THE EFFECT OF TOMATO WINE pH ON ITS BUFFER CAPACITY

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Abstract
Buffer capacity influences the stability of wine, and hence its quality. The influence of wine pH, of wines produced from three tomato musts pH levels (4.11, 3.40, and 3.20) on buffer capacity, was studied. Buffer capacity was determined by titration of the wines against 0.1 N Sodium hydroxide (NaOH) solution, and the titration continued until 10 mL of the base had been added. The pH of the solution was then determined. Then a graph of pH against volume (mL) of NaOH added was plotted, and the buffer capacity was calculated from the graph using an established formula. From the results, the change in pH of the tomato wines against volume of NaOH titrated was described by a zero order equation (R^2 = 0.863-0.9947). The tomato wine produced from must pH, 3.20 exhibited the highest buffer capacity value ($P<0.05$) while the wine produced from must pH 4.11 gave the least value. Buffer capacity correlated with pH (R = -0.9942, P = 0.048), and the free sulphur dioxide content (R = 0.9982, P = 0.027) of the wine, and this was significant at $P<0.05$. However, titratable acidity (R = 0.956, P = 0.134), total soluble sugar content (R = -0.9601, P = 0.128), reducing sugar content (R = 0.6525, P = 0.401), and ethanol content (R = -0.6272, P = 0.418) of the wines, though gave high correlation were not significant at $P<0.05$. Tomato wine of a lower pH value exhibits higher buffer capacity and vice versa.

Keywords: free sulphur dioxide, tomato musts, pH levels, stability of wine, sodium hydroxide solution

Submitted: 18.07.2014 Reviewed: 15.10.2014 Accepted: 26.11.2014

1. INTRODUCTION

Wine of lower buffer capacity may be subjected to appreciable changes and thus make it unstable. This can have a negative effect on the quality of the wine. Wine is a buffer containing weak acids in equilibrium with their corresponding salts (Dziezak, 2003), and thus the modification of wine chemical composition leads to only limited changes in wine pH due to its acidobasic buffer capacity (Ribereau-Gayon, et al., 2006). The buffering capacity of wine is defined as the quantity of acid or base that must be added to the wine in order to reduce or increase the pH value by one unit, and is expressed as milliequivalents of acid or base per liter of wine **(**Moreno and Peinado, 2012**).** The acidobasic buffer capacity of wine is mainly responsible for its physicochemical and microbiological stability in addition to its flavour balance (Ribereau-Gayon, et al., 2006).

The buffer capacity of wine may vary with the pH, type, number and concentration of organic acids, the ethanol content, and the type of amino acid (Ribereau-Gayon, et al.,2006). The amount of acid present as a salt influences the pH and buffer capacity of wine (Moreno and Peinado, 2012). Tartaric acid was reported to have higher buffering capacity than succinic acid, and was thus able to prevent sluggish or suspended fermentation, by keeping the pH within the optimal values for yeast development (Torija et al., 2003). Pisoschi et al. (2007) suggested that the presence of acids such as citric, ascorbic, and tartaric in acidic products such as orange juice and wine in a diluted buffer solution (of concentartion10^{-4}M) accounted for their strong buffer capacities. Dartiguenave et al. (2000a) have demonstrated that with the same acid concentration in water, the buffer capacity of succinic acid and citric acid is equivalent to that of malic acid, and that the value for a mixture of acid is lower than those for individual acids. In a related study to evaluate the contribution of some amino acids to the buffering capacity of wine by using a model solution Dartiguenave et al. (2000b) found that buffer capacity changes appear to be influenced by the nature of amino acid, its concentration, and the medium used. Buffer capacity or buffer power of some wines has been reported (Corona, 2010; Vivian et al., 2007). There is however, limited information on wine buffer capacity, and more so that of tomato wine. Since pH plays a key role in buffer capacity (Ribereau-Gayon, et al.,2006), the study was carried out to determine the effect of pH on the buffer capacity of tomato wine produced at different must pH levels.

2. MATERIALS AND METHODS

2.1. Tomato must preparation and fermentation

Kenwood blender (Philips HR 2006, China) was used to blend tomato after it has been washed thoroughly and dried. Pectic enzyme, potassium metabisulphite and ammonium phosphate concentrations 0.5, 0.05, and 0.5 g/L respectively were added. It was then heated at 40 ^{o}C for 1 h. The total soluble solid (TSS) was adjusted to 19.5±0.2 ^{o}Brix with sucrose (Ribereau-Gayon et al., 2006), and tartaric acid was used to change the pH from 4.11 to 3.40, and 3.20. The inoculum of the yeast, *Saccharomyces bayanus* (BV 818) was prepared according to the method previously described (Owusu et al. 2012). Fermentor of volume 5-L, containing 4.5-L of tomato must was inoculated with 24-h yeast inoculum at the concentration, 0.3 g/L. The tomato must was then batch fermented in an incubator at 20±2 ^{o}C for 10 days. The fermentation process was monitored by measuring the TSS from the third up to the tenth day, where the TSS became constant. The wines produced from tomato puree of pH 4.11, 3.40, and 3.20 were designated as Control, Wine A, and Wine B. After fermentation the wines were cold stabilized at 7 ^{o}C for 30 days, and kept frozen until needed for analysis.

