Terroir

An Integrated Wine Science Publication

PEST POWER

the ETA for IPM is now

TASTE DETECTIVES

the electronic nose, knows

COLD HARD FACTS

keeping icewine grounded

THE MATURE WINE

getting better with age

HEALTH RAISER

benefits in wine

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Terroir

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Integrated Pest Management: A Step Towards a Sustainable Future in the Niagara Wine Industry: Victoria Balkwill Tweedie, Rebecca Englert, Alexandra Kasper, Sarah McPherson, Daniella Pryke, George Wells
Experts versus Electronics: A Comparison of Electronic Sensors and Expert Panels for the Quality Control and Assurance of Wines in the Niagara Region: Jesse Bettencourt, John Buchanan, Rebekah Ingram, Philip Lauman, Eric Turner, Jared Valdron, Josanne White
From The Ground Up: Uncovering the Effect of Terroir on Niagara Vidal Icewines: Mercedes Mabee, Mary Kate MacDonald, Harrison Martin, Kira Moor, Mackenzie Richardson, Ben Windeler
Is Older Wine Always Better? Rebecca DiPucchio, Madeena Homayoun, Melissa Ling, Jacqueline Rotondi, Alex Shephard, Adelle Strobel, David Yun
Bottle-y Benefit or Bottle-y Harm? Wine, Health, and the Niagara Region: Matthew Galli, Kerri Kosziwka, Lori Minassian, Pratik Samant, Christina Spinelli, Hanna Stewart

WINE SCIENCE

HOW CAN SOMETHING THAT TASTES SO GOOD BE SO INTERESTING SCIENTIFICALLY?

This Publication is written by members of the ISCI 3A12 class of 2013

Working in small groups, students in ISCI 3A12 examined the science behind wine making, from the art of viticulture to its eventual consumption by the public. Students performed literature-based reviews and original research in order to understand the wine industry and its complexity; including the environmental requirements and consequences of winemaking, the short- and long-term health effects of drinking wine, and what factors contribute to the quality, aroma, and taste of wine. This research was formatted to resemble a publicly accessible scientific article, and compiled to create each Vintage of *Terroir*.

We hope you enjoy reading this publication.

For more information about the project please contact us at isci@mcmaster.ca

Editor: Russ Ellis

Integrated Pest Management:
A Step Towards a Sustainable Future for the Niagara Wine Industry

Weber, 2009)

"…no matter how responsible agriculture is, it is essentially about achieving the lesser of evils. To work the land is to change the land, to shape it to benefit one species over another, and thus necessarily to tame what is wild. Our task should be to delivery our blows gently."

— James E. McWilliams (2010)

By Victoria Balkwill Tweedie, Rebecca Englert, Alexandra Kasper,
Sarah McPherson, Daniella Pryke, and George Wells

The environmental movement of the past century has had far reaching effects throughout our society. It is not surprising that the notion of environmental awareness and responsibility has also spread to the agricultural industry, including the growing of grapes. This article will explore Integrated Pest Management (IPM), a sustainable approach to pest control, and its implementation in the Niagara region.

A vineyard is a complex, diverse ecosystem that contains many different species apart from grape vines. The relationship and interactions between the members of this system have a huge impact on vine health and grape quality, and thus implications for the grape growing industry. A typical vineyard ecosystem is comprised of various plant species including weeds and grasses, arthropods including insects, spiders, and mites, varieties of fungus and mildew, and non-arthropod species such as worms (OMAFRA, 2009). Many larger animals such as rodents, birds, and deer are present in and around vineyards and can play an important role in ecosystem dynamics.

Although there are many benefits to maintaining diversity within a vineyard, animals and diseases that affect grape berries and vines can be detrimental to a harvest if populations exceed specific quantifiable amounts. Organisms that damage and injure an agricultural crop to a point of economic loss are referred to as pests. Pest management has been, and continues to be, a constant challenge for viticulture in Ontario, as well as other grape growing regions around the world.

Traditionally, generalized pesticides (including insecticides and fungicides) have been used to combat vineyard pests. These techniques, although effective, have fallen under much scrutiny due to negative environmental impacts, harm to human health, and overall lack of sustainability. In 1959, Stern et al. developed the framework for a new, strategic approach to pest management called Integrated Pest Management (IPM) (Issacs et al, 2012). The grape industry was one of the first to adopt and implement IPM. This advancement has contributed to reduced costs, protection of the environment and ecosystem, and overall increased yields for grape growers.

What is IPM?

IPM encompasses a broad range of pest management practices that aim to maintain pest populations beneath levels of economic injury. IPM techniques vary widely and can include preventative practices, monitoring, biological controls, cultural controls, and responsible pesticide application. The goal of IPM is to grow a healthy crop with minimal disruptions to the rest of the ecosystem.

Monitoring and Thresholds

Monitoring, also called scouting, is the process of tracking and recording pest populations, weather conditions, plant health, and disease incidence. This process is the foundation for all IPM programs (OMAFRA, 2013a). Monitoring generally includes the sampling of different pests and plants to determine pest density and disease occurrence. All monitoring information is well documented for later use in the development of an IPM plan. Vineyard employees often perform sampling and monitoring, but external companies can also be used. Monitoring of the vineyard needs to be done at least once a week, but may be done twice a week or even daily. The frequency with which monitoring occurs is variable and is based on several factors, including the target pest, time of the year, weather conditions, susceptibility of vines, and past monitoring reports (OMAFRA, 2013a). The amount of money or staff available may limit how often monitoring can occur.

There are different types of pest sampling techniques, and the technique used depends on the target pest. The two main sampling techniques are trapping and visual observations. Trapping is the physical capture of pests using a visual, baited, or pheromone trap (OMAFRA, 2013b; Figure 1). Visual observation is the process of inspecting the vines and other plants in the vineyard for the presence of pests, diseases, and damage.

Figure 1: A pheromone trap for codling moth. The pheromone is inserted into the red capsule, which is then placed onto a cardboard plate that is covered with an adhesive. Pests are attracted to the trap and then get stuck on the adhesive (Slaunger, 2009).

Monitoring is a critical component of IPM and it is used in combination with thresholds to determine when pest levels are too high and require treatment. Thresholds are predetermined levels of pest populations where crop damage is sufficient to result in economic loss. The basic premise of IPM is that pesticides are only used when absolutely necessary; therefore when threshold levels have been met or surpassed (OMAFRA, 2013b). As such, monitoring must be done to determine where a pest population stands with respect to its threshold. There are two practices used to maintain pest populations around the threshold: preventative and corrective. Preventative practices occur before the pest reaches the threshold (Pedigo, 1999). Corrective, or therapeutic, practices occur after the pest has passed the threshold (Pedigo, 1999).

Chemical Control

Chemical control is a very important aspect of any agricultural practice, but IPM takes a different approach on the application of pesticides than traditional procedures. Traditional methods typically consist of a "better safe than sorry" approach to application, where large amounts of pesticides are used to wipe out pests, weeds, and diseases. In contrast, an IPM program uses monitoring and thresholds to determine the best and most efficient time to apply pesticides (OMAFRA, 2013b). This method allows growers to control pest populations and damage more efficiently, use fewer chemicals, and become more cost effective.

In particular, IPM utilizes target-specific pesticides, often called reduced-risk pesticides, which are less toxic than traditional products (BCMA, 2013). These allow for a finer control of pest populations and will not harm other organisms in the vineyard ecosystem. However, non-specific pesticides may still be used, just to a lesser extent.

Another distinct component of IPM is the use of pheromone traps. Pheromones are a chemical signal excreted by an individual that elicits a response in another member of the same species (OMAFRA, 2011). Pheromone traps use female sex pheromones to lure and trap males (OMAFRA, 2013b). These traps are usually species specific, but may also attract closely related species. Pheromone traps are used to determine the presence, absence, first sustained flight, and activity peaks of a pest, which help to define the optimal time for pesticide application in conjunction with thresholds (OMAFRA, 2013b). Pheromones are also used in mating disruption, where the release of sex pheromones into the vineyard environment confuses males and reduces their likelihood of successful mating (OMAFRA, 2011). Pheromones are considered to be a chemical control, but may also fall under the biological or behavioural control categories.

Biological Control

Biological pest control utilizes natural ecosystem interactions to minimize the presence of pests on the grape vines through two main methods. The first employs the natural predators of the pests to monitor population levels and includes the use of insect pathogens as a mode of population regulation (OMAFRA, 2009). The second method is trap cropping, in which secondary plant species are planted throughout the vineyard with the intention of deterring pests from the grape vines (Lopes et al., 2009).

Beneficials

The term beneficial refers to any natural enemy of the pests, including predatory insects, parasites, and pathogens (OMAFRA, 2009). Since this method exploits the existing predator-prey interactions between species, a deep understanding of this relationship is necessary to correctly choose an appropriate beneficial. There are three main ways in which beneficials are introduced into the vineyard: importation, augmentation, and conservation. Importation is generally done on a larger scale than individual vineyards. This process involves importing natural predators of invasive pests and requires government approval, but has proven to be highly effective against invasive species (Landis & Orr, 2013). Augmentation involves the use of natural enemies which can be purchased by vineyards from insectaries and then released into the vineyards. Augmentation is the least economical method, as beneficial populations must be replenished on a regular basis for the method to be effective. For this reason, augmentation may be combined with the third introduction technique, conservation. Conservation promotes beneficial populations by using a combination of techniques to make the vineyard more hospitable for them (Hoy 1988). This involves providing resources for the populations, including alternative food sources and habitats, especially for overwintering. Further, avoiding the use of chemical treatments which harm beneficials is ideal (Landis & Orr, 2013).

Figure 2: An example of a parasitic wasp, Fopus arisanus, *attacking Oriental fruit fly eggs that have been laid under the surface of the papaya (Bauer, 2011).*

Parasitic wasps have been found to be an effective beneficial to control mealybug and leafhopper species (Kent et al., 2008; Bentley, 2009; Figure 2). A study in California found that the small mymarid wasp, *Anagrus epos,* had a 90% rate of parasitism of the grape leafhopper (Bentley, 2009). Other species of wasp do not have parasitizing rates as high as 90%, but still offer significant reduction in leafhopper species. One consideration when using parasitic wasps as a biological control is the species specificity; the wasps tend to be highly specific in which species they parasitize. In the case of mealybugs, there is a different parasitic wasp to target different species of the pest, which demonstrates the importance of proper monitoring and classification prior to the implementation of any IPM strategy (Bentley, 2009).

Trap Cropping

A trap crop is a plant species which pests find more attractive than the crop (Hokkanen, 1991). These plants are placed around the perimeter of the vineyard, usually at the end of the vine rows, to attract the pests out of the vineyard (Khan et al., 2008). Ideally, the trap crops are placed at the interface between the vineyard and wooded areas, which are often the source of pest populations (Lopes et al., 2009). In addition, the trap crop ideally is not conducive to pest reproduction and should not require much of the vineyard area to be sacrificed (Lopes et al., 2009).

Trap cropping can also be combined with conservational methods of promoting beneficial populations, by choosing plants which attract natural predators and provide a habitat for the beneficials (Hokkanen, 1991). Rose bushes are a trap crop used to attract aphids away from grape vines, and can be planted at the end of vine rows. A study in Prince Edward County in Ontario found that the use of canola plants between vine rows effectively attracts cutworm larvae away from the vines in early spring, and also reduced damage due to flea beetles (Appleby, 2010).

Cultural Control

IPM cultural methods include a variety of vineyard maintenance techniques that have been shown to reduce and deter pest populations (OMAFRA, 2009). The majority of these techniques are preventative measures that do not have the ability to eliminate an entire pest population, but are effective at maintaining populations below threshold levels. Cultural IPM controls are particularly useful for treating and preventing grape pathogens such as rots and mildews by creating unfavourable conditions in the canopy environment (PRP, 2006).

There are many different cultural practices that can be implemented in a vineyard, most of which can be used to combat multiple threats. Common practices include crop sanitation, canopy management, irrigation regulation, and use of resistant cultivars (OMAFRA, 2009).

Crop sanitation includes removal and destruction of plant debris and weeds throughout the growing season as well as before and after the winter. This eliminates pest habitats and other host plants that may be present in the vineyard. Tillage and debris removal at the beginning and end of the off-season can remove overwintering pests and spores to prevent re-infestation from the previous summer.

A well-managed canopy can also go a long way in terms of pest prevention. Good canopy management involves increasing air circulation and sun exposure, which promote dry conditions (Austin et al., 2011). This can be accomplished by orienting rows in the North-South direction and by pruning and removing leaves off vines. Berries that are un-shaded and exposed are less susceptible to disease and better covered by pesticides. Removal of infected branches and berries can also aid in deterring birds and lady beetles as well as prevent the spread of infection (PRP, 2006).

Irrigation largely impacts humidity, canopy temperature, and soil moisture content, all key components of vineyard microclimates. In most cases, less irrigation is desired as overwatering leads to a dense canopy, increasing habitat for pests, and limiting sun exposure and airflow (OMAFRA, 2009). Wet conditions foster disease and fungus; therefore, under drainage systems are commonly used to prevent water accumulation.

