UNDERSTANDING QUALITY OF WINE PRODUCTS USING SUPPORT VECTOR MACHINE IN DATA MINING

Sandeep Bhattacharjee
Assistant Professor, Amity Business School, Amity University, Kolkata, India.
Email: sbhattacharjee@kol.amity.edu

Manodip Ray Chaudhuri
Ph.D, Associate Professor III, Amity Business School,
Amity University, Kolkata, India.
Email: mrchaudhuri@kol.amity.edu

ABSTRACT

The wine market is related with human civilization since a long period of time and the volumes of trade exits between different individuals, groups or organization since earliest know history. In this paper we have used two data mining techniques for classification. i.e support vector machine and Naïve Bayes classifier to understand the various factors affecting quality of wine trade such as fixed acidity , volatile acidity, citric acid, residual sugar, chlorides, free sulfur dioxide, total sulfur dioxide, density , pH, sulphates, alcohol and one output variable (based on sensory data) quality (score between 0 and 10). We have tried to compare the results of these classification techniques and also draw inferences for future applications in this trade. The data has been drawn from Center for Machine Learning and Intelligent Systems (UCI Machine Learning).

Keywords : Red wine, White Wine, Alcohol, Density, Support Vector Machine, Naïve Bayes Classifier

1. INTRODUCTION

1.1 HISTORY OF WINE

Wine is one of the foundations of Western Civilization. The story of wine is that of medicine, religion, war, discovery, science and dream. Wine and beer are both very ancient alcoholic beverages [**1,2**]. But wine is considered special. It can be produced

only once a year, in the fall, when the grapes are mature. Beer can be brewed more or less anytime. Further, if the must have enough sugar, natural fermentation produces wine that contains 12 to 14%alcohol, that is almost three or four times more than beer. Generally, Wine gives people a buzz. It is considered as a magical beverage, associated with gods and religious occasions. For more than thousands of years (until the Arabs invented distillation), wine was not just the most potent beverage but also the most powerful antiseptic available. In terms of trade in ancient times, Viticulture most likely spread through the trade of wine, vine cuttings, wine jars, and even resin from the Terebinth tree[11]. The latter was used to coat the inside of wine jars and amphorae.

In the past decade, the archeological proof of wine making, even wine technology, has been unearthed in several Neolithic sites in the Zagros Mountains of NorthEastern Iran [1,2]. The oldest site to date is called Hajji Firuz Tepeand is dated 5,400-5,000BC. 'Tepe'(or rather 'tappe', in Farsi) that refers to a small hill or mound, something an archeologist would dig up when looking for an ancient site. Six wine jars (each about 10 inches tall, with a capacity of about 2.5 gallons) were found. The proof that they did contain wine comes from the chemical analysis of the residue in the jars. The infra-red absorption spectra showed the presence of tartaric acid and its salt, calcium tartrate. Tartaric acid is the most important acid of grapes and occurs obviously only in wine.

Wine was an integral part of everyday life since the earliest days of Rome. Wines, viticulture, varietals, pruning, aging and other wine-related issues have been critically discussed by Horace, Pliny the Elder, Virgil, Cato, and many others. At the 1st century BC, wine taverns were common in cities.

The general poverty that followed World War I was disastrous for wine industry that had not yet fully recovered from two great natural disasters: mildew and phylloxera. In 1917, the Russian Revolution began, shutting off the profitable Russian market. The general poverty and despair that naturally followed the end of World War I resulted in widespread alcoholism. Governments everywhere around that time started pushing prohibition. The Finnish Diet forbaded the import of alcoholic beverages in 1910.Several northern European countries heavily taxed alcohol and restricted its sale to state-run stores.

The first known mention of grape-based wines in India was from the late 4th-century BC writings of Chanakya the chief minister of Emperor Chandragupta Maurya. In his writings, Chanakya condemned the use of alcohol while advising the emperor and his court's frequent indulgence of a style of wine known as *madhu*[1].

