FREE SO_2 MEASUREMENTS IN WINEMAKING – COST ANALYSIS OF COMPETING APPROACHES

A Project Paper

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

Master of Professional Studies in Agriculture and Life Sciences

Field of Food Science and Technology

by

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May 2018

ABSTRACT

Sulphur dioxide (SO_2) is used in winemaking to control oxidation and prevent microbial spoilage. The fraction of SO_2 that is responsible for this is the unbound free SO_2. Currently there are several methods for measuring free SO_2 in a winery. Different analyses have varying levels of technological sophistication and cost. There have been a few trade publications evaluating which methods should be used for which size wineries but they have stopped short of making recommendations based on the number of lots produced. This project uses job costing to produce a model that provides recommendations based on cost for which method out of aeration oxidation, Ripper, spectrophotometer with a colorimetric assay, and an autoanalyzer should be used. Using the assumptions of; no additional required fixed overhead, 14 analysis per lot per year, labor at $15 dollars an hour, and omitting sampling, the following recommendations were generated. Wineries producing less than two lots of wine per year should use a commercial lab, wineries producing between two and one-hundred and fifty lots a year should consider Ripper, aeration oxidation, and a spectrophotometer with a colorimetric assay, and wineries producing more than one-hundred and fifty lots a year should invest in an automated system such as an autoanlayzer. Since not all wineries have the same operating parameters a customizable calculator was also developed.

BIOGRAPHICAL SKETCH

Kevin received his bachelors degree in Chemistry from the Colorado School of Mines in 2013. Since then he's worked at the National Renewable Energy Laboratory, done a land development project in California, made what is believed to be the second descent of a few rivers in Patagonia, cofounded Roam Oatmeal, worked as an assistant winemaker in Oregon, and worked wine vintages in Chile, and Australia.

This project is dedicated to all who pursue adventure in life.

ACKNOWLEDGMENTS

I would like to thank my advisor Dr. Gavin Sacks for the opportunity to work on this project and his continued support. I would also like to than the entire Sacks lab. Not only do they provide a great amount of knowledge but their support through wine tastings and snacks was great. The entire Cornell community especially the V&E faculty along with Erin Atkins has provided great support as well. Also, Paulina Amezcua provided great accounting support. Megan Marchuk was great help with forms. I would also like to thank my family especially Tom Smith for being a great role model and opening many doors.

TABLE OF CONTENTS

Biographical Sketch	iii
Dedication	iv
Acknowledgements	v
Introduction	1
The Model	4
Results	6
Customizable Calculator	11
Conclusions	12
Appendix	14
References	15

CHAPTER 1

Introduction

Background on free SO_2 in winemaking

Sulfur dioxide (SO_2) plays an integral role in winemaking as it is one of the only tools available to the winemaker to limit oxidation and microbial spoilage (Sacks 2015). While there are naturally occurring sulfites in wines it is common to add exogenous SO_2 either in the form of a salt such as potassium metabisulfite or through the use of SO_2 gas. Once introduced into the wine the SO_2 takes on many different forms. One fraction is bound to molecules in the wine such as carbonyls and phenolics. Unless conditions allow for the reversal of this binding these bound SO_2 molecules do not play an active part in limiting new oxidation or microbial spoilage. The fraction that is unbound is called free SO_2. This fraction is in equilibrium between the molecular form, sulfite, and bisulfite. The molecular form is responsible for the antimicrobial activity of SO_2 and if the concentration is high enough this fraction is also responsible for nostril singing. The bisulfite species are involved in limiting oxidation through interactions with hydrogen peroxide and quinones (Waterhouse 2016). The sulfite species is largely absent at wine pH. Since the free SO_2 is the active portion that delivers the functionality that the winemaker desires the amount of free SO_2 is often measured separately from the total SO_2. Total SO_2 is regulated by governments to not exceed specified levels.

There are currently several choices available to the industry for measuring free SO_2. Earlier work showed in a self-reported study that aeration oxidation and the Ripper method are the most widely used in industry (Howe et al. 2015). Aeration oxidation involves acidifying a sample and aspirating under vacuum through a hydrogen peroxide solution to trap SO2, which can then be titrated back to the original color to determine the amount of free SO2 (Iland.P 2004). The

Ripper method is also a colorimetric titration but no separation step is used. Instead, SO_2 is determined by iodometric titration with a starch indicator. Both the Ripper and aeration oxidation methods require a lab technician to perform every step "by hand" and also to make visual judgements on color change to determine the results.

