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Effect of Aging in the first 5 years of Moscato d'Asti Sparkling White Wine on %w/v of Tartaric Acid by Titration and pH Monitoring using 0.100 M of NaOH

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Content

1. Personal Engagement and Problem Statement

Christmas last year after I turned 16, our dinner was concluded with delicious dessert accompanied by apple cider, some overrated champagnes and Moscato sparkling white wine. With only 7% alcohol content, Moscato is one of the sweetest alcoholic beverages and a good choice for dessert. I thought it was the safest choice other than plain water. However, my mother told me to be generous with my first experience with alcohol as white wine generally has lower pH compared to red wine. I was also told that white wine is generally not aged after fermentation – only up to 5 years for most white wine. As red wine is often aged longer in barrel, they do have high pH as well, just relatively lower than whites. I did some internet search and I came to two inferences: acidity level of wine may be affected by the age of the wine; or maybe red wine has different acid present in it compared to white wine. After searching for more information, I found that the most prominent acid in both red and white wine is tartaric acid. Since I prefer sweet taste like Moscato and want be certain on the amount of acid that I would be consuming in the future, I decided to conduct an investigation to study the effect of aging and storing of Moscato d'Asti sparkling white wine on the amount of tartaric acid in the wine.

2. Exploration

2.1. Research Question

How does aging of Moscato d'Asti for 0, 1, 2, 3, 4, and 5 years affect the percentage mass per volume of tartaric acid present when 50 mL of 100x diluted of the white wine is titrated against 0.100 M of NaOH at room temperature and constant 200 rpm stirring, indicated using phenolphthalein and pH sensor.

2.2. Background Knowledge

2.2.1. Fermentation and Aging of Wine

Wine making involves fermentation and aging towards the end of the process. Fig. 1 shows the overview process of wine making. Fermentation (step 4) which usually takes about 2 to 3 weeks, involves the conversion of sugar to ethanol and CO_2 (by product). Once fermentation is done according to desired duration, the wine is then pressed and left to age. Most white wine are not aged and rather bottled for sale right after fermentation. Moscato d'Asti is a special white wine from Italy that has different aging period with distinctive taste and flavor. Cold aging and storage can decrease the acidity of wine. After finishing (bottling), the wine can be further aged or stored to develop its taste. Since white wine is not generally aged before bottling, the year printed on the lable will be considered as how long ago has the wine been stored or aged.

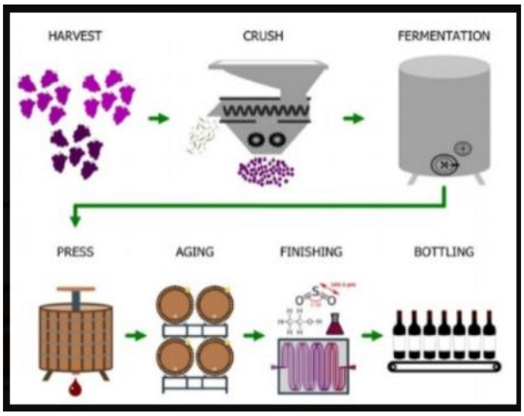

Fig.1 Wine Making

2.2.2. Tartaric Acid

Tartaric acid, $C_4H_6O_6$ (Fig. 2) is a predominant acid present in many types of wine. This acid occurs naturally in many fruits especially grapes (~6 g/L) – the main ingredient of wine (Goncalves, 2003). The carboxyl,–COOH group at both ends of the carbon chain acts as Bronsted-Lowry acid where it donates it H^+ at the –OH end. This can then be titrated using a strong base to identify the amount of tartaric acid present in the wine sample.

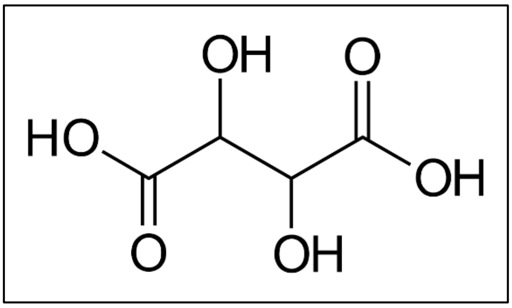

Fig.2 Structure of tartaric Acid

2.2.2. Reaction and Titration

Tartaric acid reacts with NaOH to produce its salt sodium tartrate (fig. 3) and water.