1.2 Wine Components and Wine Quality

1. **Fixed acidity**

Acids not only educe sour taste, but they also modify the perception of other taste and mouth feel sensations. This is particularly noticeable in a diminished perception of sweetness demonstrated in a recent study of sourness-sweetness interactions in water,

wine and alcohol mixture (Zamora et al. 2006). In particular, Zamora and others (2006) observed during experiments, a suppressive effect of tartaric acid (solutions adjusted to pH 3.0, 3.4 and 3.8) on the perceived sweetness of fructose.

2. **Volatile acidity**

Ethanol, a major component of the wine matrix has been observed to decrease the partition coefficient of various classes of **volatile** compounds by increasing the solubility of volatile compounds in model wine systems. [**2,3,5,16**]

3. **Citric acid**

Significant non-volatile, fixed acids in wine include tartaric, malic, **citric** and succinic acids. They are mostly produced during photosynthesis, growth and ripening of grapes. Titratable acidity (TA) in grapes usually ranges from 5 to 16 g/L whereas in wine, lower values are observed at about 5 to 7 g/L range (Zoecklein et al. 1995).The actual sour taste of a wine depends on the absolute and relative amounts of the various acids, the proportion of acids present in undissociated form or as acid salts, factors that affect the pH of the wine, the sugar and ethanol concentrations. At the same level of acidity, apparent sourness of the common wine acids proceeds in the following order as follows: malic >tartaric>citric>lactic (Amerine et al. 1965, Fischer and Noble 1994).

4. **Residual sugar**

The grape-derived ingredient responsible for the primary aroma or varietal character of wines are predominantly localized in the exocarp (skin) tissue. The majority of these compounds are stored as **sugar** or amino acid conjugates in the exocarp cell vacuoles but some compounds are there as free volatiles. The compounds that are stored as conjugates are released through the action of glycosidases and peptidases introduced at the time of crushing, pressing and during fermentation thereby increasing the amounts presented for perception in the wine (Lund and Bohlmann 2006). Volatile compounds connected with varietal aroma of grapes are comprised of terpenes, norisoprenoids, pyrazines, and carbonyl compounds.

5. **Chlorides**

The level of Chloride and sodium ions in wines basically depends on the geographic, geologic and climatic conditions of vine culture. the content of these elements is increased in wines coming from vineyards which are near the sea coast, which have brackish sub—soil or which have arid ground irrigated with salt water and the molar ratio cf Cl/Na+ therefore varies appreciably and can even have a value close to one (1) which could mean the addition of salt (NaCl) to the wine. When wine contains surplus sodium (excess sodium is equal to the content of sodium ions less the content of chloride ions expressed as sodium), it is generally less than 60 mg/L, a limit which may be exceeded in exceptional cases.[**10**]

6. **Free sulfur dioxide (FSO$_2$)**

(Free sulfur dioxide) is that segment of sulfur dioxide (SO$_2$) that is not bound to the sulfur dioxide binding compounds that are present in grape juice and wine. A small amount of SO$_2$ is produced in nature as a byproduct of fermentation, but most of the SO$_2$ has been supplemented by the winemaker.

$$FSO_2 = SO_2 + HSO_3 + SO_3$$
(molecular) (bisulfate) (sulfite)
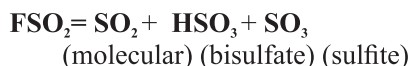
(**Source**: http://www.santarosa.edu/~jhenderson/Sulfur%20Dioxide.pdf)[11]