2.2. Physicochemical properties of must/wine

The titratable acidity (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 (Sadler and Murphy, 2010), 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 AOAC (1984) using a pH meter (PHS-2C Precision pH/mV meter, China). 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 Caputi *et al.* (1968) spectrophotometric method after distillation of the alcohol, and the results expressed as % v/v. The residual sugar content was determined by the dinitrosalicyclic (DNS) acid reagent method (Miller, 1972). The residual sugar concentration was obtained from a standard curve prepared with glucose of standard concentration, 0-500mg/L (R^2 = 0.9436). Free and total Sulphur dioxide (SO_2) was determined by the Ripper method described by Zoecklin et al. (1990), and the fixed SO_2 was calculated as the difference between the two.

2.3. Wine buffer capacity

A modified method of Touyz and Silove (1993) was used to determine the buffer capacity of the tomato wine samples. Briefly a pH meter (PHS-2C Precision pH/mV meter, China) was calibrated with the pH 7.0 and 4.0 standard solutions. Wine sample volume 10 mL was placed in a beaker and its pH measured using the pH meter. One milliliter of 0.1 N Sodium hydroxide (NaOH) was added to the wine sample, and the new pH recorded. One milliliter was added again, and the new pH recorded, and the process continued until 10 mL of NaOH had been added. A graph of pH against volume (mL) of NaOH added was plotted (Edwards et al., 1999), and the buffer capacity was calculated from the graph using the formula (Ribereau-Gayon, et al., 2006):

$$\text{Buffer capacity (mol/L)} = \frac{\text{moles of NaOH added}}{\text{change in pH X volume of wine in L}} \quad (1)$$

2.4.Data analysis

The data from the study was analyzed using statistical package for social scientists (SPSS), Version 17.0. The differences in means were separated using the Duncan Multiple Range Test. The Pearson's correlation co-efficient was used to establish the relationship between the wine parameters and buffer capacity.

3. RESULTS AND DISCUSSION

3.1.Physicochemical properties of must/wine

The physicochemical properties of the tomato wines are shown in Table 1. The pH of the wines were different ($P<0.05$). Lower tomato must pH produced wine of lower pH and vice versa. The pH values were in the range considered suitable for wines (Jackson, 2008). Wine of the lowest pH recorded the highest TA and vice versa. The Control Wine gave the highest ethanol content ($P<0.05$) and the least reducing sugar content ($P<0.05$). Wine B gave the highest free sulphur dioxide.

Table 1: Wine physicochemical properties

Parameter	Wine A	Wine B	Control
pH	3.45±0.01[a]	3.23±0.01[b]	4.01±0.01[c]
TA (g/L)	10.35±0.37[a]	12.37±0.37[b]	7.36±0.00[c]
Ethanol content (%v/v)	8.59±0.28[a]	9.04±0.21[a]	9.61±0.17[b]
Reducing sugar	2.60±0.06[a]	2.37±0.07[b]	2.05±0.09[c]
TSS	5.4±0.1[a]	5.4±0.1[a]	5.7±0.1[a]
Free SO_2 (mg/L)	16.53±0.92[a]	17.07±1.85[a]	13.87±1.85[b]

Means were obtained from triplicate measurements. Means with different superscripts in a row are significant ($p<0.05$)