First reaction: $C_4H_6O_6 + NaOH \rightarrow C_4H_5O_6Na + H_2O$

Second Reaction: $C_4H_5O_6Na + NaOH \rightarrow C_4H_4O_6Na_2 + H_2O$

Overall: $C_4H_6O_6 + 2\ NaOH \rightarrow C_4H_4O_6Na_2 + 2\ H_2O$

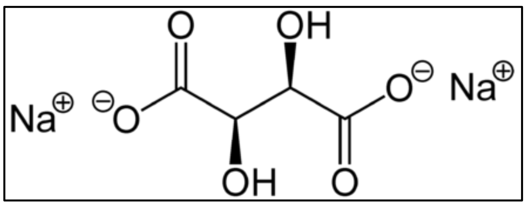

Fig.3 Sodium tartrate

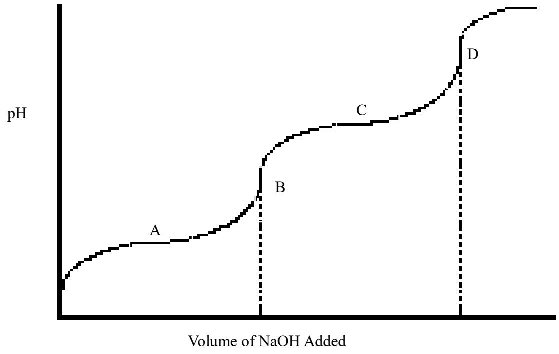

Fig.4 Titration Curve of Diprotic acid

Since tartaric acid is a diprotic acid, the titration curve will produce two inflection points (Point B and D in fig. 4) where each of these two points indicates that the amount of H^+ from an end is equal to the amount of OH^- of the added NaOH.

Since tartaric acid is a weak acid, adding a strong base to form its salt will produce buffer. This is indicated by the resistance to the change in pH in region A and C in fig. 4.

2.2.3. Data Interpretation and Analysis

Based on the titration curve (fig. 4), the pKa values of tartaric acid can be identified using the half-equivalence points. According to Lide (2005), the pKa values of tartaric acid at room temperature is 2.98 and 4.34 at room temperature. The second inflection point can be used to determine the amount of NaOH needed to fully neutralise the acid present in the sample. While this does not indicate that actual amount of tartaric acid present, the first equivalence point from the first inflection point can be used to determine the percentage mass per volume of tartaric acid in wine sample.

The steps involved in the interpretation and analysis are as follow;

I. Identify (using graph) the first equivalence point. Then find the volume and number of moles of NaOH added to 50 mL of 100x diluted wine

$$\mathbf{n_{(NaOH)} = \mathit{c}V}$$

II. Use the mole ratio of the first reaction (in 2.2.2) to find the number of moles of tartaric acid.

$C_4H_6O_6$	**:**	**NaOH**
1	**:**	**1**

$$\textbf{Hence } \mathbf{n_{(C4H6O6)} = n_{(NaOH)}}$$

III. Find the number of moles tartaric acid in the undiluted (1000 mL bottle)

$$\mathbf{n_{(undiluted\ C4H6O6)} = n_{(C4H6O6)} \times 100}$$

IV. Find the mass of tartaric acid in the bottle using its M_r

$$\mathbf{m = n_{(undiluted\ C4H6O6)} \times 150.10\ g\ mol^{-1}}$$

V. Then find the %w\v of tartaric acid in the wine bottle

$$\mathbf{\%w/v\ Tartaric\ acid = (m / 1000) \times 100}$$

2.3.Hypothesis

The longer the aging of Moscato d’Asti (0, 1, 2, 3, 4, and 5 years), the lower the percentage mass per volume of tartaric acid in the wine. This is because…..