A final cultural technique is the use of pest and disease resistant cultivars with genetically engineered features to protect against specific threats (Vivier and Pretorius, 2002). Some varieties have shown reduced risk of infestation and infection, especially those with traits such as more separated berry bunches or less dense foliage. Resistant cultivars have yet to be widely used in the wine industry due to the challenge of genetically modifying grape vines and the lack of public acceptance (Vivier and Pretorius, 2002).

Motivations for IPM Use

There are several factors, aside from the benefits of IPM techniques, which may influence whether or not these techniques are adopted by grape growers. Generally, there are three primary motivators for the adoption of IPM or other environmental practices in a vineyard. These include improved business performance, adherence to government regulations, and "green" personal values (Wright et al., 2009). In Ontario, several of the most environmentally conscious vineyards use their environmentally friendly approach as a marketing strategy. This may yield a particular payoff, as wine-drinking consumers especially have a tendency to seek out products that are considered "more green" (Wright et al., 2009). However, in order for the implementation of IPM to make sense as a business strategy, there must be a high level of consumer knowledge about what the techniques are and what they mean. The Grape Growers of Ontario (GGO) are also encouraging the implementation of environmental practices in general through their self-regulated environmental charter for the wine industry of Ontario. Through this charter, the GGO hope to improve the quality of winegrowing and winemaking in Ontario, and add value to the Ontarian wine industry (Wright et al., 2009). However, the most important determinant in the adoption of IPM and other environmental techniques is the attitude of the manager (Wright et al., 2009; Marshall et al., 2005). The more personally inclined a manager is towards environmentalism, the more likely a vineyard is to employ IPM or other environmental practices. The managers of large vineyards, with higher levels of education are also more likely to employ IPM (Bewsell & Kaine, 2004). On the other hand, it has been found that vineyard managers with more experience, who are more established in their procedures, are less likely to adopt IPM strategies (Bewsell & Kaine, 2004).

Table 1: Common Ontario pests and their management techniques.

	Description	Biological Control Method	Chemical Control Method	Cultural Control Method
Grape Berry Moth	Larvae feed on berries and create wounds which are vulnerable to disease.	- mating disruption - beneficial organisms such as earthworms and ground beetles	Timed spraying of insecticides	- removal of wooded areas or wild grape vines near vineyard - burying and disposal of old leaves in the spring from the previous season - use of grape varieties with more space between berry clusters
Leaf Hoppers	Insects feed off plant sap from stems an leaves. This affects the ability of the plant to produce sugars and distribute nutrients.	- natural enemies including: spiders, birds, and insect predators (ex. parasitic wasps)	Timed spraying of insecticides	- weeding in fall to eliminate overwintering sites - leaf removal - use of grape varieties that have greater resistance to leaf hoppers
Multi Coloured Asian Lady Beetle	Beetles feed on damaged or dropped berries. Presence of beetles can significantly taint wine.	n/a	Timed spraying of insecticides	- keep bunches healthy and disease free
Powdery Mildew	A fungus that appears as a white powder on grape berries, shoots and leaves. Infection causes vine stress and reduces berry growth and quality.	- biological control agents: *Ampelomyces quisqualis* and *Bacillus subtilis*, a fungus and bacteria that can act as fungicides	Timed and spraying of fungicides	-leaf removal and shoot thinning
Downy Mildew	A fungus that affects fruit and shoot tips leader to improper maturation and loss of fruit	n/a	Timed spraying of fungicides	- canopy management practices that promote dry conditions and good air circulation -use of less susceptible vine varieties
Botrytis Bunch Rot	A disease that causes rot in berry flusters. it can spread rapidly and result in large economic loses	- biological control agents: *Trichoderma barzjamm* a type of fungus which acts as a fungicide	Timed and spraying of fungicides	-leaf removal and shoot thinning -canopy management practices that promote dry conditions - use of less susceptible vine varieties

IPM in Ontario

In 2005, vineyards covered 5774 hectares of land in Ontario, accounting for 65.7% of Canada's grape producing area (AAFC, 2009). Within this area there is an abundance of pests that have the potential to significantly impact crop yields. These pests require constant monitoring and action by Ontario grape growers and can be managed by a suite of biological, chemical, and cultural techniques within the framework of IPM (Table 1). Recent attention to the practices and environmental impact of the wine industry has sparked interest concerning the adoption of IPM. Due to the young age of the industry, it is unclear to what extent IPM is utilized in Ontario and which strategies are best suited for this region. The Crop Protection Survey, a study conducted by Statistics Canada from January to March of 2006, has shed some light on this topic (AAFC, 2009). The survey was distributed to grape growers in Canada's top three grape growing regions (Quebec, Ontario, and British Columbia) with the goal of collecting data on pesticide use and the prevalence of other pest management practices during the 2005 growing season. 536 growers replied to this survey. The results of this survey were used to determine the sustainability of pest management practices in Ontario and the potential for further establishment of IPM.

Although insects are abundant in both variety and numbers in a vineyard, the Grape Berry Moth followed by the Multicoloured Asian Lady Beetle were found to be the most prevalent insects infesting Ontario vineyards (Figure 3; AAFC, 2009). Mildews, including both powdery and downy varieties, were rated the most extensive diseases followed by Botrytis Bunch Rot, according the survey results (Figure 3). Pesticide use was found to be widespread and applied in almost every Ontario vineyard. Additionally, most vineyards used a combination of insecticides and fungicides in their vine treatments. 82.1% of growers employed pesticide dependent strategies to manage grape insect pests (Figure 4). Growers reported applying an average of 1.6 rounds of insecticides and 2.5 rounds of fungicides per season to prevent pests from reaching unmanageable levels (AAFC, 2009). In 2005, pesticides amounted to a total of 171,410 kg of active chemicals sprayed on grapevines and released into the environment. Fungicides made up the largest proportion of this total, contributing 155 413 kg of active chemical compounds for disease control (AAFC, 2009). The majority of vineyards, 95.7%, were found to maintain a spray record, either in written (84.4%) or electronic form (11.3%). All records contained information such as the date, product applied, and rate of application. More detailed observations were made by some growers on wind speed, temperature, growth stage of crop, notes on visual inspections, and overall effectiveness of application (AAFC, 2009).

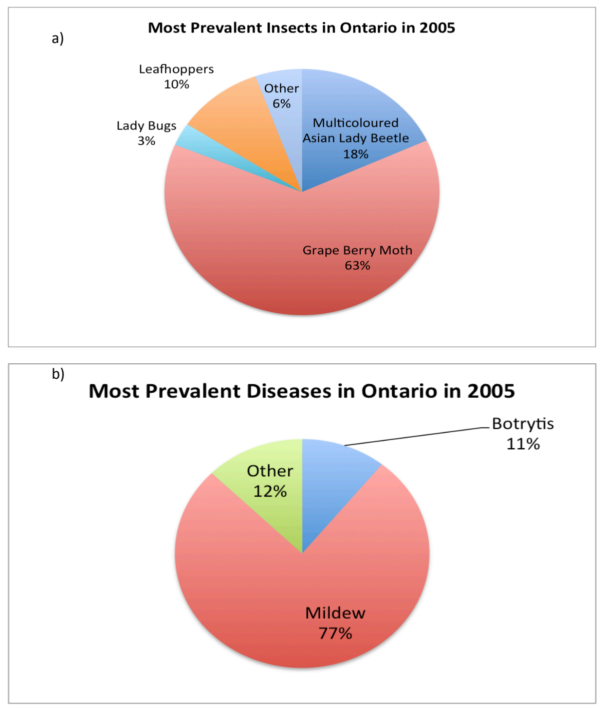

Figure 3: Most prevalent (a) insects and (b) diseases reported by Ontario grape growers during the 2005 growing season (AAFC, 2009).

Implementation of alternative methods was only documented by 25.9% of Ontario vineyards, according to survey results. Alternative methods included mating disruption, development disruption, and the release and attraction of beneficials to the vineyard ecosystem. When asked which techniques would be implemented the following year to control the highest risk insects and diseases, growers indicated a wide range of

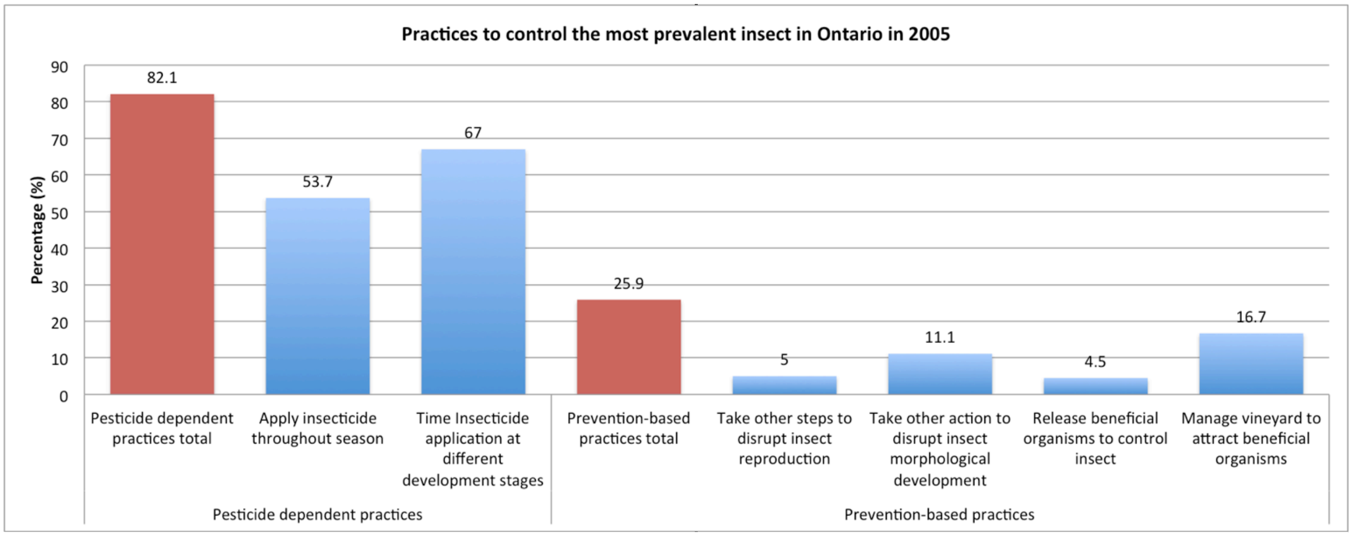

Figure 4: Common practices used in Ontario vineyards to control the most prevalent insects in the 2005 growing season. Red bars indicate overall vineyard use of pesticide dependent and/or prevention-based practices while blue bars indicate use of specific methods within each practice (AAFC, 2009).

both chemical and preventative means (Figure 5). Overall results of the study indicated that pest incidence has been on the rise in the past 5 years, while disease prevalence has remained the same or decreased.

A Discussion of What this Means for the Niagara Region

The Niagara region contains over 60% of Ontario's wineries in about 13,600 acres of land (VQA Ontario, 2013). As a large proportion of Ontario's wineries are located in this region, it is reasonable to assume that Ontario trends found in the survey would accurately reflect the Niagara wine industry. The findings from the 2005 Crop Protection Survey paint an interesting picture of pest management in Canada. Overall, Niagara growers take a more traditional pest management approach with a heavy reliance on pesticide spraying for protection from both insects and diseases. Despite this focus, there are still indications that IPM techniques are beginning to emerge in vineyards through monitoring of pest populations, responsible application of pesticides,

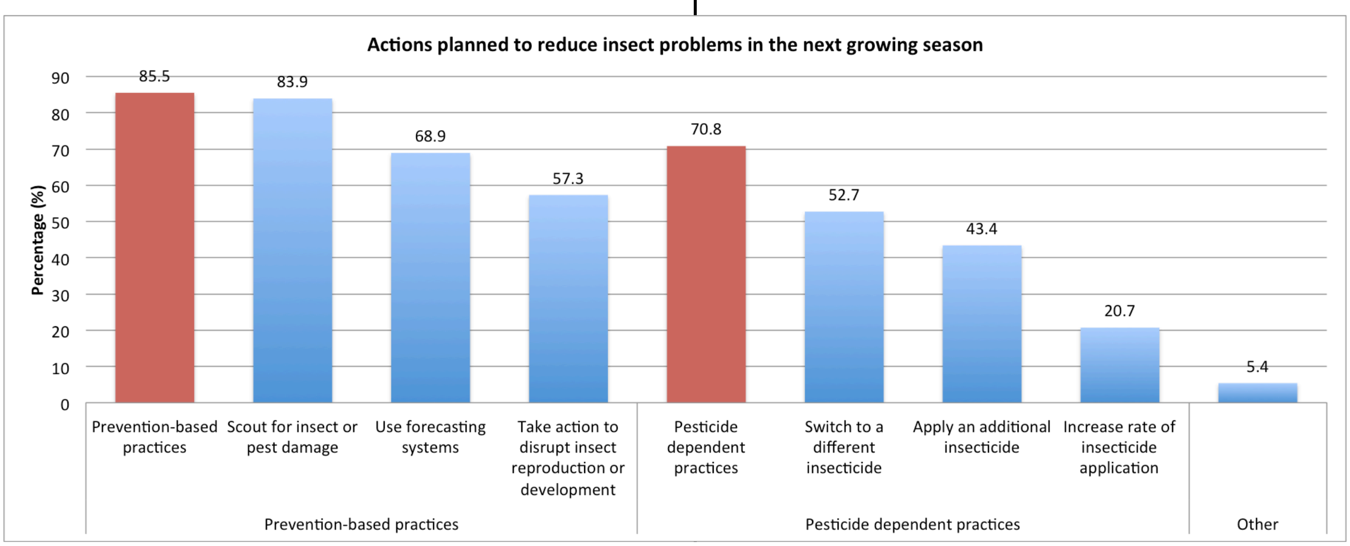

Figure 5: Intended actions to control insects in the next growing season in Ontario. Red bars indicate overall vineyard use of pesticide dependent and/or prevention-based practices while blue bars indicate use of specific methods within each practice (AAFC, 2009).

and alternative measures.