7. **Total sulfur dioxide**

During white wine production, it is supplemented at almost every stage of the process, and is more or less necessary after malolactic fermentation is complete. It is used to a much lesser extent during red wine production, but is still a essential component in many production techniques. The most important method of action for Sulfur Dioxide is as an anti-microbial agent. It controls the growth of harmful yeast and bacterial growth in the wine. However, the "good" yeasts used in the winemaking process have biologically developed a kind of resistance to SO$_2$ over the years, allowing them both to live in harmony with each other. This gives the "good" yeasts a competitive advantage over the harmful yeasts during the fermentation process. Another significant role of Sulfur Dioxide lies in its anti-oxidant properties. This protects wine against browning and protects the fruit-like qualities of the wine. SO$_2$ can also bind with a molecule called acetaldehyde. When SO$_2$ reacts with acetaldehyde, they tie together, producing a harmless, odorless molecule. [9]
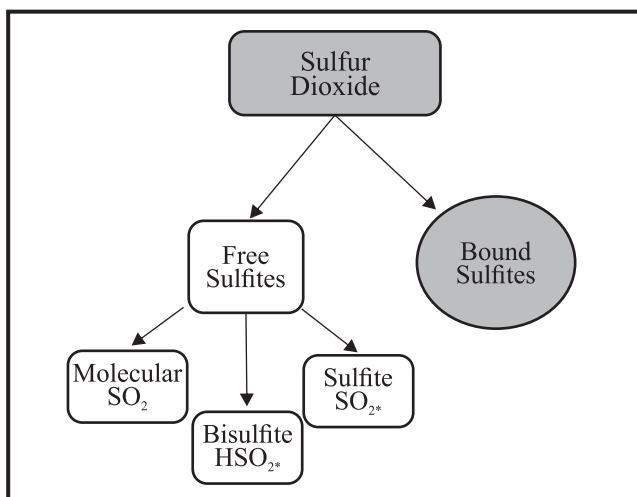

Figure 1. Sulfur dioxide in wines.
(**Source**: *http://www.santarosa.edu/~jhenderson/Sulfur%20Dioxide.pdf*) [11]

8.   Density

Density in wines is the concentration of ethanol in wines. The density of wine is close to that of water, dry wine is less, and sweet wine is higher. Water has a known density of 1.000 Kg/L.Ethanol has a density of 0.789 Kg/L.Sugar has a density of 1.587 Kg/L. So wine with 13% alcohol by volume and 0.5% sugar by volume has a density of 0.13*789 + 0.005*1587 + 0.865*1000 = 975.5 Kg/L which is considered good.**[8]**

9.   pH (phenolic compounds)

The phenolic compounds are key non-volatile components in wines, which are widely known as an essential component of wine quality. They endow wine with color (Somers 1971, Somers and Evans 1986), astringency (Landon et al. 2008) and bitterness (Fischer and Noble 1994) to wine. The phenolic composition of the finished wines actually depends on the grape and winemaking practices. Polyphenols are unbalanced compounds, with their reactions beginning as soon as the grape is crushed or pressed, ongoing throughout winemaking and aging. These reactions may involve communication or binding with aroma compounds, thus affecting aroma release and perception (Clarke and Bakker 2004).

According to (Margalit 2004; Peynaud 1984).White wines are fundamentally composed of phenols found in flesh of the grapes such as gallic acid, hydroxynammic acid esters, catechin, epicatechin, gallocatechin gallate, procyanidin and catechin gallate. The content varies and usually found in few mg/L units. On the other hand, red wines are mainly possessed of several closely related chemical groups: flavonol-3 group (catechin), flavane(3,4)diol group (leucocyanidin), flavonol-3 (quercetin), anthocyanins and tannins, in accumulation to those phenolic compounds found in white wines (Margalit 2004; Peynaud(1984).

10. Sulphates

Sulfites are a preservative to wine. Wineries have been using sulfur for a long time, since the Roman times. Wine-makers, in the Roman days would actually burn candles made of sulfur in empty wine containers. These were called Amphora. Sulfur started to be used in winemaking in the early 1900′s in order to stop bacteria and other yeasts from growing. [6]

11. Alcohol

In chemistry, an **alcohol** is an organic compound in which the hydroxyl functional group (-O H) is attached to a carbon atom. In practice, this carbon center should be saturated, having single bonds to three other atoms [**13**]. **Alcohol by volume** (abbreviated as **ABV**, **abv**, or **alc/vol**) is a standard measurement of how much alcohol (ethanol) is enclosed in an alcoholic beverage (expressed as a percentage of total volume).During the production of wine and beer, yeast is added to a sugary solution. During fermentation, the yeast organisms practically consume the sugars and produces alcohol. Technically, the density of sugar in water is greater than the density of alcohol in water. A hydrometer

is used to measure the change in specific gravity (SG) of the solution before and after fermentation. The volume of alcohol in the solution can then be calculated. Both red and white wine are found normally between 11% and 13% proof. Standard servings of beer, wine and distilled spirits each contain .06 oz of absolute or pure alcohol.[7]

2.   WINE COMPOSITION

The composition of wine is one of the key elements determining wine quality. The nature of the wine matrix actually affects the concentration of various odorants in the headspace. These effect the aroma and flavor of wine. Ethanol, the most abundant volatile compound has been shown to decrease the partition coefficient of various classes of volatile compounds in model wine systems [17](Whiton and Zoecklein 2000, Hartmann et al. 2002).[5] The suppression effect of ethanol on aroma corresponds to the increase in odor detection limit in wines in the presence of ethanol (Grosch 2001).