2.4. Variables

Independent: Age of Moscato d'Asti. 6 bottles of Moscato d'Asti white wine will be obtained from a wine store. Each bottle will represent different aging period; 0 (2007), 1 (2006), 2 (2005), 3 (2004), 4 (2003), and 5 (2002) years.

Dependent: Percentage (%w/v) of tartatic acid ($C_4H_6O_6$, IUPAC: 2,3-dihydroxybutanedioc acid) by mass per volume of Moscato d'Asti. The method of data processing is mentioned in section 2.2.3. A linear graph will be used to determine the pattern of tartaric acid content in different ages of white wine.

Controlled:

(1) Temperature of wine during aging/storing and during experiment. As tartatic acid is a weak acid, its dissociation will depend upon temperature according to Le Chaterlier's principles. During aging and storing, it is important that the temperature is kept the same (16ºC) so that the tartatic acid would interaction with other chemicals in the bottle in a controlled manner. During experiment, temperature is kept constant (20 - 25ºC) to ensure that the acid interacts with NaOH in the same dissociation rate.
(2) Type of wine: only Moscato d'Asti will be used for this investigation. This is because different wine is fermented and aged differently. More importantly, different wine has different grape and ingredient content. This will affect the amount of tartatic acid entirely.
(3) Amount and dilution of wine. Upon opening a wine bottle, the wine will be diluted to 100x up to 500mL. All of this diluted volume will be titrated on the same day (an opened bottle must be titrated on the day it was opened to avoid oxidation). 50 mL of this diluted sample will then be titrated.
(4) Base used for titration, NaOH. The concentration of NaOH used is 0.100 mol dm^{-3}.
(5) Stirring during titration will be kept constant at 200 rpm using magnetic stirrer. This stirring will facilitate constant dissociation and interaction of H^+ with NaOH.
(6) Method of monitoring the titration is controlled by using pH sensor to record the pH of the titration mixture until is reaches the end point. Since this titration involves weak acid and strong base, the equivalence point should fall on alkaline range (more than 7), therefore phenolphthalein will be used to indicate the end point qualitatively. This titration's pH range will be around 3 – 13 where there will be two inflection points.

Uncontrolled:

(1) Addition ingredient in Moscato d'Asti. Each year for any type of wine, the manufacturer will add different ingredient to produce unique and distinctive taste and appearance of the beverage. For different years of Moscato d'Asti produces, it is known that the wine has an evolved taste and aroma. The additional ingredient may interact with tartatic acid from grapes and will affect the amount of the acid at the point of titration. This is desirable for this experiment as a part of the research question. However, other unknown ingredients may or may not interact with NaOH during titration. This will affect the data obtained. To remove this possible discrepancy, it is assumed that only tartatic acid will interact with NaOH during titration as it is the most prominent acid in the wine.
(2) Rate of oxidation: once the wine is opened, it is hard to keep the rate of oxidation of each wine constant. This is because of the presence of unique additional ingredient in each year of wine. The chemical reactions that take place once the wine is exposed to the air may affect the tartatic acid content, thus has the tendency to produce an outlier.

2.5.List of Apparatus with Uncertainty

Apparatus	Uncertainty
10 mL and 50 mL pipette	± 0.05 mL
1000 mL volumetric flask	± 0.4 mL respectively
50 mL burette	± 0.05 mL
pH Sensor	± 0.1
Magnetic hot plate and stirrer	No uncertainty
Temperature probe	± 0.1 ºC
250 mL beaker	± 1.0 mL (does not cause error propagation)
Retort stand	No uncertainty