Most vineyards were found to keep written or electronic records of spray application. In some cases, observations were also made concerning vine health, growth stage, and efficacy of the applied treatment. As monitoring is an essential element of IPM, this basic spray recording is an important step towards more extensive documentation of pest populations and crop damage. Results from the study showed that the majority of grape growers planned to scout for pest populations and damage in the following season, as well as use pest prediction models. This indicates that grape growers are realizing the value and importance of crop monitoring for effective pest treatment.

Although chemical methods were dominantly used by grape growers, other cultural and biological controls have been found to be used by Ontario grape growers. These techniques were not used in abundance during the 2005 growing season; however, most growers stated that non-pesticide based approaches would be utilized in the following season. Niagara growers were not receptive to use of hybrid varieties to improve natural vine resistance but were accepting of natural controls such as the use of beneficials to maintain reasonable pest populations. Non-pesticide techniques will likely gain popularity with further awareness and promotion of these methods. Most importantly, the survey indicated that pesticide application was, at the very least, starting to be applied in an environmentally conscious manner. Growers reported timing insecticide application to coordinate with specific developmental stages of pests for maximum results.

While Niagara, and Ontario as a whole, remains in the preliminary stages of IPM implementation, IPM itself still has much room for advancement. Current research is focusing on the development of economic thresholds and monitoring systems to determine the optimal time to treat vines. Additionally, sustainable alternatives to pesticides such as pheromones are undergoing further investigation to improve accessibility and effectiveness on grape pests. New improvements in combination with greater education of vineyard ecosystems and pest life cycles are required for unanimous usage of IPM by Niagara vineyards. The future looks bright for IPM in the Niagara region and more research and promotion of IPM techniques will only increase its widespread establishment.

Conclusion

Compared to other grape growing regions, the Niagara wine industry is still in its infancy. However, Canadian viticulture has come a long way since its establishment in 1866 and recent advancements in the past 25 years have greatly improved wine production and quality. Grape growing has become a successful business in Niagara and an important component of the Ontario agriculture economy (Grape Growers of Ontario, 2010). In this prosperous atmosphere, it is important to remember the impacts of wine production on the surrounding environment and ecosystem. Surveys such as the Crop Protection Survey provide insight into sustainability of pest management and grape grower's contribution to the environmental movement. This information can be used by the government and other organizations to provide resources to guide grape growers on their path to environmental conservation.

MORE TO EXPLORE

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Experts vs. Electronics

A Comparison of Electronic Sensors and Expert Panels for the Quality Control and Assurance of Wines in the Niagara Region

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In recent years, Ontario vintners have made a name for themselves in the global wine market. The wine industry in Ontario is a high profit business, with a crop worth 89 million dollars (Wine Country Ontario, n.d.). In 2013 alone, 17.4 million litres of Vintners Quality Assurance (VQA) labeled wine was produced in Ontario, the sale of which generated a total retail value of $346 million (Wine Country Ontario, n.d.). With the wine industry producing large quantities of wine at high economic value, ensuring quality winemaking is essential to the developing reputation of Ontario wines.

Quality assurance in the wine industry is conducted both internally by wineries, as well as by external organizations such as the VQA. VQA approval is required to sell wine in many liquor retailers in Ontario, and this approval comes through laboratory analysis and scrutiny by an expert panel of wine tasters (VQA Ontario, 2013). Modern research into the analytical techniques of electronic tongues and electronic noses, however, may provide new methods of quality assurance for the Niagara wine industry. This paper will review and compare electronic tongues and noses with the current "Gold Standard" of wine quality assurance - a panel of wine tasters. Further, it will assess the feasibility of an electronic tongue and nose replacing or supplementing the panel of tasters.

CHEMISTRY OF WINE TASTE

Taste is among the most important aspects of the wine experience, and is different in every wine due to a unique combination of chemicals. It is important to note that the taste of wine is a subjective experience, and although chemical analysis may indicate the chemical content of a wine, the actual taste of the wine to a particular individual is difficult to determine due to the complexity of synergistic and antagonistic effects (Styger, Prior and Bauer, 2011).

One of the main components to the taste of a wine is its aroma. The aroma is produced by volatiles in the wine, whereas the actual taste sensations (bitter, sweet, sour, salty, and umami) result from non-volatiles (Styger, Prior and Bauer, 2011). Taste sensations of a wine come from sugar, polyol, salt, polyphenol, and flavonoid compounds. Volatiles and non-volatiles have different threshold levels in wine, the threshold level being the minimum concentration required to taste the chemical. The aroma consists of hundreds of different volatiles with wildly varying threshold levels (Rapp and Mandery, 1986). By analyzing their concentrations using gas chromatography, the more prevalent chemicals which affect the aroma can be identified, and a chart can be used to determine the aroma and taste. Chemicals also have threshold levels under which they are undetectable by taste (Styger, Prior and Bauer, 2011).

"The actual taste of wine is difficult to determine due to the complexity of synergistic and antagonistic effects of the chemicals (Styger, Prior, and Bauer, 2011)"

The process of wine aging has a major effect on the properties of the aroma and taste. The oxidation and reduction reactions during storage can change the concentrations of many compounds (Salmon, Fornairon-Bonnefond and Mazauric, 2002). Storing wine in oak barrels can leach chemicals from the wood into the wine, and the contribution of these chemicals to flavour is the main reason for storing wine in this manner. The origin and toasting level of the oak, and amount of time spent in the oak barrel affects the chemical composition of the wine (Parra et al., 2006). Aging processes create long-chained alcohols, fatty acids, tannins, volatiles, and polyphenols, which are important, but must be limited to certain levels to preserve the wine's taste (Saucier, 2010). These chemicals could serve as markers to test the age of a wine and ensure that it is consumed at the proper time. Malolactic fermentation, another effect of aging, reduces the acidity of wine, which is why the process is particularly useful for high-acid wine like that produced in cold climates, such as the Niagara wine region (Styger, Prior and Bauer, 2011).

FAULTS IN WINE TASTE

Some chemicals are considered faults in wine after crossing their concentration thresholds. The most commonly documented faults are produced by the metabolic activities of micro-organisms in the wine. The most significant of these metabolically-derived faults are acetaldehyde and acetic acid, which are produced by bacterial oxidation (ASU, n.d.).

Acetaldehyde is commonly found in red wines, where it catalyzes the polymerization of colour-producing anthocyanins (Osborne et al., 2000).

Above its threshold of ~ 500 ppb, acetaldehyde tends to reduce the natural aromas of the wine, and produces a pungent grassy scent (ASU, n.d.). Acetaldehyde is formed by the bacterial oxidation of ethanol:

$$CH_3CH_2OH \rightarrow CH_3CHO + H_2$$

The conversion of ethanol to acetaldehyde by oxidation is commonly performed by yeasts or acetic acid bacteria, meaning that the levels of these organisms in wine barrels must be minimized (Osborne et al., 2000).

Acetic acid is another chemical commonly found in many wines, and is thought to contribute to the sharpness and roughness of a wine's mouthfeel (Bartowsky et al., 2003). The threshold of acetic acid is fairly low (200-300 ppb). Levels above these thresholds produce an unpleasant vinegar-like aroma and burning sensations in both the nose and mouth (ASU, n.d.). Acetic acid formation is another type of bacterial spoilage similar to that of acetaldehyde. Although acetaldehyde and acetic acid formation are both forms of oxidation, they differ in the sense that production of the latter is strictly an aerobic process:

$$CH_3CH_2OH + O_2 \rightarrow CH_3COOH + H_2$$

Consequently, acetic acid formation is limited by the presence of oxygen, and so this chemical fault is typically found only in barrels with excessive headspace, the gaseous phase above a liquid (Bartowsky et al., 2003).

There is a large variety of less common microbe-generated chemical faults, the more important of which include 4-ethyl phenol and trichloroanisole. 4-ethyl phenol is produced by yeasts and generates an unpleasant smell of sweat, while trichloroanisole is released by fungi in bottle corks and produces a smell of rotting earth (ASU, n.d.). An important but even less common chemical fault is a high concentration of flavonoids, which are produced through interactions with the barrel rather than by microbial activity. Flavonoids such as catechins and epicatechins contribute to the desired bitterness of certain wines, but can make these wines unpalatable when in high concentrations (Polaskova, Herszage and Ebeler, 2008).

EXPERT WINE PANELS

Since the purpose of quality assurance (QA) for wine is to guarantee certain standards for making a product for human consumption, one way to evaluate the quality of a wine is through sensory analysis by a human taster (Ferrer, 1955). Taste is subject to a wide range of circumstantial variations which are independent of wine quality, including the taster's mood and hunger level (Jackson, 2008). If an analytic approach to wine assessment is to be taken, then the arbitrary biases of tasters needs to be mitigated. This mitigation comes in the form of a wine tasting panel. Evaluation of wine requires a minimum of 12 tasters to buffer the idiosyncrasies of individuals in the perception of flavour. This number can fall as low as one for quality control (QC; certifying the product for human use), but this is inadequate due to daily and personal variations in taste (Jackson, 2002).

Testing a wine against the palates of a number of experienced tasters statistically reduces the effect of subjective factors on sensory assessment. Withholding the identity of wines under examination further removes bias due to winery or varietal reputation (Jackson, 2002). Although statistical analysis of sensory evaluations by an experienced panel blind tasting wines may seem sufficient for objective assessment, modern standards for taste panels require greater objectivity. Panelists must not only be well-trained in the vocabulary and have high sensory acuity, but they must also be motivated for the job (Jackson, 2002). While this critical trait can be assessed in person, the rigorous part of selecting panelists tests discrimination of distinct flavours, taste acuity at dilute concentrations of compounds, and subjective sensitivity to certain qualities (Jackson, 2002).

Once a reasonably unbiased panel is assembled, the group engages in certain procedures for discerning the content and quality of wine samples. Wine is served to meet International Standards Organization (ISO) benchmarks, including the use of clear, large glasses; a well-lit cubicle; and possibly red lighting or dark glasses.

Functions of wine tasting vary from academic assessment to maintaining a proprietary flavour, ranking different vintages and blends, and QC. The latter evaluation is most relevant to electronic tasting in the Niagara Wine industry (Jackson, 2002).

Wines are scored by tasters using a variety of scorecards specific to wines (Jackson, 2002). When a wine tastes either good or bad as a whole, a taster's ratings of individual aspects might be skewed in those directions. This "halo effect" from the general impression of the wine should be mitigated in individually evaluating its qualities (Jackson, 2002). Often, independent scoring of the qualities of a wine is used to force the taster to assess each aspect of its flavour separately.

ELECTRONIC TONGUE/NOSE BACKGROUND

Electronic tongues (ETs) and noses (ENs) mimic human aroma and taste receptors using electronic sensors and artificial neural networks. When used in tandem, ETs and ENs are able to simulate linked olfactory and gustatory perception, which is useful for consumable volatiles including wine. These sensors can recognize a vast array of chemicals, and have been researched extensively for wine testing (Baldwin et al., 2011).

ENs were introduced in 1982, and can be built on several different technologies such as gas chromatography or metal oxide semiconduction (Latha and Lakshmi, 2012). ENs often sample headspace of a wine (Baldwin et al., 2011). ETs were first proposed in 1995, with models varying highly in method and material, but achieving a common goal: determining the flavour of a substance (Latha and Lakshmi, 2012). ETs use an electrochemical cell to acquire voltage-based measurements (Winquist, Wide and Lundström, 1997). The material of the cell electrodes is specific to the chemicals it will detect. These can range from common metals, to nanoparticles or even biosensors (Cetó et al., 2012a,b). Data from ETs/ENs (Figure 1) give a "fingerprint" of the chemical composition of the analyte. This highly complex data is routed to an artificial neural network which uses an algorithm to separate the signals (Baldwin et al., 2011).

"Electronic tongues and noses mimic human aroma and taste receptors using electronic sensors and artificial neural networks (Baldwin et al., 2011)"

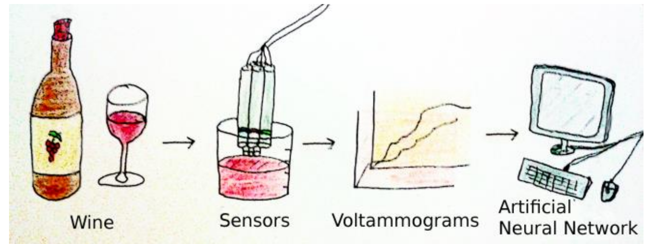

FIGURE 1: USING AN ET/EN TO ANALYZE WINE.