The self-reported results showed that a small fraction of the industry uses more sophisticated instrumentation than the above described glassware. These methods include the use of a spectrophotometer coupled with colorimetric assays to determine the relative absorbance and subsequent free SO_2 concentration. This approach can have varying degrees of automation. A lab technician can do most of the pipetting necessary for the assay "by hand" and manually put the sample into the spectrophotometer. This approach can also be automated through the use of autoanalyzers. These expensive machines do both the mixing of the chemicals needed for the assay and also automatically read the results.

There is also another option for wineries to measure free SO_2. Commercial labs such as the popular Enological Testing Services (ETS) can perform the analysis for a fee. The advantage is that commercial labs can be certified and the winery only has to obtain the sample but does not need to be technically versed in the lab methods.

Motivation for the cost analysis

With several methods available to a winery for measuring free SO_2 there has been some work to determine which methods should be employed. Some work has focused on determining the robustness of the methods (Howe et al. 2015). This work can help a winery choose their preferred method based on the desired level of accuracy and precision they desire. Other trade publications have focused on making recommendations on which type of equipment should be invested in based on winery size (Jacobson 2009; Jacobson 2015). While these publications provide a valuable starting point and information for deciding which type of equipment to buy for “large” vs. “small” wineries, a rigorous analysis was not performed to determine how to define the cutoff between “large” and small” and their operating parameters. Also, some of the prices for the tests were listed as being low instead of having an actual number. In interpreting this it could be assumed that the price of the materials and chemicals needed to perform the tests such as Ripper and aeration oxidation are low but that the hourly cost of the technician may not have been fully accounted for. The goal of this work was to create a cost model that can provide specific recommendations on which method to use based on operating parameters of a winery.

CHAPTER 2

The Model

Job Costing

Job costing was used to determine the cost of each analysis. Job costing is a system that accounts for direct materials and direct labor and then adds in a distributed overhead cost. The overhead costs can include both variable and fixed overhead. This costing system allows for costs to be determined for both goods and services.

Assumptions

To determine the cost per test and total yearly cost a few operating assumptions had to be made for wineries. The first is that it is not the total volume of wine produced that determines the amount of lab work necessary but rather how that wine is divided into lots. A lot of wine is a designation in the winery that states that all the wine in the lot will be treated the same. The wine can all be in the same tank or a lot could be a mix of tanks and barrels. Since the wine in each lot is treated the same it is all analyzed at the same time using single sample if it's in the same tank or a composite sample if there are multiple storage containers. With this in mind it does not matter if the tank holds 10,000 gallons or 100 gallons since the sampling and analysis will be the same. The second assumption is that free SO_2 would be measured fourteen times per year per lot of wine. This number could certainly change from winery to winery but fourteen captures measuring free SO_2 before inoculation and fermentation, post fermentation, and once a month during storage for a year.

In allocating the cost of the equipment a depreciable life of ten years was used with a salvage value of zero. Since the cost of sampling is the same for each analysis and could vary from winery to winery the cost of sampling was omitted. Also, ETS was used as the commercial lab and their rate of $20 (repeated use discount) was used. Since ETS offers a free courier service in larger wine producing areas such as California and Oregon shipping costs were not added but could be easily added in for wineries in other regions.

Time per analysis was assumed to be a function of the number of analyses run in a batch, where the batch size is the number of lots. To create this curve we estimated reasonable values for amount of time per test if someone only runs one analysis per month and the fastest amount of time someone can perform a test if they run the test daily and are well trained. The formula for the efficiency curve is as follows:

$$= min + (max - \mathrm{min}) * \left(\frac{one\ lot\ of\ wine\ produced\ per\ year}{number\ of\ lots\ of\ wine\ for\ subject\ winery}\right)$$

where min is the minimum amount of time needed per test for the most efficient lab and max is the amount of time needed per test for the winery that only performs fourteen analyses per year. This efficiency function was then multiplied by an hourly rate of $15. This hourly rate of $15 comes from first hand experience working for small family owned wineries however, large producers such as E&J Gallo are reported to be higher. Since the hourly rate will vary between wineries a producer should always use their own numbers and a customizable calculator has been developed.