2.6. List of Materials with Risks' Assessments

Materials	Hazard	Precaution
1000 mL of 0.100 M of NaOH	Highly corrosive. It can cause irritation to the eyes, skin, and mucous membrane; an allergic reaction; eye and skin burns; and temporary loss of hair	Always keep NaOH pallets in its bottle with close to no exposure to the air as it can absorb moisture and produce a strong base solution. When diluted, the base is kept in the volumetric flask in fume hood and only small amount of it is taken out for titration.
Phenolphthalein	Irritation to eye and skin. Ingestion causes gastrointestinal irritation with nausea, vomiting and diarrhoea. In a more chronic effect, this chemical can cause kidney injury.	Diluted phenolphthalein should be kept in a small bottle with dropper so that a few drops of it can easily be applied during titration.
1L bottles of Moscato d'Asti containing Tartatic Acid (2002 – 2007)	Wine can cause heart disease, high blood pressure, atrial fibrillation, stroke and cancer. Tartatic acid can cause skin, eye, and lung (inhalation) irritation.	Open the bottle carefully as it may pop due to the high internal pressure. Avoid consuming the alcohol
Distilled water	Does not pose any hazardous property	Uncontaminated water can be drained into the sink

In general, primary safety precaution should be done by using protective wears / gears to avoid direct contact and intake such as lab coat, goggles, mask, and latex gloves. NaOH is a strong base. Disposing directly into the sink without diluting it will affect the plants, microorganisms and aquatic life as it can leak into underground water and increase the pH of soil and water. Moscato d'Asti is an alcoholic beverage. Other that it contains suphide ions that will affect liver function, the nature of the beverage itself may rise ethical and cultural issues in some part of the world especially when conducting this investigation in a secondary school. Multiple biological properties of phenolphthalein, including its ability to form free radicals, its clastogenic activity, and its estrogenic activity, contributed to the carcinogenic effects. Free radicals may cause mutation in aquatic lives.

2.7. Experimental

2.7.1 Sample Preparation

1. Obtain from an adult, 6 X 1L bottles of Moscato d'Asti from year 2002 – 2007 respectively. Store all bottles in chiller at 16ºC
2. Open 2012 bottle carefully by twisting the cork
3. Let the bubbling to settle for 2 minutes
4. Use pipette to transfer exactly 10 mL of the wine into a 1 L volumetric flask.
5. Top up the flask with water until the 1 L mark is reached by meniscus of solution. Close using lid.
6. Homogenise the solution by turning the flask several times. Then keep the volumetric flask at room temperature before and during titrations.

2.7.2 Titration

1. Set up the titration experiment as shown in fig. 5.
2. Transfer 50 mL of the 100x diluted Moscato d'Asti using pipette into a 250 mL beaker. Measure the temperature of the sample using digital temperature probe. [*Titration will only be done if the temperature is at room temperature*]
3. Add 2 – 3 drops of phenolphthalein in the beaker and put a magnetic stirrer
4. Fill the (washed with 0.100 M NaOH) 50 mL burette held by retort stand with 50 mL 0.100 M of NaOH
5. Place the beaker on the magnetic hot place and set the stirring to 200 rpm
6. Record the pH of the titration mixture using pH sensor where the probe is fully immersed in
7. Start the titration by adding 1 – 5 mL of 0.100 M of NaOH by controlling the stopcock. Record the pH each time NaOH is added.
8. Repeat all steps in section 2.7.2 until a reproducible data were obtained or at least for three times

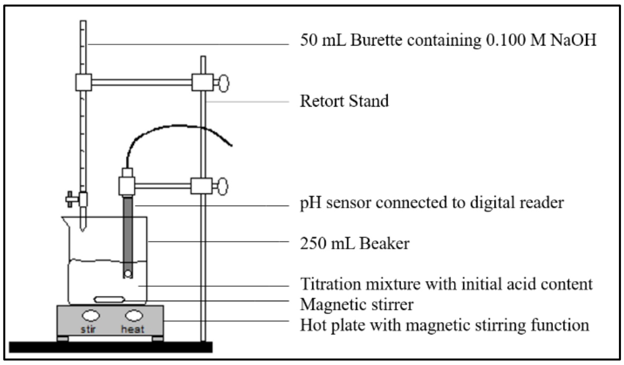

Fig.5 Titration Setup

2.7.3 Data Analysis

1. To obtain data from different aged period of Moscato d'Asti, section 2.7.1 and section 2.7.2 are repeated with different bottles of wine from different years respectively.
2. For each year (for instance 2002), the primary data will be averaged for all trials before drawing a titration curve
3. The first equivalence point from each titration curve will be identified by using first derivative method.
4. Analysis will be done according to steps mentioned in section 2.2.3.
5. The correlation between aging period and % w/v of tartaric acid will be represented and tubulated
6. The errors and uncertainties are considered by using formulae:

$$\%\ of\ Uncertainty = \frac{(Absolute\ uncertainty)}{Average\ or\ mean\ value\ taken\ using\ the\ apparatus}\ X\ 100$$

and…

$$\%\ of\ error = \frac{(Theoritical\ value - Experimental\ Value)}{Theoritical\ value}\ X\ 100$$

…where the theoretical value of %w/v of tartaric acid is 5.7 g/L (e-catalogue on belsitwinery.com)

3. Result

3.1 Qualitative Data

Before conducting the experiment, a general observation was done and it was found that there was a white-to-transparent crystal formed at the bottom of the wine bottles from 2002 and 2003 (more was observed in 2002). A darker yellowish share of Moscato d'Asti was observed before the titration for wine bottle year 2002 – 2005. All phenolphthalein changed colour accordingly at the expected range of pH. In the more recent year, it is found that the carbonation (sparkling property) is done heavier than the older years. This was observed by the formation of excess foam and bubbles after opening the bottle. This may also be due to the poor handling of the bottle by domestic transport that result in shaking and releasing the CO_2 in the bottle.

3.2 Quantitative Data

[Your task starts here…]

Appendices

Table 1: pH of titration curve for Moscato d'Asti 2002

Volume of NaOH Added (± 0.05), mL	pH of Titration mixture (± 0.1)		
	Trial 1	Trial 2	Trial 3
0.00	3.1	3.0	2.8
0.50	3.2	3.2	2.8
1.00	3.2	3.3	2.9
1.50	3.4	3.3	3.1
2.00	3.3	3.5	3.0
2.50	3.2	3.3	2.9
3.00	3.4	3.3	3.1
3.50	4.3	4.7	4.3
4.00	7.8	6.5	7.6
4.50	9.0	8.1	8.3
5.00	9.4	8.8	8.8
5.50	10.1	9.1	10.7
6.00	10.2	9.3	10.5
6.50	10.2	9.3	10.8
7.00	11.3	9.5	10.7
7.50	11.7	10.5	12.4
8.00	12.1	10.9	12.5
8.50	12.3	11.3	12.7
9.00	12.2	11.2	12.6
9.50	12.7	11.8	12.8
10.00	12.8	11.9	12.9

Table 2: pH of titration curve for Moscato d'Asti 2003

Volume of NaOH Added (± 0.05), mL	pH of Titration mixture (± 0.1)		
	Trial 1	Trial 2	Trial 3
0.00	2.6	2.9	2.8
0.50	2.6	2.8	2.9
1.00	2.7	2.9	3.0
1.50	2.9	3.1	3.1
2.00	3.2	3.2	3.3
2.50	3.6	3.2	3.9
3.00	4.1	3.3	4.3
3.50	4.7	4.8	4.8
4.00	5.6	6.1	7.7
4.50	9.2	9.3	8.5
5.00	9.3	9.3	9.4
5.50	9.3	9.4	9.0
6.00	9.7	9.4	9.4
6.50	10.1	9.9	9.5
7.00	10.5	10.3	10.4
7.50	10.9	11.3	10.5
8.00	11.6	11.5	11.7
8.50	11.9	11.6	11.8
9.00	12.2	12.2	12.8
9.50	12.3	12.6	12.8
10.00	12.9	12.7	12.9