This cumulatively effects the contribution of aroma volatiles towards building the overall characteristic of wine aroma, smell and perception. It also enhances the overall fruity and flowery intensity of wine as a whole (Escudero et al. 2007, Guth 1998).

It has also been witnessed that the phenolic compounds also affect the release of aroma compounds in wine to some degree. Jung & Ebeler (2003) evaluated the effect of catechin on flavor volatility. Their study revealed a significant reduction in the ion response for hexanal and ethylhexanoate when compared to water but not for heptanone. The addition of tannin was found to have less effect on perceived aroma in Cabernet Sauvignon and Chardonnay wines although headspace analysis revealed reduction in odorant volatility (Aronson and Ebeler 2004). It has also been seen that the perception of fruity, citrus, strawberry, and floral aromas are high in wines with higher polyphenol content (Goldner et al. 2011).

3.   RESEARCH OBJECTIVES

The research objectives in this study are:

1.   To understand the various factors which are responsible for determining the quality of red and white wine samples.
2.   To compare such factors and identify the prominent factors among them.
3.   To identify the impact of classification techniques on data points available in both red and white wine samples.
4.   To measure the accuracy of classification techniques in both red and white wine samples.
5.   To identify the better classifier among Support Vector Machine and naïve bayes classifier.
6.   To identify the prospects of application of support vector machine in determining wine quality.

4. ASSUMPTION/HYPOTHESIS

The current research paper has been evaluated on the basis of two set of assumptions:

A.) **Regarding Quality of Wine**
1. **Ha_0**: Quality of red wine is dependent upon the alcohol content of the wine.
2. **Ha_1**: Quality of red wine is not dependent upon the alcohol content of the wine.
B.) **Regarding Accuracy metric of Classification technique**.

H_{b0}: Higher amount of accuracy is present when support vector machine is used for classification of wine data points in red and white wine samples.

H_{b1}: Higher amount of accuracy is not present when support vector machine is used for classification of wine data points in red and white wine samples.

5. RESEARCH METHODOLOGY

In this paper we have used exploratory research method to collect and inseminate data from various secondary sources such as websites, journals and published information from other sources. We have also taken insights from various web based analyst reports available in journals and online repositories.

6. DATA COLLECTION

The relevant data has been collected from different websites available over internet and other reliable sources. The data is based on 11 Input variables (based on physicochemical tests): fixed acidity , volatile acidity, citric acid, residual sugar, chlorides, free sulfur dioxide, total sulfur dioxide, density , pH, sulphates, alcohol and one output variable (based on sensory data) quality (score between 0 and 10). In this research, we have considered two datasets The two datasets are related to red and white variants of the Portuguese "Vinho Verde" wine [**4**] (**Source**: http://www.vinhoverde. pt/en/) the reference taken from [Cortez et al., 2009].(www3.dsi.uminho.pt/pcortez/ wine/).Due to privacy and logistic issues, only physicochemical (inputs) and sensory (the output) variables are used. (e.g. there is no data about grape types, wine brand, wine selling price, etc.).

7. DATA ANALYSIS

Two sample sets of wine were used i.e one contained 1599 samples of red wine and the other contained 4898 White Wine samples. These samples based datasets were tested using statistical software STATISTICA 7.