Variable overhead was calculated at 51% of labor costs. This number, like the hourly labor rate is also variable and a producer should use their own numbers. 51% was chosen from personal communications with an institution that provides analytical services to many industries including wine. Fixed overhead was omitted from the analysis as it was indicated through personal communication that accounting for fixed overhead was unnecessary in a typical winery, under the assumption that no additional building facilities or supervision would be needed to do the analyses.

CHAPTER 3

Results

Yearly Cost to the winery

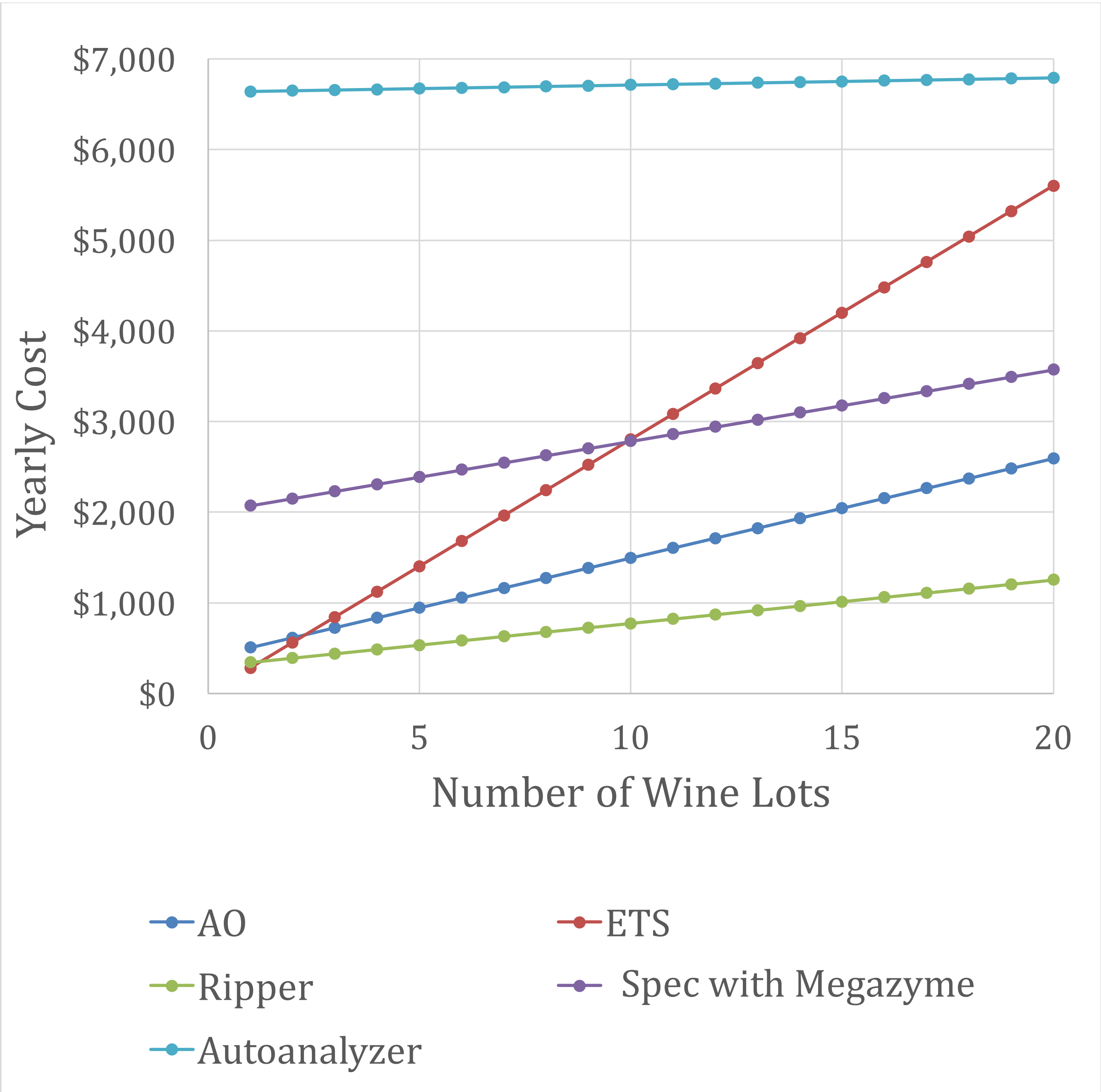

Figure 1. Yearly cost to the winery

The first parameter that was evaluated was comparing the yearly cost to the winery of using each analysis method. Figure 1 shows the results for the low end of the range with wineries producing between one and twenty lots. As can be seen in the graph the commercial lab ETS provides the lowest cost when a winery produces less than two lots of wine per year. Once more lots are produced the lowest yearly cost is the Ripper method followed by aeration oxidation. The spectrophotometer does not become more cost effective than the commercial lab until ten lots of wine are produced.