The data from an EN and an ET may then be combined in a final software package to represent the total olfactory experience (Baldwin et al., 2011).

ETs/ENs are able to organize both volatile and dissolved compounds into categories. These categories can range from general flavour categories (bitter, sweet) to specific wine descriptors such as woody and fruity (Arroyo et al., 2009). The ability of an ET/EN to categorize chemicals in this way is a result of "training": research on which chemicals cause a specific flavour is used to program the artificial neural network to categorize recognized chemicals, and define the "taste" of wine (Baldwin et al., 2011).

QUALITATIVE COMPARISON

A preliminary consideration for comparing human taste panels with ETs/ENs and evaluating the latter's role in QA is to determine the mandate of QC practices. The foremost responsibility of QC practices is to protect the consumer. This protection involves both health and economic considerations (Lozano et al., 2008). Further, QC protects the interests of the wine industry by guaranteeing certain product standards across a global market. The considerations involved in QC practices are presently not limited to human analysis; some preliminary physiochemical techniques are also utilized for certification including alcohol and pH measurement (Lawless and Heymann, 2010).

The potential role of ETs/ENs in QC against health concerns is promising. ETs/ENs can be calibrated to detect concentrations of spoilage metabolites. Rudnitskaya et al. demonstrated this by constructing an ET to measure the phenolic compounds in wine associated with bitterness and spoilage. This method, although preliminary, was successful in differentiating very bitter wines, indicating spoilage, from non-bitter wines (Rudnitskaya et al., 2010). Although expert taste panels are capable of determining the spoilage of a wine from bitterness, this ET/EN method can detect metabolites associated with spoilage that are not strongly represented in taste. These may be precursors to noticeable spoilage, as they can suggest the activity of microbial metabolism in the wine. In general, ETs can complement the analysis of an expert wine panel by confirming suspicions of spoilage or fault.

The roles proposed for ETs supporting economic interests though QC are speculative. Complications arise from the complexities of human taste, both from chemical interactions and psychological perception (Styger, Prior and Bauer, 2011). An ET/EN system is able to determine the amounts of specific chemicals present in a wine, but is not able to identify the multiple different flavours that may be formed through interactions between different chemicals. A human tongue on the other hand, would much more easily be able to identify the unique flavours caused by chemical interactions (Styger, Prior and Bauer, 2011). The primary economic concern in QC is whether the wine is good. In this regard the expert taste panel is overwhelmingly more capable than any ETs, as even advanced analytical techniques may not address the complex chemical and psychological considerations when evaluating wine. Although it can analyse the chemicals present, an ET cannot use this information to provide a definitive conclusion as to the perception of the wine by a human taster.

As the ET/EN cannot feasibly replace wine panels in the analysis of wine, it is necessary to use this technology in the wine industry in areas where a human sensory system is inadequate. Lozano et al. (2008) suggest a role for ENs in age detection. Since the wine ageing process is fundamental to obtaining quality wines, the age of the wine is closely correlated with taste and price. Lozano et al. (2008) suggest that classifying the age of wines is important in preventing fraud. As an ET is able to accurately distinguish between wines aged for differing times and with differing methods, it may be useful to the VQA in QA, ensuring that the statements made by wineries regarding the ageing of their wines are not exaggerations.

Lozano et al. (2008) used an ET with a tin oxide multisensor to evaluate wines of different ages from both American and French oak. They accurately detected the different aging processes of the wine, at 97% and 84% respectively. This agrees with the study done by Parra et al. showing that an ET was able to distinguish between a wine aged for 11 months in oak barrels of varying geographical origin and toasting levels. Parra et al. (2006) also showed that the ET was able to differentiate between wines aged for 3 or 6 months in oak barrels of different origin and toasting. A final example involved distinguishing red wine aged in oak barrels from those aged in steel barrels with oak wood chips by their differences in phenolic composition (Apetri, et al., 2007).

As suggested, this technology could be used to prevent age fraud during the QC analysis of Niagara wine, as well as ensuring that wineries have been honest about the ageing methods used. Additionally, Niagara wineries may wish to use an ET to analyze their wines at stages throughout the ageing process to establish the optimal time for ageing to be concluded.

QUANTITATIVE COMPARISON

ETs/ENs have been quantitatively compared to human sensory panels in the context of wine evaluation.

One study used an ET to analyze 56 samples of Italian red wines: Barbera and Gutturnios. The ET was able to distinguish between wines of the same varietal (Figure 2) and vintage from different vineyards (Legin et al., 2003). Chemical analysis using the ET was successful in identifying key wine compounds with an average prediction error of 12% or less.

The ET was also able to predict sensory panel scores (Table 1), with an average error of 13% for the Barbera wines and 8% for the Gutturnios (Legin et al., 2003). This shows that ETs can provide a similar evaluation of wine as a human sensory panel, while maintaining an accurate chemical analysis.

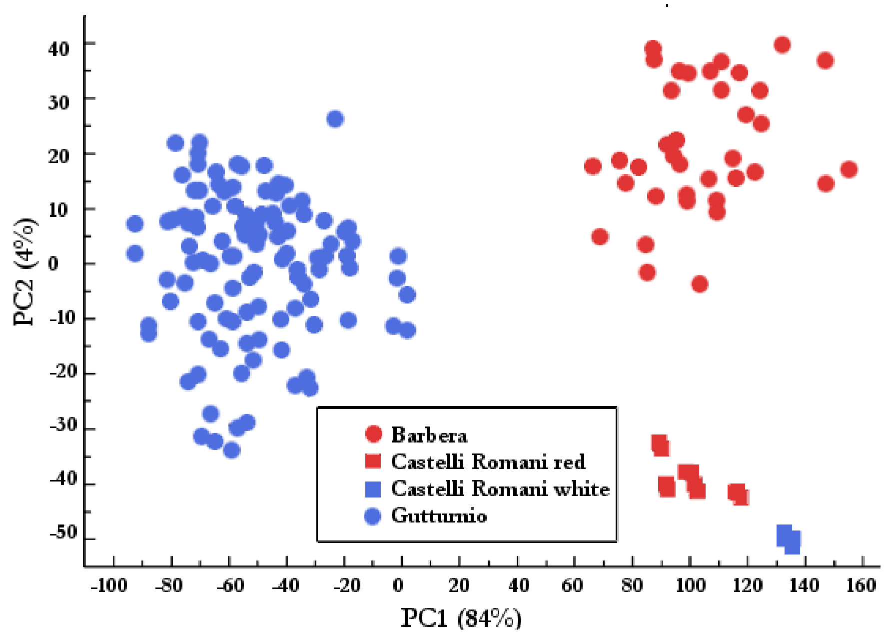

FIGURE 2: A PCA SCORE PLOT SHOWING DIFFERENTIATION BETWEEN WINE VARIETALS. Castelli Romani red and white were used for initial testing and setup (Legin et al., 2003, p.37).

Another study evaluated the differences in sensory thresholds for wine compounds using a wine evaluation panel and an EN (Arroyo et al., 2009). Both the sensory panel and EN were trained to recognize 17 wine compounds at different concentrations. The differences in sensory panel and EN evaluations varied depending on the character given by a chemical, with woody character giving the most similar results between the two (Figure 3). It was found that the human nose had a superior perception level to the EN, as it is able to notice and experience wine aroma. However, the EN displayed a superior recognition threshold, or ability to recognize individual wine components and concentrations, to that of human noses (Arroyo et al., 2009). This shows that ENs and human noses both have advantages and drawbacks, and their limitations often depend on the type of chemical being detected.

TABLE 1: EXAMPLE OF ONE WINE TRAIT (GRADEVOLEZZA) SCORE COMPARED BETWEEN ET AND SENSORY PANEL (Legin et al., 2003, p.43).

Sample	Sensory Panel Minimum	Sensory Panel Maximum	Sensory Panel Median	Electronic Tongue	Standard Deviation
Gradevolezza (general acceptance)					
19	4.7	10	7.2	7.3	0.2
12	2.3	10.3	7.3	7.4	0.2
29	5.4	9.8	7.8	7.7	0.2
2	2	10.7	7.3	7.2	0.2
11	2.2	11.4	7.7	7.8	0.2

Santos et al. conducted a similar study in 2010. An EN was contrasted with a human sensory panel in recognizing eight common wine compounds (Santos et al., 2010). This study aimed to compare performance in threshold detection and concentration quantification of aromatic wine compounds. The results demonstrated the EN to be superior to human noses in aromatic compound discrimination and threshold detection (Santos et al., 2010). Additionally, the EN was able to detect much lower concentrations than the human nose: for some compounds, concentrations of up to ten times those detectable by the EN were required for detection by the human sensory panel (Santos et al., 2010). This study shows that ENs may be engineered to be sensitive enough to outperform human noses, and detect contributing compounds that may subtly influence the taste of a

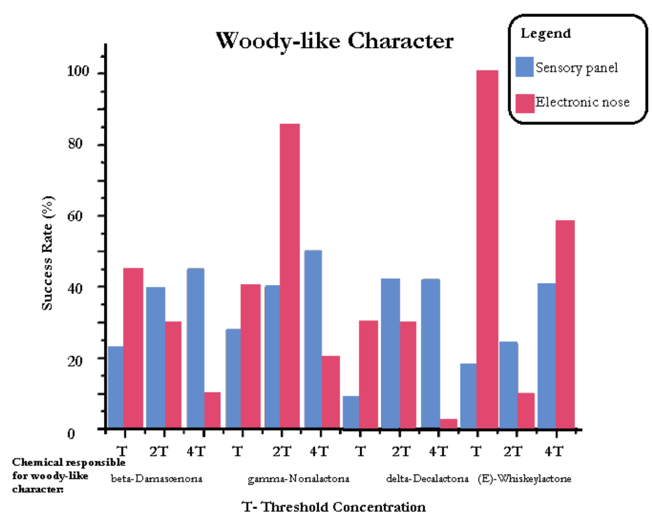

FIGURE 3: A DATA SAMPLE SHOWING RECOGNITION OF CHEMICALS CAUSING A WOODY CHARACTER BY CONCENTRATION, T BEING A THRESHOLD CONCENTRATION. Correct answers of the human sensory panel are shown in blue, and those of the EN are red (Arroyo et al., 2009, p.11547).

wine, yet not be perceived by a human nose.

"ENs and human noses both have advantages and drawbacks, and their limitations often depend on the type of chemical being detected"

FINANCIAL COMPARISON

Economic feasibility should also be considered when comparing wine panels and ETs/ENs for QA. Specifically, when would different-sized wineries recuperate their investment in these tools?

The price of a model 7100 Z-nose electronic nose system is approximately $25,000 (Electronic Sensor Technology, 2013). Sensory assessment of a wine by a panel at the Liquor Control Board of Ontario (LCBO), including QA and fault detection, costs between $70-$120 per label (Brasoveanu, 2013). The upper end of this estimate ($120) will be used in the upcoming calculation. Furthermore, it will be assumed that the labour costs and convenience of operating an ET/EN will be comparable to arranging sensory assessments by the LCBO.

With these assumptions, it can be estimated after how many QA tests it starts being financially feasible to make an investment in an ET/EN:

$$\text{Initial cost of electronic tongue or nose} = (\text{Cost of sensory assessment per label}) * (\text{Number of quality assurance tests})$$

Given the initial cost of an ET/EN and the cost of sensory assessment per label, an estimated 210 QA tests are required to recuperate the investment.

This number is more easily interpreted in the context of how many QA tests a winery conducts each year. In 2011, an average of six wines per winery were submitted for QA testing in Nebraska (Menke, 2011). Given the typical smaller size of Nebraskan wineries, it is reasonable to assume that this is a good estimate of QA tests needed per year for small wineries (Vintage Nebraska, 2013). The Jackson-Triggs Estate Winery will be classified as a large winery, and its number of QA tests per year can be extrapolated from the ratio of yearly QA tests conducted to wine produced in small wineries (Gerling, 2013; Suellwold, 2013). With 2,000,000 litres of wine produced yearly by the Jackson-Triggs Estate Winery, the estimated number of QA tests conducted per year would be around 260 (Cutz-Thompson, 2013).

Comparing the number of yearly QA tests with the previously calculated number of total QA tests necessary to recuperate an investment on an ET/EN system provides an estimate for the amount of time required to break even. It would take more than 35 years for a small winery producing 45,000 L of wine per year to recover its investment, whereas it would take a large winery slightly less than one year.

$$\text{Time to recuperate investment} = \frac{\text{Number of QA tests to recuperate investment}}{\text{Number of QA tests conducted per year}}$$

Given this estimate, it would not be financially feasible for a small winery to invest in an ET/EN system, but it could be for a large winery. However, this analysis assumes that the wine panels and ETs/ENs can perform exactly the same level of QA, which is not currently true.

"It would not be financially feasible for a small winery to invest in an ET/EN system, but it could be for a large winery"

This estimates the possible cost of being an early adopter of this technology, but the price of these instruments could go down if significant demand arose in the wine industry.