7.1   DESCRIPTIVE STATISTICS

RED

Descriptive Statistics (winequality-red DATA NEW)								
	Valid N	Mean	Sum	Minimum	Maximum	Variance	Std.Dev.	Standard Error
fixed acidity	1599	8.31964	13303.1	4.6	15.9	3.031	1.7411	0.043541
volatile acidity	1599	0.52782	843.99	0.12	1.58	0.032	0.17906	0.004478
citric acid	1599	0.27098	433.29	0	1	0.038	0.1948	0.004872
residual sugar	1599	2.53881	4059.55	0.9	15.5	1.988	1.40993	0.035259
Chlorides	1599	0.08747	139.86	0.012	0.611	0.002	0.04707	0.001177
free sulfur dioxide	1599	15.87492	25384	1	72	109.415	10.46016	0.261586
total sulfur dioxide	1599	46.46779	74302	6	289	1082.102	**32.8953**	**0.82264**
Density	1599	0.99675	1593.8	0.99007	1.0037	0	**0.00189**	**0.000047**
pH	1599	3.31111	5294.47	2.74	4.01	0.024	0.15439	0.003861
Sulphates	1599	0.65815	1052.38	0.33	2	0.029	0.16951	0.004239
Alcohol	1599	10.42298	16666.35	8.4	14.9	1.136	1.06567	0.02665

Table 1 Descriptive statistics of 1599 Red Wine samples

WHITE

Descriptive Statistics (winequality-white DATA NEW)								
	Valid N	Mean	Sum	Minimum	Maximum	Variance	Std.Dev.	Standard Error
fixed acidity	4898	6.8548	33574.7	3.8	14.2	0.712	0.84387	0.012058
volatile acidity	4898	0.2782	1362.8	0.08	1.1	0.01	0.10079	0.00144
citric acid	4898	0.3342	1636.9	0	1.66	0.015	0.12102	0.001729
residual sugar	4898	6.3914	31305.2	0.6	65.8	25.726	5.07206	0.072473
Chlorides	4898	0.0458	224.2	0.009	0.346	0	0.02185	0.000312
free sulfur dioxide	4898	35.3081	172939	2	289	289.243	17.00714	0.243009
total sulfur dioxide	4898	138.3607	677690.5	9	440	1806.085	**42.4981**	**0.60724**
Density	4898	0.994	4868.7	0.98711	1.039	0	**0.00299**	**0.000043**
pH	4898	3.1883	15616.1	2.72	3.82	0.023	0.151	0.002158
Sulphates	4898	0.4898	2399.3	0.22	1.08	0.013	0.11413	0.001631
Alcohol	4898	10.5143	51498.9	8	14.2	1.514	1.23062	0.017584

Table 2 Descriptive statistics of 4898 Red Wine samples

From **table 1 & 2**, two different samples of red and white wine were taken with variables such as fixed acidity, volatile acidity, citric acid, residual sugar, chlorides, free sulfur dioxide, total sulfur dioxide, density, pH, sulphates, alcohol to test the quality of wine being used (score between 0 and 10).It was intresting to note that in both the samples, **minimum** standard deviation and standard error was observed [Red wine sample ,**density**(0.00189 & 0.000047), White wine sample ,**density**(0.00299 & 0.000043)].On the other hand maximum standard deviation and standard error was observed [Red wine sample , **total sulfur dioxide** (32.89532 & 0.82264), White wine sample , **total sulfur dioxide** (42.49806 &0.607239)].This shows that density factor is more stable in all samples collectively (1599+4898=6497 samples.)

7.2   FEATURE SELECTION

RED				WHITE		
Best predictors for categorical dependent var: quality (winequality-red DATA NEW)				Best predictors for categorical dependent var: quality (winequality-white DATA NEW)		
	Chi-square	p-value			Chi-square	p-value
alcohol	574.9988	0		alcohol	1329.556	0
volatile acidity	401.9997	0		density	793.637	0
sulphates	327.3359	0		chlorides	556.327	0
density	195.6695	0		free sulfur dioxide	554.471	0
citric acid	183.4316	0		total sulfur dioxide	488.061	0
total sulfur dioxide	173.306	0		volatile acidity	452.605	0
fixed acidity	137.5384	0		citric acid	423.868	0
chlorides	116.9871	0		residual sugar	248.207	0
pH	103.3113	0.000002		pH	175.676	0
free sulfur dioxide	64.1325	0.001911		sulphates	166.203	0
residual sugar	49.5434	0.013827		fixed acidity	161.475	0

Figure 1. Feature Selection for Red wine samples and White wine samples. In figure 1, we can observe   the best features for prediction of quality for both red wine as well as white wine. If we consider the top four variables according to chi-square calculations, for   both set of samples, we can detect **alcohol** and **density** as common among them. Therefore, both alcohol and density in wine is important for testing the quality of the red wine and white wine.