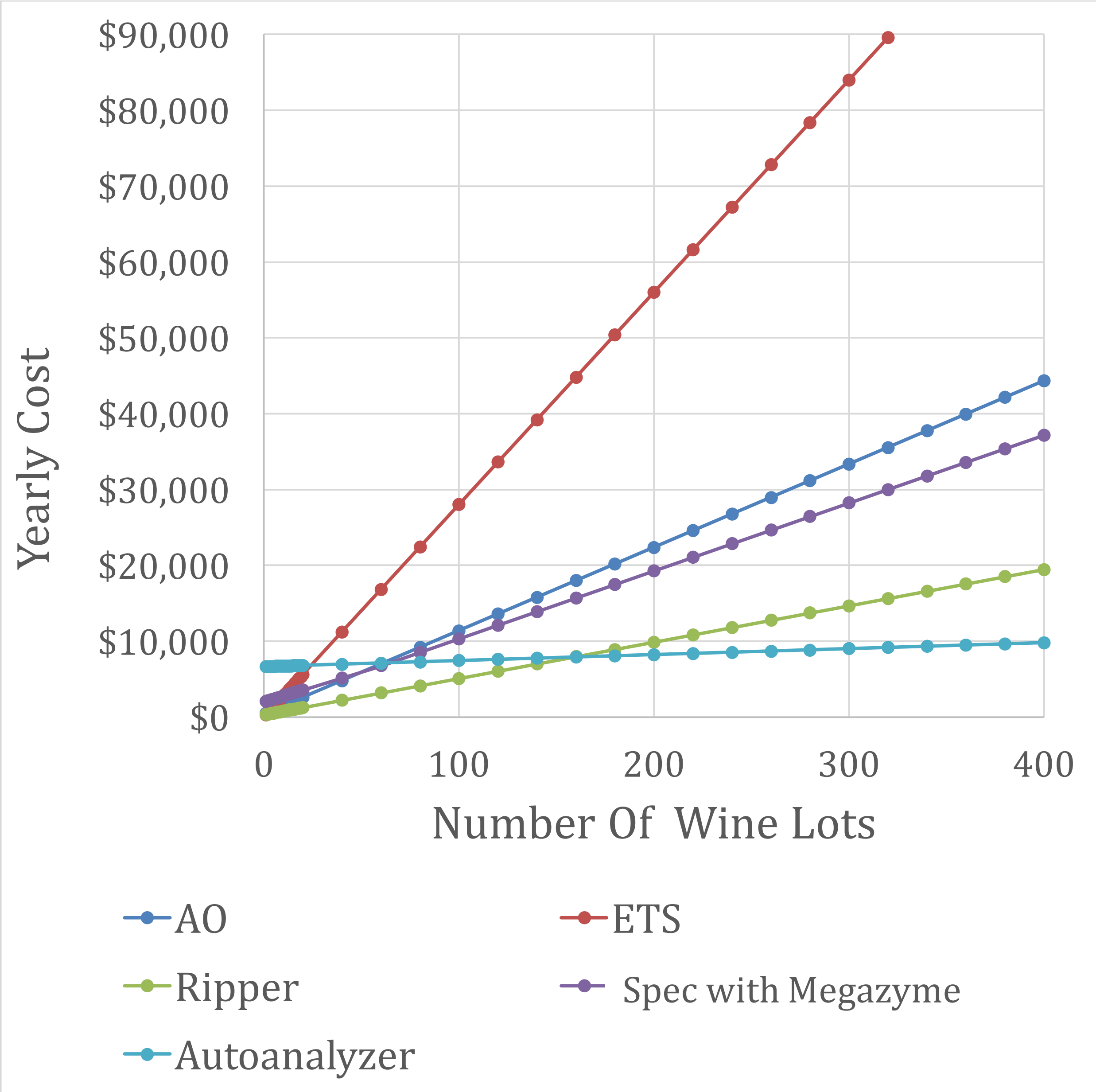

Figure 2. Yearly cost to the winery

Looking at yearly cost to the winery but on the upper end of the scale (figure 2) it becomes clear that a winery that produces around 150 lots of wine can look to purchase an autoanalyzer as it beats out the Ripper test for lowest annual cost. The spectrophotometer becomes more efficient than aeration oxidation for a winery producing around 50 lots of wine. It is also shown as a winery produces more and more lots the gap between the commercial lab and in-house testing services grows.

