.2±0.2[b]	12.3±0.1[d]
Sensory evaluation						
Taste	-	-	-	1.74±0.01[a]	3.90±0.01[b]	4.20±0.02[b]
Aroma	-	-	-	1.77±0.02[a]	4.23±0.01[b]	3.92±0.02[b]
Colour	-	-	-	1.92±0.01[a]	3.69±0.02[b]	4.08±0.02[b]
Overall acceptance	-	-	-	1.90±0.02[a]	3.40±0.01[b]	4.50±0.01[c]

[Table-1]: Enological parameters of tomato wine

Means with the same superscripts in a row are not significant ($p<0.05$). Means were obtained from triplicate measurements.