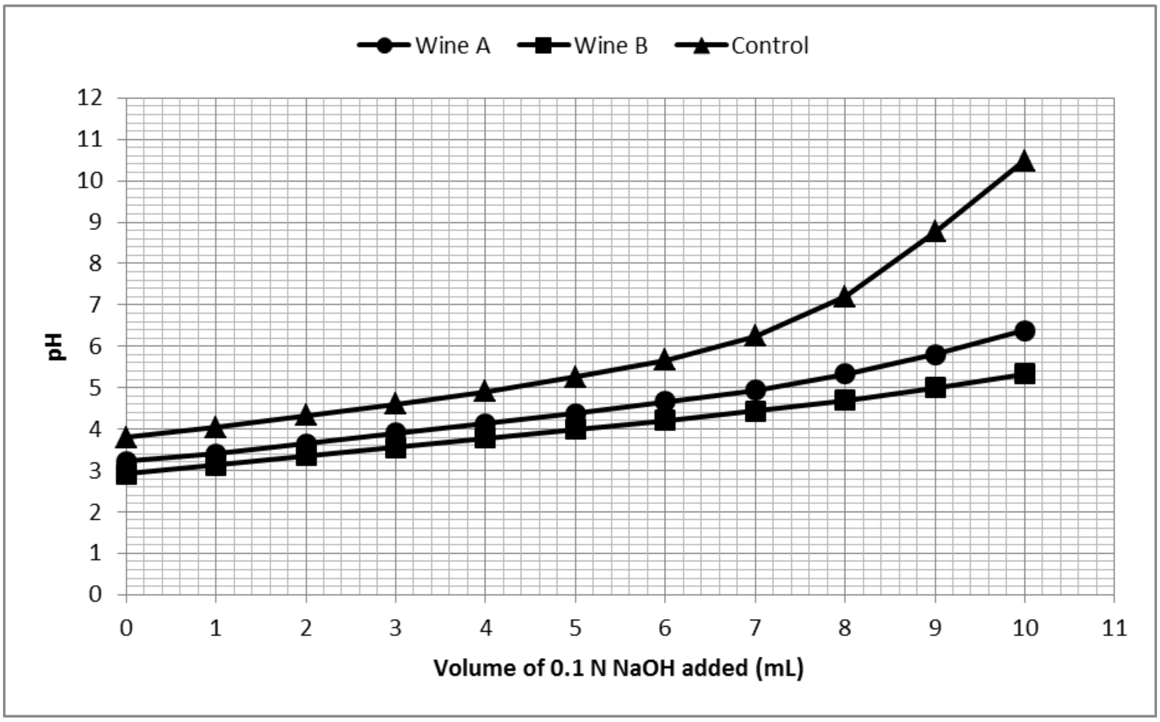

Fig. 1: Change in wine pH with volume of 0.1 N NaOH added

Table 2: Buffer capacity of tomato wines

Buffer capacity	Wine A	Wine B	Control
Buffer capacity (mol/L)	0.038±0.002[a]	0.042±0.002[b]	0.023±0.00[c]
Buffer capacity (mEq/L)	38.0±2.0[a]	42.0±2.0[b]	23.0±0.0[c]
Model	y=0.3009x +3.0236	y=0.2343x +2.8659	y=0.5908x +2.9823
R^2	0.9731	0.9947	0.863
Slope	0.3009	0.2343	0.5908

Means were obtained from triplicate measurements. Means with different superscripts in a column are significant ($p<0.05$)

Table 3: Correlation of tomato wine parameter with buffer capacity

	Buffer capacity	
Wine parameter	R	p
TA	0.9560	0.134
PH	-0.9942*	0.048
Ethanol content	-0.6272	0.418
TSS	-0.9601	0.128
Reducing Sugar	0.6525	0.401
Free SO_2 content	0.9982*	0.027
Fixed SO_2 content	-0.3910	0.372
Total SO_2 content	0.0120	0.496

*Correlation is significant at the 0.05 level (1-tailed)

3.2 Buffer capacity

Figure 1 shows how the pH of wine varies with the volume of 0.1 N sodium hydroxide added.
The buffer capacities of the wines were calculated from equation 1, using Fig. 1, and the results are shown in Table 2. Wine B exhibited a significantly higher buffer capacity than Wine A and the Control. The slope of the curve for Wine B was the lowest compared with Wine A and the Control.
This is an indication that there was only a small change in pH with increased volume of sodium hydroxide for Wine A, meaning it had the greatest ability to resist changes in pH. Buffer power of 33.3±0.9 and 37.4 meq/L were reported for wines produced from must protected from oxidation with sulphur dioxide, and control wine respectively (Corona, 2010). Wines A and B recorded buffer capacity values (Table 2), which were in the range, 0.038-0.046 mol/L reported for five red wines (Vivian et al., 2007), but that of the Control was far below. The correlation between buffer capacity and the various wine parameters are shown in Table 3. Buffer capacity had a strong correlation with pH (R^2 = -0.9942) and TA (R^2 = 0.956). Whiles the correlation between buffer capacity and pH was significant ($p<0.05$), that between buffer capacity and TA was not. This suggests that even though the pH of the wines made a significant contribution to their buffer capacity values (Ribereau-Gayon, et al., 2006), the TA's contribution was insignificant. There was also a very strong positive correlation between buffer capacity and the free SO_2 content of the wines (R^2 = 0.9982). Buffer capacity also correlated with fixed SO_2 (R^2 = -0.6893) and total SO_2 contents (R^2 = -0.2874), though not significant as free SO_2. Thus the contribution of the different forms of SO_2 to buffer capacity may be varied. Total soluble solids (R^2 = -0.9601) also gave very strong correlation with buffer capacity. Reducing sugar (R^2 = 0.6525), and ethanol (R^2 =-0.6272), showed moderately strong correlation with buffer capacity. However, these were not significant (P>0.05).