7.3   CLASSSIFICATION TECHNIQUES

7.3.1   *SUPPORT VECTOR MACHINE ANALYSIS*

	RED				
Classification summary (Support Vector Machine), quality, Overall sample (Split Input Data into Training and Testing Samples (Classification))					
Number of support vectors= 496 (3 bounded)					
Class Name	Total	Correct	Incorrect	Correct(%)	Incorrect(%)
3	316	209	107	66.13924	33.8608
4	97	2	95	2.06186	97.9381
5	31	0	31	0	100
6	352	279	73	79.26136	20.7386
7	0	0	0	0	0
8	0	0	0	0	0

	WHITE				
Classification summary (Support Vector Machine), quality, Overall sample (Split Input Data into Training and Testing Samples (Classification))					
Number of support vectors= 1658 (1 bounded)					
Class Name	Total	Correct	Incorrect	Correct(%)	Incorrect(%)
3	1099	916	183	83.3485	16.6515
4	427	49	378	11.47541	88.5246
5	65	0	65	0	100
6	713	330	383	46.28331	53.7167
7	7	0	7	0	100
8	3	0	3	0	100
9	0	0	0	0	0

Figure 2. Support Vector machine for Red wine samples and White wine samples.

As seen in **figure 2**, we have tried to classify the available data points using support vector machine. In case of red wine samples, we could see high amount of accuracy in 2 classes of clusters (**class 3,**66.13 %) and (**class 6,**79.26). Also, in case of white wine samples, high amount of accuracy (**class 3,**83.34%) and (**class 6,**46.28%) was recorded.

7.3.2   NAÏVE BAYES CLASSIFIER ANALYSIS

	RED				
Classification summary (Naive Bayes Classifier), quality, Overall sample (Split Input Data into Training and Testing Samples (Classification))					
Class Name	Total	Correct	Incorrect	Correct(%)	Incorrect(%)
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	809	8	801	0.988875	99.01112

	WHITE				
Classification summary (Naive Bayes Classifier), quality, Overall sample (winequality-white DATA NEW)					
Class Name	Total	Correct	Incorrect	Correct(%)	Incorrect(%)
3	1112	2	1110	0.17986	99.82014
4	1774	23	1751	1.29651	98.70349
5	161	65	96	40.37267	59.62733
6	1793	717	1076	39.98885	60.01115
7	58	2	56	3.44828	96.55172
8	0	0	0	0	0
9	0	0	0	0	0

Figure 3. Naïve Bayes for Red wine samples and White wine samples.

In **figure 3**, we can see the results of classification technique Naïve bayes classifier. It was observed that in case of red wines, only one class had some kind of result (**class 8,** 0.988875). While on the other hand, in white wine sample, we observed standard amount of accuracy (**class 5,**40.37%) and (**class 6,**39.98%). This is based on classification of group of sample (red & white) being divided into training samples (50%), testing and validation (50%).

8.   DISCUSSION

1. Standard deviation in **density** of both the samples was less as compared to all other 10 variables, as evident from descriptive statistics (Table1).
2. **Alcohol** and **density** factors are the most important factors for predicting the quality of the wines, i.e both red and white wine samples.(Figure 1).

3. During classification of available data points through support vector machine, higher amount of correctness and accuracy (Min. 43 % and Max. 86% approx.) was recorded for 2 classes i.e for both red wine samples and white wine samples.

4. On the contrary, classification of available data points through naïve bayes classifier revealed lesser amount of accuracy (Min. 0.98 % & Max. 40%).

5. If we compare **Support Vector Machine** with **Naïve Bayes Clasifier**, we find that Support   vector Machine gives better results (Max 86 %) as compared with Naïve Bayes (Max. 40%).