Cost Per Test

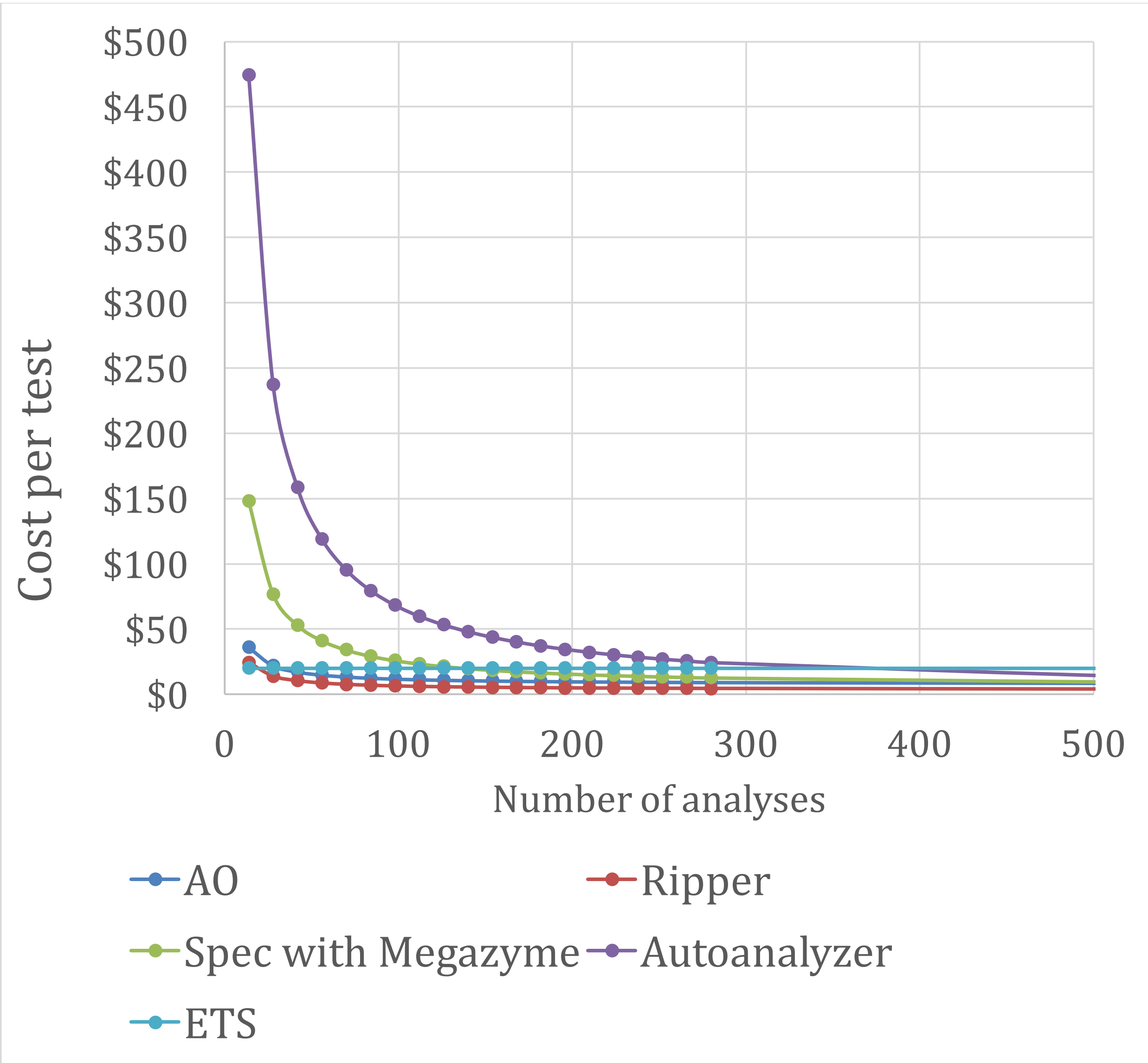

Figure 3. Cost per test vs. number of analyses

To better show the efficiency curves the cost per test can be evaluated. Please note that this cost per test still uses the previously described assumptions, particularly analyses become faster with increasing number of lots and that each wine lot is tested fourteen times per year. As discussed above the most cost-effective method for a winery producing less than two lots per year is to use a commercial lab such as ETS. The price for this service is $20 however for a small winery the cost of using an autoanalyzer can be as much as $474 per test.