Table 3: pH of titration curve for Moscato d'Asti 2004

Volume of NaOH Added (± 0.05), mL	pH of Titration mixture (± 0.1)		
	Trial 1	Trial 2	Trial 3
0.00	3.0	3.0	2.8
0.50	3.1	3.2	2.8
1.00	3.2	3.3	2.9
1.50	3.4	3.3	3.1
2.00	4.7	4.7	4.3
2.50	7.9	6.8	7.9
3.00	8.3	7.3	8.3
3.50	8.4	8.8	8.8
4.00	8.9	9.1	10.7
4.50	9.2	9.3	10.5
5.00	10.2	9.3	10.8
5.50	11.3	9.4	10.9
6.00	11.7	9.4	12.4
6.50	12.1	9.6	12.5
7.00	12.3	11.3	12.6
7.50	12.4	11.2	12.6
8.00	12.7	11.8	12.7
8.50	12.8	11.9	12.7
9.00	12.9	12.2	12.7
9.50	12.9	12.1	12.9
10.00	12.9	12.1	13.0

Table 4: pH of titration curve for Moscato d'Asti 2005

Volume of NaOH Added (± 0.05), mL	pH of Titration mixture (± 0.1)		
	Trial 1	Trial 2	Trial 3
0.00	3.1	3.0	2.8
0.50	3.2	3.2	2.8
1.00	3.2	3.3	2.9
1.50	3.4	3.3	3.1
2.00	4.3	4.7	4.3
2.50	7.6	6.8	7.9
3.00	8.9	7.3	8.3
3.50	9.4	8.8	8.8
4.00	10.1	9.1	10.7
4.50	10.2	9.3	10.5
5.00	10.2	9.3	10.8
5.50	11.3	9.4	10.9
6.00	11.7	9.4	12.4
6.50	12.1	9.6	12.5
7.00	12.3	11.3	12.6
7.50	12.4	11.2	12.6
8.00	12.7	11.8	12.7
8.50	12.8	11.9	12.7
9.00	12.9	12.2	12.7
9.50	12.9	12.1	12.9
10.00	12.9	12.1	13.0

Table 5: pH of titration curve for Moscato d'Asti 2006

Volume of NaOH Added (± 0.05), mL	pH of Titration mixture (± 0.1)		
	Trial 1	Trial 2	Trial 3
0.00	3.2	3.1	3.2
0.50	3.3	3.2	3.2
1.00	4.5	4.8	4.2
1.50	7.6	6.9	7.3
2.00	8.1	8.3	7.9
2.50	9.0	8.9	9.1
3.00	10.1	9.6	10.1
3.50	10.1	10.1	10.2
4.00	10.3	10.1	10.3
4.50	11.3	11.2	10.7
5.00	11.4	11.2	11.4
5.50	12.1	12.1	12.1
6.00	12.1	12.1	12.2
6.50	12.2	12.2	12.1
7.00	12.5	12.1	12.3
7.50	12.7	12.5	12.8
8.00	12.8	12.5	12.6
8.50	12.8	12.8	12.7
9.00	12.9	12.6	13.0
9.50	12.9	13.0	12.9
10.00	12.9	12.9	13.0

Table 6: pH of titration curve for Moscato d'Asti 2007

Volume of NaOH Added (± 0.05), mL	pH of Titration mixture (± 0.1)		
	Trial 1	Trial 2	Trial 3
0.00	3.5	3.6	3.5
0.50	3.6	3.6	3.5
1.00	4.3	4.2	4.4
1.50	6.9	6.9	7.0
2.00	7.6	7.3	7.3
2.50	7.9	7.6	7.6
3.00	8.1	8.0	8.2
3.50	8.1	8.4	8.2
4.00	8.3	8.2	8.3
4.50	8.8	8.7	8.8
5.00	9.2	9.1	9.2
5.50	9.6	9.9	9.6
6.00	11.0	10.8	11.0
6.50	11.2	11.1	11.2
7.00	11.3	11.1	11.2
7.50	11.4	11.3	11.3
8.00	11.7	11.5	11.7
8.50	11.8	11.8	11.8
9.00	12.3	11.9	12.1
9.50	12.2	12.1	12.2
10.00	12.5	12.0	12.6