Some of the suggestions which can be implemented at different levels include:

1. Red wine is better for preventing tooth decay as prevalent in French society. **[12**]

2. Red wine contains melatonin which can help an individual to sleep peacefully. **[12**]

3. Red wine also contains flavonoids and saponins which protect individuals against cardiovascular diseases. **[12**]

4. A controlled, regulated intake of red wine is beneficial in terms of health benefits, though alcohol content in red wine should be reduced from current levels of (10–13) % to (5-6)% for reducing harmful effects of alcohol.

5. White wine also has the ability to protect the heart against aging, which can provide preventive benefits to the organ, though not all whites have the power to do so.

6. A diet with 10 percent of energy derived from white wine was found to be as effective in assisting weight loss as a diet with 10 percent of energy derived from juices along with the additional benefits from consuming wine.

7. Statistical experiments related to factual studies in wine should use Support vector Machine instead of Naïve Bayes classifier technique.

9.   CONCLUDING NOTE

Wine trade has been in existence since centuries in past. Density and Alcohol beverage volume has been found to be major factors determining quality of red wine or white wine being used. Also, Support Vector Machine gives more accurate classification than Naïve Bayes classifier technique .Therefore, we accept the two null hypothesis $H_{a0 \text{ and }} H_{b0}$ that Quality of red wine is dependent upon the alcohol content of the wine and Higher amount of accuracy is present when support vector machine is used for classification of wine data points in red and white wine samples.. Also, we reject the alternate hypothesis H_{a0} and H_{b0}.

10.   RESEARCH IMPLICATIONS

The current research can have numerous implications mostly related to how global wine manufacturing and trade and can be conducted in more efficiently and effectively in this current age of cut throat competition. Further, the suggestions mentioned in the research paper can be incorporated for social benefits without limiting the possibility of gaining higher demand in the market, higher growth in terms of market share, higher productivity and improved overall performance for all the parties involved.

11.   LIMITATIONS OF THE STUDY

Our present work is limited to exploring the factors related to composition of red wine and white wine. Time and cost factors were also responsible for limiting the boundaries of the current research. Most of the data had been collected from open ended secondary sources which are freely available over the internet.

12.   SCOPE FOR FURTHER RESEARCH

We also propose of enhancing the results of current paper by studying more variables involved and their interrelationship in the near future. The paper also gives certain insights on different inter-related factors which determine the levels of improvements that can be made for understanding the wine industry with focus on other aspects or physiochemical properties of wine. The future objective could be directly or indirectly related with improving the quality of wine for health benefits, thereby influencing customers in terms of acceptability and usability.

REFERENCES

- Amerine, M. A., Roessler, E. B., & Ough, C. S. (1965). Acids and the acid taste. I. The effect of pH and titratable acidity. *American Journal of Enology and Viticulture, 16(1),* 29-37.
- Aronson, J., & Ebeler, S. E. (2004). Effect of polyphenol compounds on the headspace volatility of flavors. *American journal of enology and viticulture, 55(1),* 13-21.
- Camara, J. S., Arminda Alves, M., & Marques, J. C. (2006). Development of headspace solidphase microextraction-gas chromatography-mass spectrometry methodology for analysis of terpenoids in Madeira wines. *Anal. Chim. Acta,* 555, 191-200.
- Clarke, R. J., & Bakker, J. (2004). *Wine flavour chemistry (p. 339).* Oxford: Blackwell.
- Cohen-Goldner, S., & Paserman, M. D. (2011). The dynamic impact of immigration on natives' labor market outcomes: Evidence from Israel. *European Economic Review, 55(8),* 1027-1045.
- Conner, J. M., Birkmyre, L., Paterson, A., & Piggott, J. R. (1998). Concentrations of ethyl esters at different alcoholic strengths. *J. Sci. Food Agric,* 77, 121-126.
- Cortez et al., 2. *http://www.vinhoverde.pt/en/.*

- Escudero, M., Querol, X., Pey, J., Alastuey, A., Pérez, N., Ferreira, F., ... & Cuevas, E. (2007). A methodology for the quantification of the net African dust load in air quality monitoring networks. *Atmospheric Environment, 41(26)*, 5516-5524.

- Fischer, U., & Noble, A. C. (1994). The effect of ethanol, catechin concentration, and pH on sourness and bitterness of wine. *American Journal of Enology and Viticulture, 45(1),* 6-10.