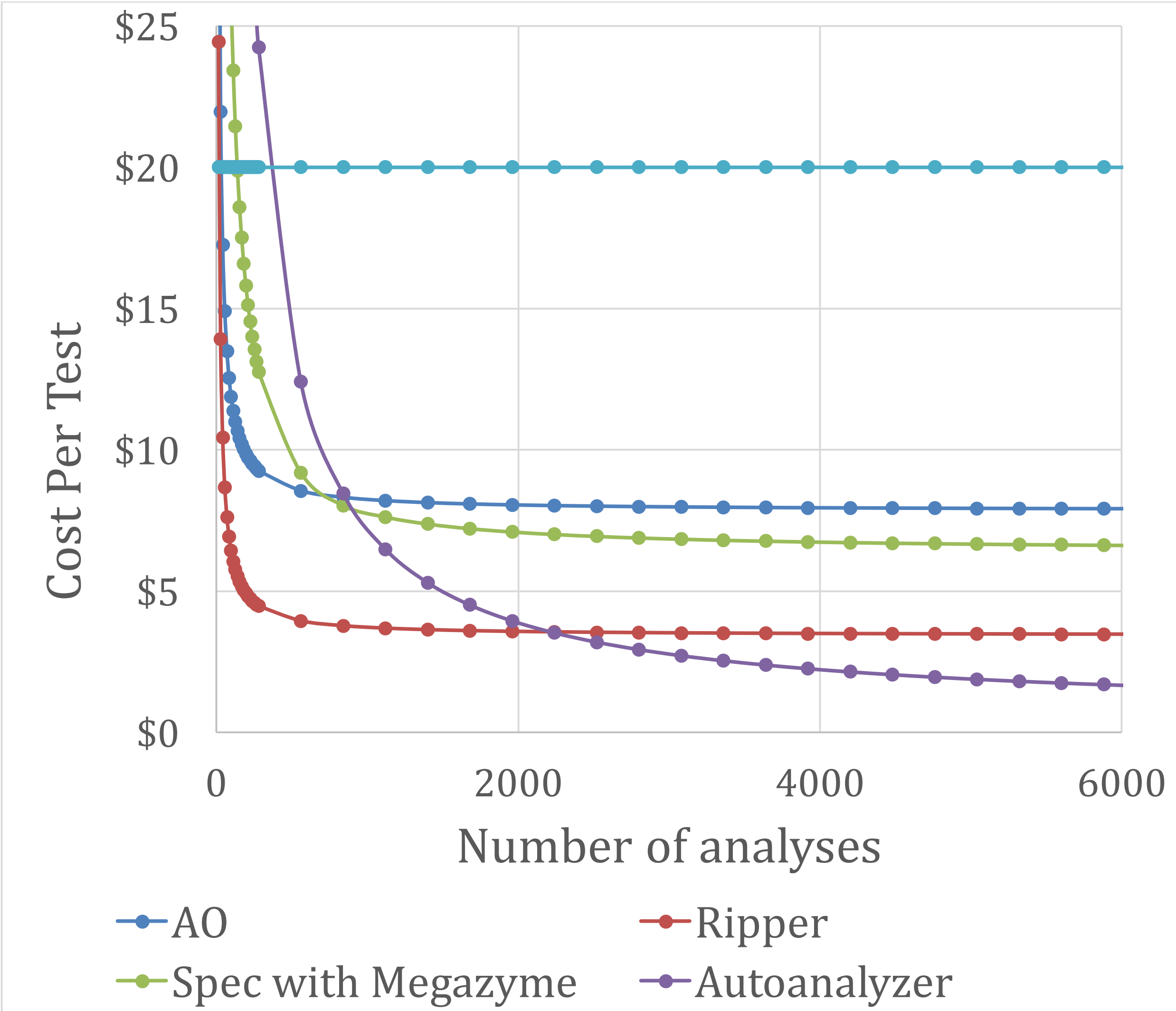

Figure 4. Cost per test vs. number of analyses

Looking at the cost per test for larger wineries producing a large number of lots per year the cost per test for the autoanalyzer can be bellow $2. This is significantly less expensive than using a commercial lab at $20 per test. Since winery size for this analysis is based on number of lots not volume produced a winery that would benefit from an autoanalyzer would be a winery producing over 150 lots of wine. These lots could be individual barrels that are treated separately or large tanks containing thousands of gallons of wine.

CHAPTER 4

Customizable Calculator

Customizable Calculator

		Yearly Analyses
Number of Lots	1	14
Yearly Number of analyses per lot		
Hourly cost of employee performing the analyis		
Variable overhead rate (percent of direct labor)		
Additional fixed overhead needed		
Required		
Optional		

	AO	Ripper	Spec with Megazyme	Autoanalyzer	ETS
Yearly cost	$505.02	$342.04	$2,071.94	$6,639.97	$280.00
Cost per test	$36.07	$24.43	$148.00	$474.28	$20.00
time per test (mins)	60	60	120	120	1 day

Figure five. Customizable calculator

Since not all wineries will have the same operating parameters as the above assumptions a customizable calculator was built to allow for individualized inputs. If a winery needs to build additional facilities or hire additional supervision fixed overhead can be included. The percent of variable overhead as a percent of labor cost that is applied can be changed as well. The hourly cost of employees can be updated. This could be used if a more senior staff member such as the winemaker is performing the analysis for $50/hour vs the currently assumed $15. The number of analyses per lot per year can also be changed to account for more or less testing.

CHAPTER 5

Conclusions

Conclusions

As discussed in the assumptions section one important factor in determining which analysis method to use a winery size should be defined by the number of lots of wine produced not based on volume of wine produced. This also ties in with the idea of efficiency being very sensitive to the number of analysis done at one time. This is due to both labor efficiency and the time it takes to setup and calibrate the equipment.

