The project: Predictive shelf life model for wine

The team: Provisor and Food Science Australia have joined forces to tackle a project on predicting the shelf life of wine.

MISG attendees

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Provisor: Provisor is a technical research consultancy organisation that provides services to the wine and food industry. The company was founded about four years ago based on a strong request to link knowledge with practical commercial applications. We fill gaps in our customers' technical programs with our skilled consultants in process engineering, lean six sigma, food technology, sensory analysis and winemaking. Our premises are based at the Waite campus of the University of Adelaide, and include sensory and chemical laboratories, as well as world class small scale winemaking facilities. Provisor's shareholders are CSIRO, University of Adelaide, AWRI and SARDI.

Food Science Australia: Food Science Australia (FSA) is Australia's leading food, health and nutrition research organisation and a joint venture of **CSIRO** and the **Victorian Government**. FSA is committed to turning scientific research into innovative solutions for the food industry in Australia and overseas. Through our science we support the health and well-being of consumers. FSA aims to deliver innovative food research that generates high quality outcomes, to be the food industry's principal source of expertise, objective opinion and knowledge; and to support industry sustainability and community well-being while providing competitive advantages to the Australian Industry.

Project background

The shelf life of wine depends on the environmental conditions a packed wine is exposed to as well as the chemical composition of the wine. The term shelf life includes all aspects related to irreversible damage to the product. With foods the microbial, chemical and physical changes that can take place over time must be known and a manufacturer must be confident in statements related to best before and use by dates. With wine these parameters have never been established as wine compositional changes have never been considered to pose a threat to consumer health. More recent insights however show that wine exposed to heat will actually speed up the formation of ethyl carbamate (EC, a carcinogenic component) depending on the level of urea in the original wine (Butzke et al., unpublished article). Apart from the health risk, the impact of heat on qualitative sensory changes is likely to be significant.

We realise that there is a great need for a determination tool to predict the remaining shelf life of a wine or the loss of shelf life as a function of wine composition and temperature fluctuations. The temperature profile and temperature cycling determines the input of energy into a bottle of wine and the consequent changes that take place can be determined in controlled trials. A predictive computer model will be developed that uses the input and output data to determine the relationship between energy accumulation and the estimated remaining shelf life of wines.

Under ideal storage conditions (cool, dark and humidity controlled environment) wine will exhibit the longest theoretically possible shelf life. Environmental factors influence the rate of chemical reactions taking place inside the bottle. For example the rate of oxygen uptake is increased with higher temperatures whereas the level of free sulphur dioxide is reduced. Wine composition parameters that influence the shelf life are: the acidity and pH, (free) SO_2 levels, ascorbate, the concentration of tannins and phenolics, and the colour as defined by spectrophotometric measurement. Tannins protect the wine from oxidation by acting as an anti-oxidant, and thus the level of tannins co-determines the potential shelf life of wine. Thus chemical analysis can provide insight into what stage of shelf life the wine is, if the relationship between heat load and chemical composition can be established. In addition the sensory assessment of a wine can indicate the potential shelf life and is an important tool to determine the quality status of wine at any point in time.

Whilst the chemical reactions that take place inside a bottle are complex if not unknown, the potential shelf life is still a guessing factor. The composition of a wine is largely determined by the grape variety and regional growing conditions and the winemaker has great influence on protective measures such as acidity, pH, SO2, ascorbate and tannin extraction levels. The time of harvest, processing parameters and additions all influence the final composition of the wine. Limitations to protective measures are formed by the sensory characteristics as defined by wine style and legal requirements in place.

Once a wine gets bottled, boxed, and stored in a climate controlled environment, the product will be ready for the market at some point in time. When a product leaves the site, and transport companies take over the responsibility of maintaining optimum conditions, the winery has little control over the product. In particular, temperature fluctuations during shipments have been a major issue with respect to reducing the quality of the product. In a transport experiment it was shown that the effect of temperature fluctuations impacted on shelf life (Butzke at al., unpublished article). In order to quantify this effect the equivalent time under ideal cellar conditions was calculated assuming first order reaction kinetics. The classic Arrhenius equation assumes that the activation constant or rate of a first order chemical reaction increases exponentially with temperature. Subsequently, the following equation was used to summarize the heat exposure:

Time1 = Time2 x 10E((Temperature2 - Temperature1)/k10)

Time1 is the equivalent time at reference cellar temperature. Time2 is the time spent at elevated or lowered temperature. Temperature1 is the ideal reference cellar temperature. Temperature2 is the elevated or lowered temperature recorded by the data logger. k10 (°F) indicates the increase in temperature to speed up a reaction tenfold.