4 CONCLUSIONS

Buffer capacity of wines produced with different levels of must pH was investigated, and the results indicate that wine produced from tomato must of pH 3.20 recorded the best buffer capacity value. The free sulphur dioxide content of the tomato wines gave a significant correlation with buffer capacity (R = 0.9982, P = 0.027)

5. ACKNOWLEDGEMENTS

The funding for this project was provided by Open Fund of Jiangsu Provincial Key Laboratory for Physical Processing of Agricultural Products (JAPP2010-6), the Jiangsu Province Science and Technology Support Project (BE2011382).

6. REFERENCES

[1] AOAC, Official methods of Analysis. 4th ed. Association of Official Analytical chemists. Washington, DC., USA, 1984.

[2] Caputi, A. J. R., Masao, U., Brown, T. Spectrophotometric determination of ethanol in wine. American Journal of Enology and Viticulture, 1968, **19**, 160-165.

[3] Corona, O. Wine-making with protection of must against oxidation in a war, semi-arid terroir. South African Journal of Viticulture, 2010, **31** (1), 58-63.

[4] Dartiguenave, C., Jeandet, P., Maujean, A. Study of the contribution of the major organic acids of wine to the buffering capacity of wine in model solutions. American Journal of Enology and Viticulture, 2000a, **51** (4), 352-356.

[5] Dartiguenave, C., Jeandet, P., Maujean, A. Changes in the buffer capacity of model solutions of 40 mM tartaric or malic acids in relation to amino acids. American Journal of Enology and Viticulture, 2000b, **51** (4), 347-351.

[6] Dziezak, J. D. Acids. In: Encyclopedia of Food Sciences and Nutrition. Edited by Caballero, B. Elsevier Sciences Ltd. pp 7-12, 2003.

[7] Edwards, M., Creanor, S. L., Foye, R. H., Gilmour, W. H. (1999). Buffering capacities of soft drinks: the potential influence on dental erosion. Journal of Oral Rehabilitation, 1999, **26**, 923-927.

[8] Miller, G. L. Use of dinitrosalicyclic acid reagent for determination of reducing sugars. Analytical Chemistry, 1972, **31,** 426-428.

[9] Moreno, J., Peinado, R. Enological Chemistry. 1st ed. Academic Press, London, UK., 2012.

[10] Owusu, J., Ma, H., Abano, E. E., Engmann, F. N. (2012). Influence of two inocula levels of *Saccharomyces bayanus*, BV 818 on fermentation and physico-chemical properties of fermented tomato (*Lycopersicon esculentum Mill*.) juice. African Journal of Biotechnology, 2012, **11** (33), 8241-8249.

[11] Pisoschi, A.-M., Danet, A.-F., Negulescu, G.-P. Influence of the buffer capacity on glucose potentiometric determination in synthetic solutions and in real samples with different acidities Proceedings of Romanian Academy, Series B, 2007, **2,** 75-81.

[12] Ribereau-Gayon, P., Glories, Y., Maujean, A., Dubourdieu, D. Handbook of Enology Volume 2: The Chemistry of Wine and Stabilization and Treatments. 2nd ed. John Wiley & Sons Ltd. Chichester, England. pp 3-49, 2006.

[13] Sadler, G. D., Murphy, P. A. pH and Titratable Acidity. In: Food Analysis Edited by Nielsen, S. S. Springer Science + Business Media, LLC, New York, pp 219-238, 2010.

[14] Torija, M. J., Beltran, G., Novo, M., Poblet, M., Rozès, N., Mas, A., Guillamón, J. M. Effect of organic acids and nitrogen source on alcoholic fermentation: study of their buffering capacity. Journal of Agriculture and Food Chemistry, 2003, **51** (4), 916-922.

[15] Touyz, L. Z. G., Silove, M. (1993). Increased acidity in frozen fruit juices and dental implications. Journal of Dentistry for Children, 1993, **60** (3), 223-225.

[16] Vivian, A., Moreno, J., Peinado, R. A. Differentiation of young red wines obtained in a warm climate region. International Journal of Food Science and Technology, 2007, **42,** 523–527. Doi: 10.1111/j.1365-2621.2006.01240.x

[17] Zoecklin, S. W., Fugelsang, K. C., Gump, B. H., Nury, F. S. Production wine analysis, Van Nostrand Reinhold, New York, 1990.