Using the assumptions listed above a few recommendations can be made. Wineries producing less than two lots of wine per year should use a commercial lab such as ETS for free SO_2 measurements. Wineries producing between two and one hundred and fifty lots per year should consider Ripper, aeration oxidation, and spectroscopy with the Ripper method being the most cost effective. Wineries producing more than one hundred and fifty lots per year should consider investing in automated systems such as an autoanalyzer. A number of factors such as labor cost, overhead, and the number of times per year a wine lot is tested can affect the above recommendations and should be taken into account.

Another factor effecting the choice of system to use that was excluded from this model is the accuracy and precision of different methods. The likely impact is that a winery would have to rerun samples or quality control checks for methods that are considered less robust and this would increase the cost. Another hidden cost could be if the number produced by the test is very wrong the wine quality may be affected and winery economics could suffer.

Also, not included in this model is that for some of the methods such as aeration oxidation one person can run multiple units at one time and this would increase efficiency. Also, not included in this model is that some equipment such as a spectrophotometer can be used for other lab analysis and the cost of the equipment can be spread between other tests.

APPENDIX

AO Depreciation	price	schedule	salvage	yearly amount
Glass setup free and total (Davidson)	$310.00	10	0	$31.00
vacuum (Davidson)	$495.00	10	0	$49.50
Burette with squeeze bottle	$86.00	10	0	$8.60
20 ml pipet	$6.95	10	0	$0.70
pipet bulb	$20.95	10	0	$2.10
total				$91.89
Ripper Depreciation				
25 ml burette	$31.95	10	0	$3.20
Burette Stand	$26.95	10	0	$2.70
single burette clamp	$14.95	10	0	$1.50
pipet 25	$6.95	10	0	$0.70
pipet 5	$4.80	10	0	$0.48
pipet 1	$3.25	10	0	$0.33
flask 125	$3.50	10	0	$0.35
flask 250	$4.25	10	0	$0.43
total				$9.66
Spectrometer depreciation				
Thermo Scienfific Genesys 840-208100 UV/vis (Cole Parmer)	$6,900.00	10	0	$690.00
total				$690.00
Autoanalyzer depreciation				
Chemwell Autoanlyzer	$30,000.00	10	0	$3,000.00

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