Relative rates (relative to 10 ºC) for some important reactions such as oxygen uptake, browning and sulphur dioxide decline are known (Boulton et al, 1996). This knowledge will be useful in our modelling approach; however no distinction was made between varying wine compositions.

Whilst climate controlled transport is ideal, wine companies cannot always afford this sort of transport. Cheaper alternatives such as insulation blanketing have been trialled in the past with some success. Extreme conditions such as exposure to hot weather or extreme cold will not always safeguard the protective measures. Insulated containers might delay the warming up inside but will also capture the heat and thus extend the period wine is exposed to high temperatures. In addition, human error or incomprehension of the effect of environmental conditions on wine quality are other factors to consider.

In summary the shelf life and quality of wine is mostly unknown and depends on compositional as well as external factors. While a perfectly “good” wine may leave the winery to be marketed, the consumer might end up with a reduced quality product.

In this project we will first need to investigate the chemical composition changes by controlled heat load exposure trials. A literature review on the topic will provide some useful data which together with the trial data and the MISG input can provide the basis for semi-empirical relationships that form the basis of shelf life model. The proposed project entails six phases:

1. Research into the effect of temperature on wine composition
2. Determination of trial set up in order to obtain useable modelling data
3. Chemical and sensory analyses
4. Building a predictive model using mathematical analyses

5. Proof testing of the model
6. Commercialising the Intellectual Property by offering testing and advice

Although the initial focus of this project is to establish the effects of heat load on compositional changes, further factors to be considered will be packaging materials and container configurations. Bottle closures differ in their capacity to exclude oxygen from entering the bottle. Cork is more porous and will allow oxygen to enter whilst screw caps are known to create a reductive environment. The exposure to heat will consequently be different.

Considering the vast range of wine styles available, the project will focus on around eight styles that are the most important to Australian economy, e.g. white versus red, premium versus commercial. For example we could include a barrel fermented premium Shiraz and a commercial Shiraz, similarly a Cabernet Sauvignon and a Chardonnay.

The input from MISG will be to investigate and where possible establish the mathematical relationships with respect to the above mentioned problems. In addition we would like to establish a practical program to verify the theoretical relationships and statistical reliability. Ultimately the outcome of this project will be a user friendly model and suggestions towards data presentation will be beneficial.

Useful Project Literature References (incomplete list):

1. Berg, H.W., and M. Akiyoshi. Some factors involved in the browning of white wines. Am. J. Enol. Vitic. 7:1-7 (1956).

2. Boulton, R.B. The relative rates of selected reactions in wines. In Principles and Practices of Winemaking. p. 443. R.B. Boulton, V.L. Singleton, L.F. Bisson and R.E. Kunkee. Aspen Publishers, New York, NY (1995).

3. Bisson, L.F. Nitrogen metabolism during fermentation. In Principles and Practices of Winemaking. pp. 153-167. R.B. Boulton, V.L. Singleton, L.F. Bisson and R.E. Kunkee. Aspen Publishers, New York, NY (1995).

4. Butzke, C.E., and L.F. Bisson. Ethyl carbamate preventative action manual. (http://www.cfsan.fda.gov/~frf/ecintro.html) University of California Cooperative Extension, Davis, CA (1997).

5. Francis, I.L., M.A. Sefton and P.J. Williams. The sensory effects of pre- or post-fermentation thermal processing on Chardonnay and Semillon wines. Am. J. Enol. Vitic. 45:243-251 (1994).

6. Henschke, P.A. and C.S. Ough. Urea accumulation in fermenting grape juice. Am. J. Enol. Vitic. 42:317-321 (1991).

7. Ough, C. S. Some effects of temperature and SO_2 on wine during simulated transport or storage. Am. J. Enol. Vitic. 36:18-22 (1985).

8. de la Presa-Owens, C. and A.C. Noble. Effect of storage at elevated temperatures on aroma of Chardonnay wines. Am. J. Enol. Vitic. 48:310-316 (1997).

9. Riberéau-Gayon, J. Contribution des oxydations et réductions dans les vins. Application à l'étude du vieillissement et des casses. Ph.D. thesis, University of Bordeaux, France (1933).

10. Stevens, D.F. Ethyl carbamate formation in wines undergoing long-term storage. M.S. Thesis, Dept. of Viticulture and Enology, University of California, Davis (1994).

11. Stevens, D.F. and C.S. Ough. Ethyl carbamate formation: reaction of urea and citrulline with ethanol in wine under low to normal temperature conditions. Am. J. Enol. Vitic. 44:309-312 (1993).