CONCLUSIONS

ETs and ENs are a novel technology available to the wine industry. From a functional standpoint, they have comparable acuity to a human taste panel and require less preparation and training, but cannot replicate the psychological construct of taste. Each technique has its strengths and weaknesses, and the optimal choice depends on the specific task and specific chemicals being analyzed. While a larger winery could save money by using these tools, there is an inherent risk to being an early adopter of new techniques. Advances in the technology will ultimately determine if wineries in the Niagara region should switch to these novel methods of QA.

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From The Ground Up

Uncovering the Effect of Terroir on Niagara Vidal Icewines

Mercedes Mabee, Mary Kate MacDonald, Harrison Martin, Kira Moor, Mackenzie Richardson, and Ben Windeler

In the picturesque wine country of southern Ontario, a farmer stands beside his budding crop. A man in his early thirties, he has traded the traditional straw hat and overalls for sunglasses, a stylized t-shirt and fitted jeans. He is in the middle of answering a question from one of the vineyard's daily flocks of visitors, discussing how he and his siblings are using social media to interact with potential customers.

It is fitting. Despite how the winery's unmistakably European palatial headquarters juts out of the landscape, this is most definitely a New World operation. Promotional shirts are printed, market research surveys are conducted, and tastes are geared to appeal to a burgeoning market comprised mostly of young men and women. The experience is as unique as the surroundings. From the villa's front steps, no less than three different varietals, or strains of wine grapes, can be seen filling experimental plots. This is not the old world of wine making.

This is the Niagara wine industry.

This is the new world of wine.

ICEWINE IN CANADA

Though not generally known for its table wines, Canada has become the world's leading producer of icewine. Icewine has its origins in 18th century Germany and was brought to Canada by German immigrants in the mid-1900s (VQA Ontario, 2013). Canada's icewine industry came to maturity in the late 20th century when the Pelee Island and Hillebrand wineries began to produce icewine for commercial consumption (Wine Country Ontario A, 2013). It was the Inniskilin winery that put Canada on the map for icewine production when their 1989 vintage of Vidal icewine won the Grand Prix d'Honneur at the 1991 Vinexpo in France (Wine Country Ontario B, 2013). Today, Ontario's main wine-producing regions are the Niagara Peninsula, Pelee Island, Prince Edward County, and Lake Erie North Shore. They produce 75% of Canadian icewine. The remaining 25% is produced in the Okanagan Valley and Similikamen Valley regions of British Columbia (Cliff et al., 2002).

While Germany still produces icewines, the reliable Canadian climates in the aforementioned regions are better suited to produce this high quality niche market wine. The Vintner's Quality Alliance of Ontario is the province's regulatory wine making authority, responsible for setting wine quality standards. Their icewine regulations state that the fruit must be frozen naturally and cannot be frozen cryogenically. Winters in the Niagara region are cold enough to allow grapes to freeze naturally on the vine, but are not generally cold enough to cause major vine damage. The climate-moderating effects of the Great Lakes ensure that spring frosts remain rare in Niagara, preventing frost damage to the vines. During the fall, freeze-thaw cycles allow sweetness and acidity to develop within the fruit. These cycles are crucial to the taste profile of the wines produced. Niagara remains the centre of the world's quality icewine production because of its moderate and reliable winter conditions (Bowen, 2011; VQA Ontario, 2013).

The Niagara region has soil composed of lacustrine clays, sands, and gravels; an unusual soil profile when compared to other wine producing regions of the world. Traditionally, these finer clay soil types pose drainage issues. However, advances in the viticulture industry, related technologies, and the sloping topography of the Niagara region allow this problem to be mitigated (Shaw, 2011).

> "The consistently warm summers and cool winters of the Niagara region are optimal for icewine production"

ICEWINE PRODUCTION

In the Niagara region, fruit harvest for icewine production typically occurs between December and January. This is partially due to the VQA requirement that any harvests must occur after November 15 (VQA Ontario, 2013). According to grape growers and winemakers, an early harvest produces a poor quality wine as the grapes do not have an opportunity to develop the sugars necessary for a balanced product. These wines taste bitter and are referred to as "green" (Ziraldo, 2007). On the other hand, late harvests occurring between March and April have very low yields as additional freeze-thaw cycles desiccate the grapes, making harvest and pressing beyond economic justification (Bowen, 2011). Harvesting the grapes between December and January allows enough time for the grapes to mature sufficiently, while preventing the dehydration, mould, and pest issues which naturally accompany a later harvest. According to VQA regulations, icewine must be made from grapes harvested and pressed at temperatures between -8ºC and -12ºC (Ziraldo, 2007). At these low temperatures, much of the water content of the grapes is frozen and remains in the skin during pressing. This results in a grape juice, or must, with higher concentrations of the sugars, acids, and aromatic compounds that have become the trademarks of a quality icewine. After fermentation, the resulting wine is distinctly sweet but balanced by a high acidity. VQA standards mandate a minimum sweetness for icewines; residual sugars of anything less than 125g/L will prevent VQA-approval of an icewine (Shaw, 2011).

ICEWINE VARIETALS

The two major grape varietals used for the production of icewine in Canada are Riesling and Vidal. These varietals are particularly suited to the Niagara region as they are late ripening, exhibit high acidity, and are physiologically better suited to withstand winter damage (VQA Ontario, 2013). Riesling icewines commonly have a floral and fresh fruit flavour while Vidal icewines have flavour profiles indicating raisin, honey, oak, and caramel. Vidal wines are considered to be more aromatic, a characteristic contributing additional dimensions to the sweetness of the wine. Vidal icewines also have a darker colour than Rieslings. While Riesling grapes are considered to produce a higher quality wine, they are also notoriously vulnerable to pests and disease. Vidal, on the other hand, is much more pest and cold resistant. This varietal is a hybrid, bred from the crosspollination of Ugni blanc, which is of the *Vitis vinifera* variety, and Rayon d'Or, another hybrid varietal. The hardiness of Vidal vines results in a greater number of successful batches from each harvest, and thus, a lower price per bottle than the Reisling icewines made from pure *V. vinifera* varieties (Bowen, 2011).

If you ask any vintner in the province, they will tell you the icewine industry is a precarious one. With fruit production heavily dependent on weather and the potential for their crop to be devastated by pests or disease, icewine producers have no shortage of worries to keep them up at night. Their worries are even more troubling during the time of harvest. Icewine grapes must be picked by hand at night in sub-zero temperatures (VQA Ontario, 2013). To complicate matters further, the yield of icewine is low, around 5%. Unfortunately, this is a natural result of crushing frozen grapes, as a majority of the water is locked in the skin as ice crystals. For these reasons, the price of icewine is considerably higher than that of table wines. Consumers on a tight budget will often pass by icewine in the liquor store, as the average cost of a bottle sits between \$25 and \$60 with sparkling icewines costing up to \$80 (Ziraldo, 2007).

TERROIR

In the classical wine making world, the term terroir refers to all of the factors that go into making a wine its own: the unique climate, geology, geography, and wine making practices that differentiate each vineyard, but not batch (Douglas, Cliff, and Reynolds, 2001). The designation of terroir is extremely important and can be a mark of high quality exemplified by the reputation of the Champagne or Cognac regions of France. Ontario, as a new addition to the wine making world, has no official authority to designate terroir. Of course, this has not stopped the designation efforts of viticulturists and enologists (Douglas, Cliff, and Reynolds, 2001; Hayes, 2000). These efforts have sparked one of the most heated debates to come out of Niagara wine research. To some, the idea of breaking Ontario down into official terroirs is of immense importance and would help to differentiate wines of varying qualities, hopefully helping the Ontario wine industry to appear more coherent and distinguished (Douglas, Cliff, and Reynolds, 2001). However, not all people in the wine industry have been sold on the idea. Skeptics argue that terroir designation is superfluous marketing. Naysayers cite many reasons to avoid adopting terroirs in the Niagara region, chief among them is the claim that terroir may not be an accurate or acceptable way of classifying wines or predicting wine qualities (Douglas, Cliff, and Reynolds, 2001). Regardless of scientific context, terroirs are useful for efficiently discussing certain wine making areas. Both winemakers and consumers can understand when one refers to, for example, the Niagara-on-the-Lake region.

"It is easy to see the allure of terroir delineations, harkening back to visions of small sun-soaked European vineyards."

Nonetheless, it is clear that further investigations are needed to determine whether terroir designations (or, rather, the properties by which they are defined) can manifest themselves through specific traits in finished wines. This ongoing debate motivated us to investigate the relationship between terroir and icewine characteristics. Our first step was to identify the three main icewine producing regions of Southern Ontario: Niagara-on-the-Lake, located in its namesake, Vineland, about 20km to the west, and Amherstburg, far to the southwest, near the Windsor-Detroit border (Cliff, et al., 2002). The next step was to investigate how the climate and soil structure within these regions impact icewines produced in each of these areas.

JUSTIFICATION

We certainly weren't the first to wonder how exactly geological and meteorological factors affect the sensory (i.e. taste and aroma) properties of table wine. In 1999, Fischer et al. published evidence to support the idea that the classification of wines based on terroirs is inaccurate, and that a wine should be graded on a case to case, batch to batch basis. However, tradition is an important factor in the wine making practice, and complete abandonment of the prestigious terroir and appellation designations is not a solution with which many wine makers and connoisseurs would be happy. Such a move could upset consumers, tasters, winemakers, and winegrowers alike, while negatively affecting those wines which profit most from historical prestige. Nonetheless, Southern Ontario still has no formal terroir classification as recognized by the French Appellation d'Origine Contrôlée (Douglas, Cliff, and Reynolds, 2001; Hayes, 2000).

The sensory profiles of Niagara icewines have been recorded and analyzed over the past two decades by various research groups and yet there have been no studies to relate meteorological and geological patterns to the quality or characteristics of icewines produced anywhere in Canada (Bowen, Reynolds, and Lesschaeve, 2010; Cliff et al., 2002). We sought to rectify this research gap. By looking for patterns while reviewing available sensory data and local environmental information, potential impacts that different soil types and climatic conditions can have on icewines may be found. The wines we studied were produced across a range of geographic locations within Southern Ontario and were bottled in various years.

The data that this study generates may well indicate whether the tradition of terroir designations is viable within the winemaking regions of the New World. Moreover, the purpose of this investigation is to give insight into how soil and climate impact the characteristics of icewine. We began our study with aspirations to further develop knowledge of environmental factors that can influence the quality and sensory characteristics of icewines. This could lead to new wine making procedures that could be used to craft icewines of high quality or with a specific, planned character.

RESEARCH QUESTIONS AND HYPOTHESES

We had two research questions in mind: Do the chemical characteristics of icewines vary when the fruit is grown in different terroirs? Also, how do climate and soil vary between terroirs?

For the first question, we proposed for our null hypothesis that neither sugar content, alcohol content, nor acidity would vary significantly between terroirs when compared to within individual terroirs. This null hypothesis would imply that terroir does not have a significant effect on the final chemical properties of an icewine. In looking at the literature, we found suggestions that sugar and alcohol content will vary more with winemaking practices than with terroirs, as both chemical properties seem to be more closely correlated with the fermentation process than with geographical or climactic factors (Ziraldo, 2007). As mentioned previously, the VQA has specific requirements for sugar content in icewines. pH, however, is a different story. Previous research has suggested that the freeze-thaw cycles that occur prior to harvest cause acids to precipitate out of the unpicked grapes (Bowen, 2011). If pH is more dependent on uncontrollable yearly variations in growing climate, then it is fitting that the VQA does not regulate the acidity of finished wines (VQA Ontario, 2013).

For the second research question we propose the null hypothesis that neither weather nor soil will vary significantly between terroir regions. Winemakers tend to put a lot of emphasis on the concept of 'microclimate', or the specific atmospheric trends of a very small area, such as an individual vineyard or neighbourhood (Douglas, Cliff and Reynolds, 2001). We know that temperature has been shown to affect the properties of wine; tradition teaches us that variations in growing climate can make or break an entire vintage of wine. This question was particularly interesting to us as we were unable to find sufficient literature that could elaborate on the relationship between freeze-thaw cycles and acidity. Soil is much of the same story. Geologic surface properties can vary over such small distances that we hypothesized no unifying theme would be found that could both unite a terroir and significantly differentiate it from other terroirs.