- Grösch, S., Tegeder, I., Niederberger, E., Bräutigam, L., & Geisslinger, G. (2001). COX-2 independent induction of cell cycle arrest and apoptosis in colon cancer cells by the selective COX-2 inhibitor celecoxib. *The FASEB Journal*, *15*(14), 2742-2744.

- Guth, A. H. (1998). The inflationary universe: The quest for a new theory of cosmic origins. Random House.

- Hartmann, P., Mc Nair, H., & Zoecklein, W. (2002,). Measurements of 3-alkyl-2-methoxypyrazine by headspace solid phase microextraction in spiked model wines. *J. Enol. Vitic*, 53, 285-288.

- Hermjakob, H., Montecchi-Palazzi, L., Lewington, C., Mudali, S., Kerrien, S., Orchard, S., ... & Margalit, H. (2004). IntAct: an open source molecular interaction database. Nucleic acids research, 32(suppl 1), D452-D455.

- http://winefolly.com/tutorial/sulfites-in-wine/. (n.d.).

- http://www.answers.com/Q/Is_red_wine_stronger_than_white_wine.

- http://www.answers.com/Q/What_is_the_density_of_wine. (n.d.).

- http://www.calwineries.com/learn/wine-chemistry/chemical-components-of-wine/sulfur-dioxide. (n.d.).

- http://www.oiv.int/oiv/files/6%20-%20Domaines%20scientifiques/6%20-%204%20Methodes%20d%20analyses/6-4-1/EN/OIV-MA-D1-03.pdf. (n.d.).

- http://www.santarosa.edu/~jhenderson/Sulfur%20Dioxide.pdf. (n.d.).

- https://www.in.lifestyle.yahoo.com.

- *IUPAC, Compendium of Chemical Terminology, 2nd ed.the "Gold Book".* (1997, Online corrected version: (2006)).

- J. R. (2006). *The Oxford Companion to Wine Third Edition.* (pp. 355–356). Oxford University Press.

- Jung, D. M., & Ebeler, S. E. (2003). Headspace solid-phase microextraction method for the study of the volatility of selected flavor compounds. *Journal of agricultural and food chemistry, 51(1),* 200-205.

- Lund, S. T., & Bohlmann, J. (2006). The molecular basis for wine grape

quality-a volatile subject. *Science,* 311(5762), 804-805.

- McGovern, P. (2003). Ancient Wine.

- P.E. McGovern, S. F. (2000). *The Origins and Ancient History of Wine.* (Gordon and Breach, Amsterdam).

- Pers, J. O., Devauchelle, V., Daridon, C., Bendaoud, B., Berre, R. L., Bordron, A., ... & Berthou, C. (2007). BAFF-modulated repopulation of B lymphocytes in the blood and salivary glands of RITUXIMAB-TREATED patients with Sjögren's syndrome. *Arthritis & Rheumatism, 56(5),* 1464-1477.

- Peynaud, E. (1984). *Knowing and making wine* (No. 663.22/P515). New York: Wiley.

- Somers, T. C. (1971). The polymeric nature of wine pigments. *Phytochemistry*, 10(9), 2175-2186.

- Somers, T. C. (1986). Evolution of red wines I. Ambient influences on colour composition during early maturation, *Vitis, 25,* 31-39.

- Voilley, A., Beghin, V., Charpentier, V., Charpentier, C., & Peyrond, D. (1991). Interactions between aroma substances and macromolecules in a model wine. *Food Sci. Technol.* , 24, 469-472.

- Whiton, R. S., & Zoecklein, B. W. (2000). Optimization of headspace solid-phase microextraction for analysis of wine aroma compounds.. , 51 (4),. *Am. J. Enol. Vitic* , 379-382.

- Zamora, J., Abraira, V., Muriel, A., Khan, K., & Coomarasamy, A. (2006). Meta-DiSc: a software for meta-analysis of test accuracy data. *BMC medical research methodology, 6(1),* 1.

- Zoecklein, B. W., Fugelsang, K. C., Gump, B. H., & Nury, F. S. (1995). Laboratory procedures. In Wine analysis and production 310-516. Springer US.