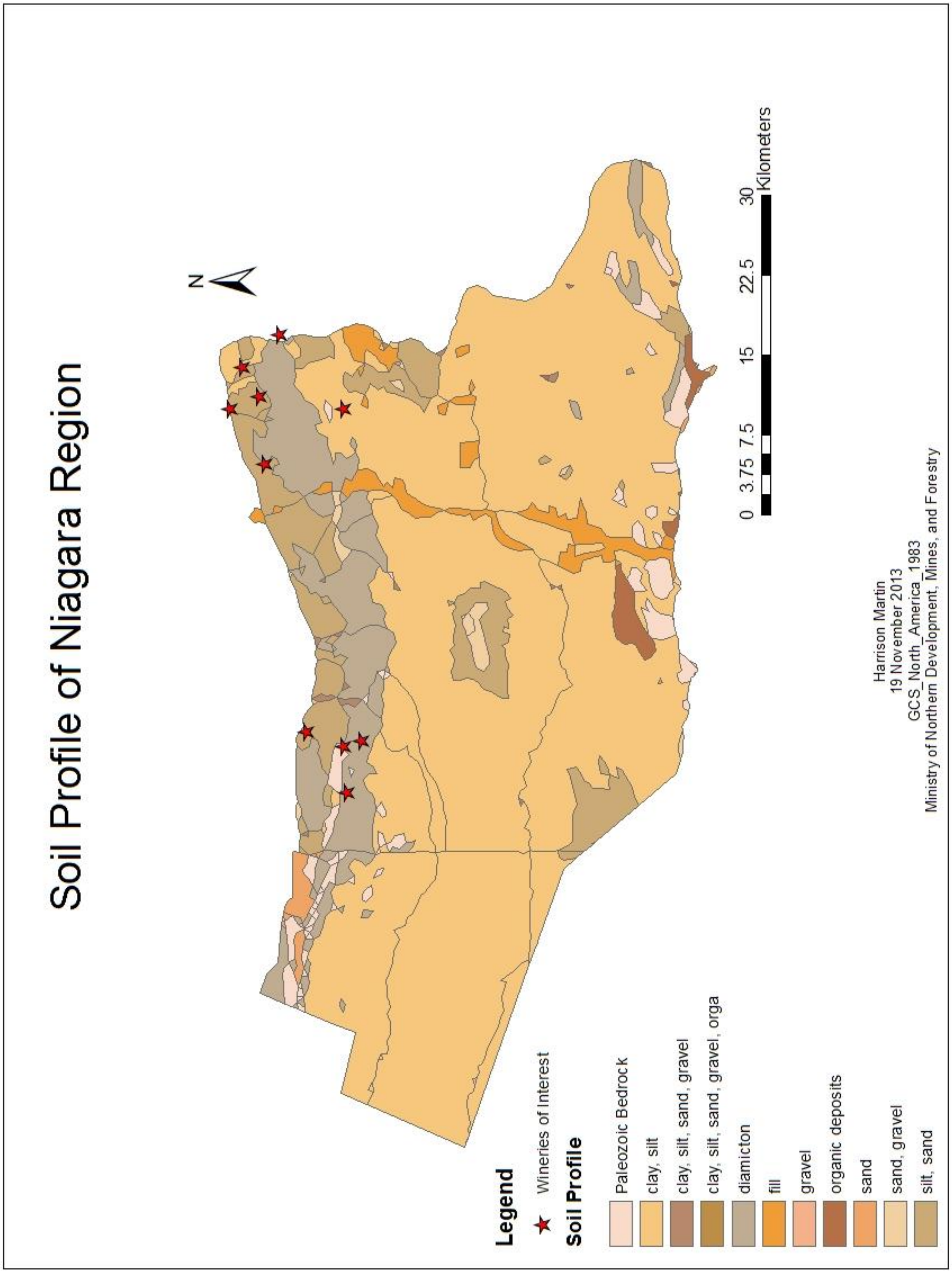

Figure 1: A map depicting the surficial geology of the Niagara region. Data has been projected in the NAD 1983 system, and is taken from a section of data published by the Ontario Ministry of Natural Resources (OMNR). Different soil types are indicated by different colours, and wineries are marked by red stars. As can be seen, both regions have similar soil types with low variability.

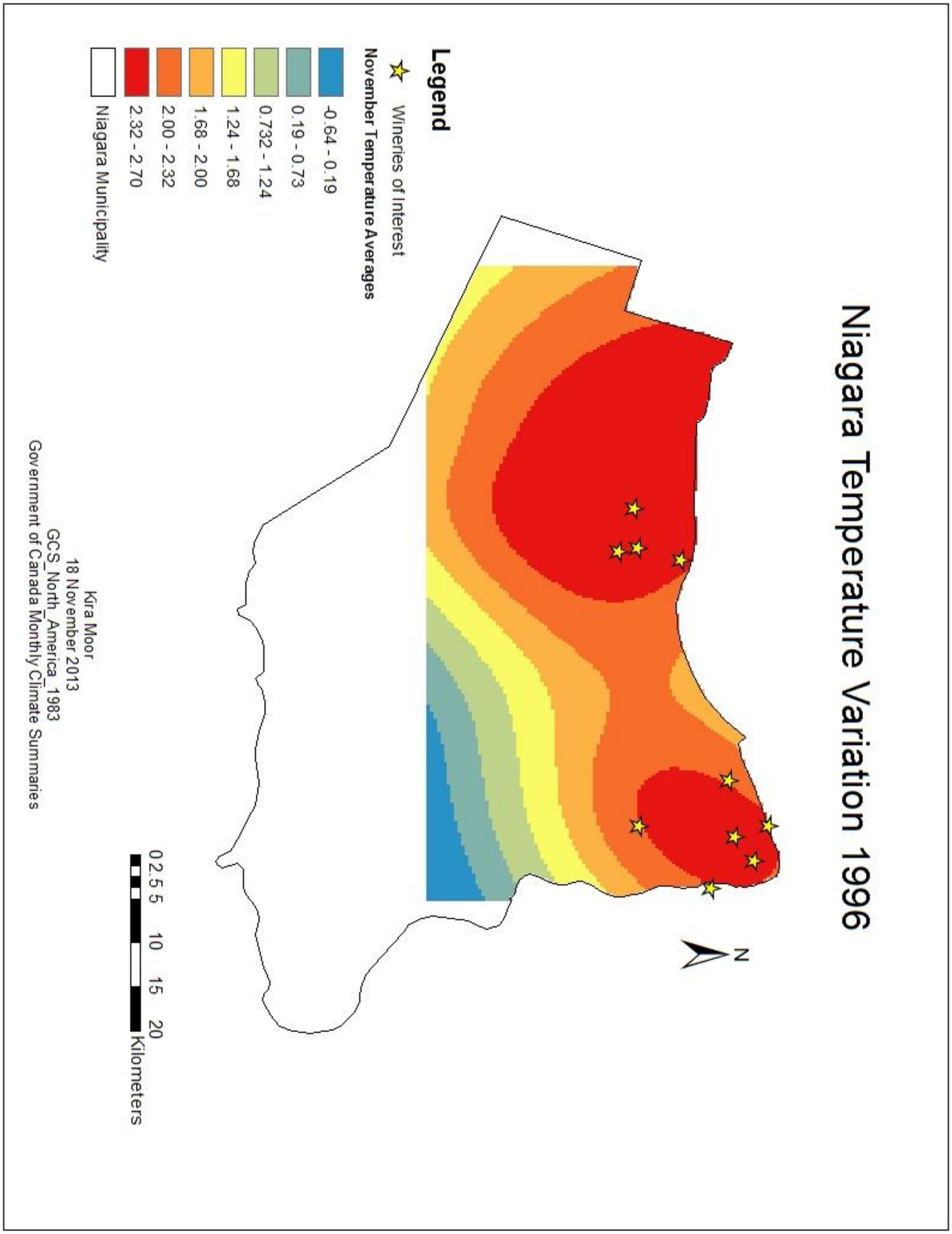

Figure 2: For the month of November 1996, average daily temperatures depict two distinct regions of high temperature. Each region is located near the cluster of wineries in our two visible terroirs.

METHODS

We collected and analyzed publicly available data on the sugar content, pH, and alcohol percentages of various icewines. Data was reviewed for nine Vidal icewines from 1996 and six more wines from 2005 to 2009, including four vintages of icewine from Pillitteri Estates Winery (Cliff et al., 2002; Pillitteri Estates Winery, 2012; Chateau des Charmes, 2013; Winery to Home, 2013). Local precipitation and average temperatures were compiled monthly from May to November (the usual growing season) for every year with representative wine data (1996, 2005, 2006, 2007, 2009). We considered each year's average November temperature to be our indicator of freeze-thaw cycles, with a colder November suggesting more cycles. This weather data was collected from stations within or near to the three regions from which the wines originated.

We then searched for trends of significance within both the chemical composition of icewine samples and microclimate differences between different terroirs. To find these trends, an analysis of variance test was performed on different sets of data by comparing variations between groups to variations within groups. First, the nine icewines from 1996 were analyzed. This analysis allowed us to discover trends that varied by terroir, but not with time. Next, the four vintages of icewines from Pillitteri Estates Winery were analyzed to find the effect of yearly climate variations, independent of the different practices and soil conditions that come with different wineries. Finally, the trends of acidity and weather conditions were studied with regression analysis of all the wines for which data was collected. This was done in order to find any overarching correlations between terroir, weather, and chemical composition.

Trends in soil (seen in Figure 1) were explored qualitatively using a 2010 map of surficial geology within Southern Ontario, produced by the Ministry of Northern Development, Mines, and Forestry.

> "There may be a relationship between freeze-thaw cycles and icewine acidity"

RESULTS AND DISCUSSION

Comparing the variability of chemical composition within and between terroirs for the 1996 vintage, we found that sugar and alcohol content did not vary significantly between wines from different terroirs. pH, on the other hand, did ($p<0.05$). On the whole, wines from Vineland and Amherstburg were more acidic than Niagara-on-the-Lake wines. Although it is impossible to attribute this variance solely to terroir using only our analysis, it does allow us to tentatively reject our null hypothesis as acidity did vary between terroirs.

For the four vintages from Pillitteri Estates Winery (2005, 2006, 2007, and 2009), it was found that pH varied significantly ($p<0.05$) between vintage. Sugar and alcohol content did not vary significantly. This pH variation implies that either variable weather conditions or changes in viticultural and enological practices had an effect on icewine acidity. While this does not affect our above-discussed rejection of the null hypothesis, it certainly implies that terroir does not solely determine pH. We suggest that both wine making practices and yearly variation in weather conditions will play an important role in determining icewine acidity.

Next, weather data for all relevant years and locations was analyzed to determine whether microclimate differences between terroirs were detectable. We found that average temperatures across the growing season varied significantly ($p<0.05$) between years. This implies that variance between pH in different vintages from the same winery could be due to variance in yearly average temperature. Precipitation was not found to be significantly correlated with either terroir or year, meaning that precipitation is too variable to be a good predictor of acidity in a terroir.

Next, the correlations between pH and both average annual temperature and average temperature in November (seen in Figure 2) were examined. Lower average annual temperature and lower average temperature in November (suggesting more freeze-thaw cycles) were both very weakly correlated with lowered acidity ($r^2=0.20$, $r^2=0.24$ respectively. Although this does not confirm our first hypothesis, it does suggest that there may be a relationship between freeze-thaw cycles and icewine acidity. It also does not serve as sufficient evidence for us to accept or reject the role of freeze-thaw cycles in icewine acidity, since average temperature is a somewhat poor quantification of freeze-thaw cycles.

Our qualitative analysis of soils within the Niagara region indicated that there is no justification for a geologic definition of these three terroirs. All three regions were populated by very similar geologic units which were mainly comprised of glacially-deposited clays and silts with sporadic sands (OMNR, 2011). Not only was there no one unifying soil type for any of the terroirs, there was no real way of distinguishing any of them based on unique or missing soil types. As such, we could not reject our second null hypothesis.

CONCLUSION

Analysis of our results provides an impetus for further research. We have shown that acidity is more variable between different terroirs than within terroirs for at least one vintage. Also, although the relatively weak correlations between temperature and acidity do little to demonstrate the role of freeze-thaw cycles in icewine acidity, they do justify further examination. These correlations may indicate, perhaps, the presence of a hitherto-unconsidered third factor in this relationship.

To more closely investigate the variance of freeze-thaw cycles between terroirs, future studies would do well to record the frost and thaw degree-days of the growing season. These are measures of how many days per month the temperature is below and above, respectively, 0°C (Government of Canada, 2013). While our usage of average November temperatures was a justifiable proxy statistic, analysis would doubtless be improved by the availability of this data. Furthermore, to remove the effect of individual winemaker practices, studies should look instead at the acidity of musts pre-fermentation, or instead look at icewines produced by the same winery using grapes from different vineyards. These unmeasured human variations could also be partially mitigated by increasing our sample size, a simple task for future teams with the capability to perform their own chemical analyses.

MORE TO EXPLORE

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Is Older Wine Always Better?

The science of wine aging and how consumers can get the most from their wine

By: Rebecca DiPucchio, Madeena Homayoun, Melissa Ling, Jacqueline Rotondi, Alex Shephard, Adelle Strobel and David Yun

Saling Hall, situated in the beautiful countryside of Essex County in the United Kingdom, is home to the famed wine connoisseur Hugh Johnson. The hall's Elizabethan-era architecture and immaculate gardens are impressive enough, yet Johnson takes the most pride in what lies beneath its floors. Purchased by Johnson and his wife Judy in the early 1970s, Saling Hall features a magnificent five-room wine cellar. Over the past 40 years, Johnson has certainly done his best to fill the cellar, accruing one of the largest personal wine collections in the world (Booth, 2013).

Clearly, Johnson has accumulated far more wine than one could ever hope to enjoy in a lifetime, thus some of his wines have been cellared for quite some time. Moreover, he enjoys purchasing antique wines, and his collection includes a bottle dating back to 1830. When Johnson and his wife began looking to sell their home in 2011, he made the decision to auction off the majority of his wine collection. In total, the collection was valued at over $150 000, with a single bottle of 1971 German dessert wine listed at $9 000 (Booth, 2013).

For the aspiring millionaire, the way forward seems clear: buy some nice wines now, put them in the basement, then sit back and wait as the bottles grow in value. If only it were that easy! There is a common misconception that wine can be aged indefinitely and that all wines will improve with age. Unfortunately, wine aging is a complex process and some wines are better suited for it than others. However, the right chemical makeup can definitely allow a wine to improve in colour, flavour, and mouthfeel as it ages (Waterhouse, 2002). Given some knowledge of a wine's chemical composition, an informed wine consumer should

FIGURE 1: WINE COLOUR CHANGES WITH AGE. As wine ages, it will undergo a colour transformation. White wines tend to develop a brownish colour, while red wines lose some of their colour intensity (Waterhouse, 2002; Wine Folly, 2013).

be able to pick out wines that will age nicely. In particular, a proud Ontarian could apply their knowledge to choose some ideal Niagara wines to add to the collection for aging. After purchase, wine remains a somewhat fickle investment; without proper storage conditions it is easy for it to spoil. Despite the apparent risk of wine spoilage, recent research concerning wine storage methods may offer answers to consumers who are looking to optimize their wine (Blake, et al., 2010; Butzke, 2008; Mas, et al., 2002;).

HOW DOES WINE GET BETTER WITH AGE?

Wine aging in bottles can be an incredibly time consuming process, yet it is a commonly practiced technique because the process can confer some benefits to wine. During aging, colour, flavour, and mouthfeel of the wine can all evolve to produce a more desirable end product.

COLOUR

When opening a bottle of wine, colour is often the first thing that the consumer will notice, so a fine wine must be visually appealing. As shown in Figure 1, a wine's colour evolves with age. Within red wines, phenolic compounds known as anthocyanins are the primary contributors to colour (Brouillard and Dangles, 1994). On the molecular level, anthocyanins have a multiple-ring structure, helping explain why they are fluorescent while other phenolics in wine are not. These anthocyanins can exist in either a red or a blue form, and the transition between these two structures is responsible for most of the colour change in red wine during aging (Brouillard and Dangles, 1994; Gomez-Cordoves and Gonzalez-SanJose, 1995). The conversion between red and blue structures is pH-dependent; the red structure, flavylium predominates in acidic conditions while the blue structure, quinoidal base, is most prevalent under basic conditions (Figure 2) (Waterhouse, 2002).

During aging, organic acids are degraded, causing a loss of acidity. As a result, the wine has an increased concentration of hydroxide ions, which then interact with red flavylium molecules to

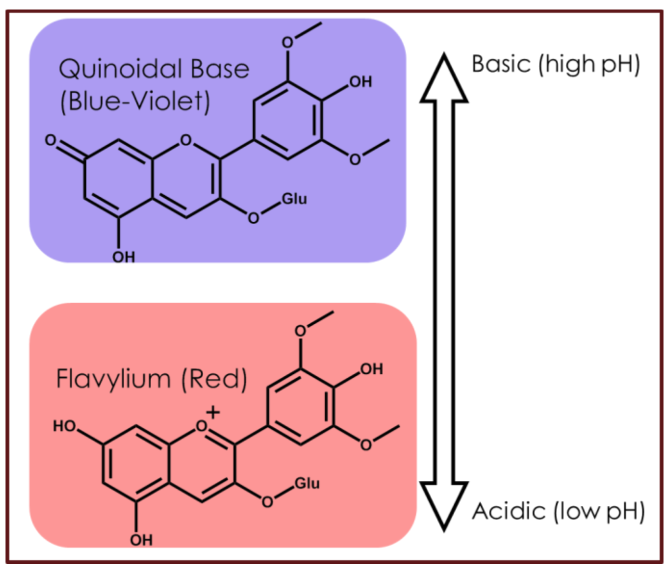

FIGURE 2: pH-DEPENDENT COLOUR CHANGE. There are two differently coloured structures of anthocyanins. The red structure, flavylium, dominates in acidic conditions, while the blue structure, quinoidal base is favoured in basic conditions (Waterhouse, 2002).

produce blue quinoidal base (Waterhouse, 2002). This shift from flavylium to quinoidal base ultimately leads to a loss of red colour intensity for older red wines. If a wine is stored for a sufficiently long time, the consumer may even notice a slight bluish tone (Waterhouse, 2002).

Although red wine may lose some of its colour intensity with age, aging improves colour stability. As wine ages, oxygen may gradually enter the bottle, where it is consumed through oxidation reactions (Somers, 1971). In one such reaction, oxygen can activate a second type of phenolic compound called tannins. Once activated, tannin molecules have a tendency to polymerize with anthocyanin molecules. The resulting anthocyanin-tannin polymers retain some of the colour from anthocyanins and are more stable than anthocyanins alone (Somers, 1971).

In contrast to red wines, white wines do not contain a significant amount of anthocyanins. Instead, their colour change during aging is dependent on a class of molecules known as hydroxycinnamates, which themselves do not contribute to the colour of white wine (Waterhouse, 2002). Alternatively, it is the destruction of hydroxycinnamates by light and oxygen that causes white wine to undergo oxidative browning (Li, et al., 2008). Since oxidative browning is an undesirable outcome in the aging of white wines, research is being done to combat its effects. One such solution is to add sulfur dioxide to wine (Simpson, 1982). Unfortunately, some people are allergic to sulfur dioxide, and many consumers dislike the change in wine taste that sulfur dioxide causes. As a result, winemakers are responsible for finding a balance between preventing browning, and maintaining an appealing taste profile for their product (Waterhouse, 2002).

FLAVOUR

The flavour of wine, which encompasses both taste and smell, is arguably the most important component of the wine drinking experience. While consumers may be familiar with "floral", "vegetal", or "crisp" as wine flavour descriptors, these flavours are ultimately the result of interactions between specific chemical constituents. Compounds affecting the smell of a wine are referred to as volatiles, and those affecting the taste are termed non-volatiles (Rapp and Mandery, 1986). The chemical composition of a wine, and hence, its flavour, is determined by four factors: the grape type, growing conditions, the fermentation process, and aging. The first two factors are probably out of the consumer's control; however, people can choose how long to wait before opening their wine. Over time, both volatile and non-volatile compounds will chemically

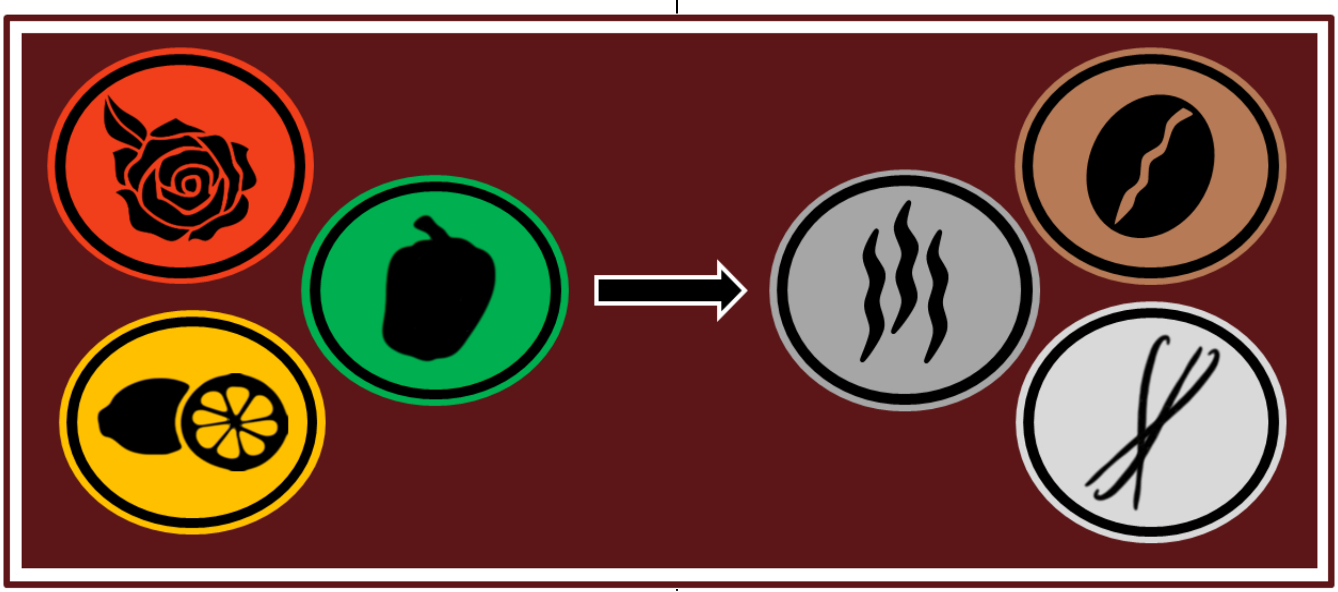

FIGURE 3: CHANGING TASTES. A wine's flavour (taste and smell) evolves as it ages. Various compounds in young wines cause them to have floral, crisp, or vegetal flavours. These compounds break down during the aging process, and different compounds associated with smoky, vanilla, and roasted coffee flavours take their place (Ebeler, 2001; Tominaga, et al., 2003).

evolve, changing a wine's flavour as it ages (Figure 3; Rapp and Mandery, 1986).

The acidity of a wine is typically associated with flavour descriptors including "crispness" and "freshness". On the chemical level, acidity can be attributed to the presence of tartaric and malic acid (Jackson, 2008). These acids have a propensity to react with ethanol in the wine during aging to form flavour molecules known as esters. The impact of this conversion process is twofold; the removal of acids reduces acidity, while the creation of esters can enhance flavour of the wine (Jackson, 2008).

In addition to "crispness", young wines are commonly described as "floral" and the collection of a wine's flavours is known as the bouquet. Monoterpenes have been identified as the major contributors to floral fragrances and tastes, and their evolution with age can greatly affect the floral character of a wine (Jackson, 2008). Linalool is one such monoterpene, and its concentration has been shown to decrease by as much as 90% during the first two years of white wine aging (Rapp and Mandery, 1986). Since floral character is an important flavour component for many white wines, the degradation of monoterpenes is one reason that white wines are not typically aged. Of course, there are always exceptions to the rule as some white wines do possess chemical profiles that are compatible for and benefit from aging (Rapp and Mandery, 1986). In these cases, chemical compounds which positively alter the wine's flavour are often added. For example, in some Rieslings, vitispiranes and furfural compounds are added by winemakers, which will increase the vanilla and caramel flavouring of the wine if it is allowed to age (Rapp and Mandery, 1986).

Though monoterpene levels decrease with age, several volatile compounds have been identified to increase in concentration during a wine's lifetime (Tominaga, et al., 2003). These chemicals form gradually in Champagne wines and may contribute to the toasty, smoky, and roasted coffee flavours typically associated with older wines. The resulting set of more complex, yet less floral flavours is sometimes referred to as an aged bouquet (Tominaga, et al., 2003).

A third flavour descriptor is the term "vegetal", used to describe tastes reminiscent of cooked vegetables or bell peppers. The chemical known as MIBP (2-methoxy-3-isobutyl pyrazine) is most commonly cited for vegetal flavours (Ebeler, 2001). The introduction of small amounts of oxygen to a wine, which may occur naturally with bottle aging, has been correlated with less intense vegetal tastes and aromas in red wines (Llaudy, et al., 2006).

There is no guarantee that a wine's taste and smell will improve as it gets older; there are too many possible flavour modification reactions to perfectly predict the end result of prolonged wine storage. Even when considering a single reaction such as the degradation of linalool, these flavour modifications could improve the complexity of some wines, while completely ruining others (Jackson, 2008). That being said, connoisseurs would not waste their time collecting and storing older wines without potential flavour payoffs. The subtle complexity of an old wine's aged bouquet may be well worth the wait.

MOUTHFEEL

A good wine should be appealing to all of the senses; there is more to the picture than just taste and physical appearance. The collection of physical sensations that a wine creates inside the mouth is referred to as mouthfeel (Jackson, 2008). Although the term encompasses all touch sensations, the most commonly discussed attribute is astringency, which refers to a dry, puckering mouthfeel. Tannins can be divided into flavanols, non-flavonoids, and pigmented polymers; they are considered the major contributors to wine astringency (Gawel, 1998). These compounds are present in the skins and seeds of grapes and are imparted to a red wine during the winemaking process. Much like over-steeped tea has an undesirable, puckering mouthfeel, young red wines can be strongly astringent due to their high concentrations of these tannins (Gawel, 1998).

As previously mentioned, oxygen entering the bottle can initiate oxidation reactions. Ethanol in wine reacts with oxygen to produce acetaldehyde, which can either react again with oxygen again, or activate flavanol molecules. When acetaldehyde interacts with free flavanol in the wine, the flavanol molecules form polymers with other flavanols. While free flavanol molecules contributed to astringency, flavanol-flavanol

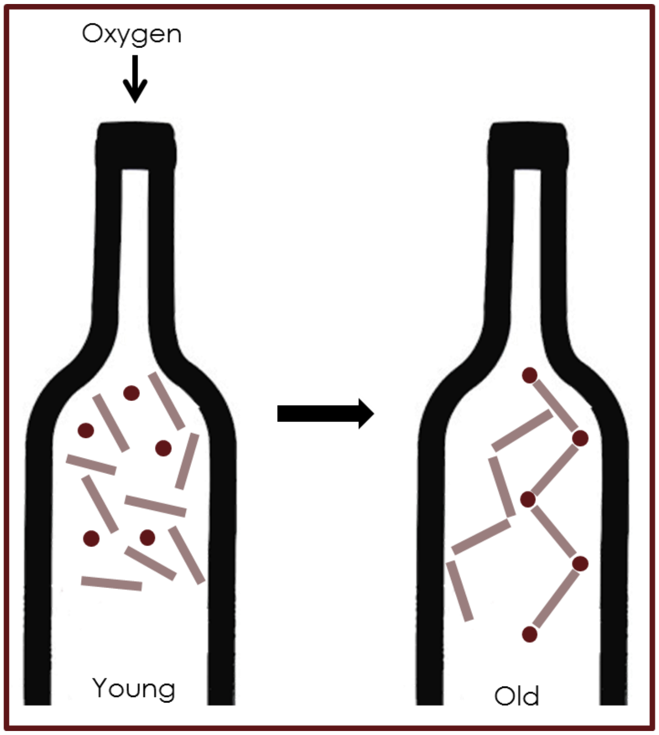

FIGURE 4: PHENOLIC POLYMERIZATION. Oxygen can enter wine bottles during aging, initiating polymerization reactions. Flavanol (shown as brown sticks) can form polymers with anthocyanins (shown as red dots), which results in colour stability. Flavanol can also combine with other flavanol molecules, leading to a decrease in astringency (Gawel, 1998).

complexes do not have the same effects (Figure 4) (Gawel, 1998). In fact, red wines typically lose some astringency with age, as flavanol and other tannins are given time to polymerize (Llaudy, et al., 2006).

Though oxygen can improve the mouthfeel of a wine by initiating the polymerization of tannins, these reactions require consumers to wait before opening their wines. In an effort to minimize this waiting period, some wine manufacturers are beginning to use micro-oxygenation (MO) while the wine is still barreled (Llaudy, et al., 2006). In MO, small amounts of oxygen are allowed to enter the wine to trigger polymerization reactions. The process is still rather new; however, early results indicate that it may be effective in reducing the astringency of young red wines, thereby improving the mouthfeel (Llaudy, et al., 2006).

SELECTING A NIAGARA WINE TO AGE

Hugh Johnson's collection contains hundreds of aged wines, yet it is unlikely that many Niagara wines are present. Winemaking is a relatively young industry in the Niagara region, and it was not until the 1990s that Niagara wineries started to produce wines that could compare with their international competitors (Peters, 2013). Consequently, Niagara wines have not yet been afforded the opportunity for long-term aging, thus there has been little research to determine their aging potential. Nevertheless, Niagara wines are beginning to garner attention globally as their quality continues to improve. Wine connoisseurs may soon look to add Niagara wines to their collections, so it is worthwhile to predict which Niagara wines will benefit the most from bottle aging.

Terroir is an all-encompassing term in the wine industry to describe the impact that climate, soil, and geographical location have on a wine's character for a particular growing region. Smaller geographical regions called appellations are used to differentiate locations that are close in proximity, but differ in terroir (Douglas, et al., 2001). The Niagara peninsula, bordered by Lake Ontario, the Niagara River, and the Welland River, is essentially divided into three sub-appellations, each with its own terroir (VQA Ontario, 2013). The Bench refers to the region along the Niagara Escarpment, while the Lakeshore is the region immediately adjacent to Lake Ontario, and the Lakeshore Plain is between the Bench and Lakeshore (Figure 5). The Lakeshore Plain is characterized by warmer temperatures than the other two regions, while the Lakeshore is thought to have a slightly longer growing season (Douglas, et al., 2001).

In 2005, a team of researchers from Brock University's Cool Climate Oenology and Viticulture Institute conducted chemical and sensory analyses to compare Bordeaux-style red wines from the three different Niagara sub-appellations (Kontkanen, et al., 2005). Wines from the Bordeaux region of France are considered to have excellent aging potential, thus it is interesting to discuss Bordeaux-style wines in Niagara. The researchers found that wines produced from the Lakeshore Plain had the highest phenolic compound levels, alcohol content, and colour intensity. All of these results are consistent with the observation that the Lakeshore Plain has the warmest growing season, allowing grapes to accumulate greater concentrations of phenolics and sugars (Kontkanen, et al., 2005). As previously

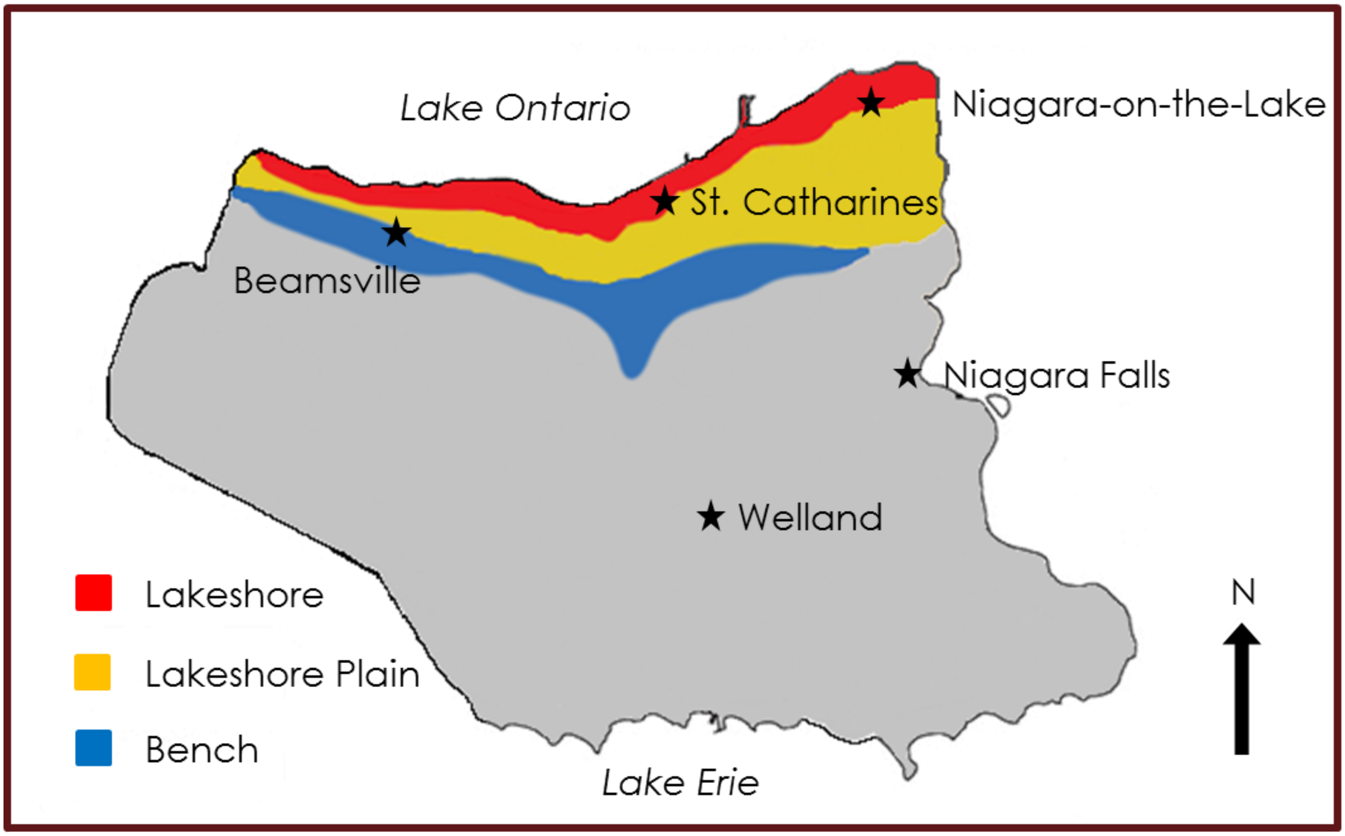

FIGURE 5: NIAGARA SUB-APPELLATIONS. The Niagara wine growing region is divided into three distinct sub-appellations, each with their own terroir. The Bench is characterized by the coolest temperatures, while the Lakeshore Plain has the warmest. The Lakeshore is also thought to have the longest growing season (Douglas, et al. 2001).

mentioned, high phenolic content (including monoterpenes, tannins, and anthocyanins) can contribute to greater aroma, flavour complexity, and long-term colour stability (Jackson, 2008). Lakeshore Plain wines also had the greatest initial colour intensity, which is good sign that they will develop more pleasing tones as anthocyanins polymerize with tannins during aging. Overall, it seems that wines from the Lakeshore Plain sub-appellation are the best choice when looking to add a Niagara wine to a developing collection.

HOW TO STORE A WINE DURING AGING

After choosing some Niagara wines for aging, the aspiring connoisseur needs to find a place to keep them. While most winemakers are skilled at maintaining ideal storage conditions for their wine prior to bottling, the task does not end once wine reaches the consumer. The reality is that consumers need to maintain appropriate storage conditions or risk losing their bottled wines due to spoilage. By carefully monitoring wine storage conditions, there are many ways that people can improve the longevity of their wine. It probably is not feasible for everyone to invest in a professional wine cellar, but exercising some control over the light levels and temperature at which wine is stored can significantly benefit the aging process. Even a bottle's orientation and type of seal can determine a wine's aging potential. Recent research into wine storage methods may offer assistance to consumers who are looking to benefit from the wine aging process, while minimizing the dangers of long-term storage (Figure 6).

BOTTLE ORIENTATION AND SEALING

Small amounts of oxygen can be good for a wine as it ages, stabilizing the colour of the wine and reducing its astringency. Yet oxygen is also an important part of many biological systems, so the presence of oxygen encourages the growth of acetic acid bacteria (AAB) in wine (Bartowsky and Henschke, 2008). Similar to the metabolism performed in the human liver, AAB convert ethanol to acetaldehyde and then to acetic acid. The resultant acetic acid gives wine a characteristic vinegar taste. As well, large AAB colonies can form a bacterial ring around the neck of the bottle.

FIGURE 6: STORAGE RECOMMENDATIONS. It is important to maintain the proper bottle orientation, light levels, and temperature when aging wine in bottles (Mas, et al., 2002; Blake, et al., 2010; Butzke, 2008).

The thickness of the ring can be used to estimate the concentration of acetic acid in the wine, and it is an indication that the wine has spoiled (Bartowsky and Henschke, 2008).

In order to control the growth of AAB colonies in wine, it is important to ensure that wine has minimal contact with atmospheric oxygen. Thus, a proper wine bottle with a tight seal can protect wine from AAB-related oxidation (Bartowsky and Henschke, 2008). Wine bottles have traditionally been sealed using natural cork, and while they are still a popular choice for many wines, screw caps and plastic stoppers are becoming increasingly prevalent. As expected, different bottle seals have varying degrees of effectiveness in preventing wine oxidation (Mas, et al., 2002).

In a 2002 study, a team of Spanish researchers investigated the role of bottle sealing in the prevention of wine oxidation (Mas, et al., 2002). To quantify the degree of oxidation, the authors used both chemical analyses and human tasters. Using wine bottles with natural cork stoppers as a control, the researchers found that bottles with screw caps had significantly higher levels of oxidation than the control after only six months of storage. This observation was consistent for both the chemical analyses and human tasters. Based on the results of their study, researchers recommend storing wines with screw caps for a maximum of six months for white wines and twelve months for red wines (Mas, et al., 2002).

Interestingly, the team also found a correlation between a wine bottle's orientation during storage and its degree of oxidation. Bottles stored horizontally were significantly less prone to oxidation than vertically-stored bottles (Mas, et al., 2002). One proposed explanation for this result is that horizontal storage will keep the cork or cap moist, creating a better seal and preventing oxygen from spoiling the wine. Although bottle position may initially seem unimportant, results indicate that storing wine bottles on their side will reduce the risk of wine oxidation (Mas, et al., 2002).

LIGHT EXPOSURE

As previously discussed, white wine contains hydroxycinnamates, which have a role in white wine browning. One type of hydroxycinnamate, caftaric acid, can be broken down into molecules called quinones in the presence of light. These quinones then polymerize to form yellow-brown macromolecules via oxidative browning (Recamales, et al., 2006).

Since light stimulates white wine oxidation, storing bottles of wine out is preferrable. A 2006 study done at the University of Huelva in Spain revealed that wine exposed to light contained lower levels of caftaric acid. The decrease in caftaric acid concentration indicates that caftaric acid is being oxidized into quinones, producing a visible browning effect. Thus, this paper's results confirm that wine exposed to light will experience a greater degree of oxidation than wine kept in the dark.

As well, sulfur dioxide is often added to white wine to prevent oxidative browning. Light influences the effectiveness of this addition as wine kept in the dark possesses a higher retention of free and bound sulfur dioxide (Blake, et al., 2010). Additionally, the hue of a wine bottle can have an effect on sulfur dioxide content with the concentration being the greatest in amber bottles, and the lowest in clear bottles. Therefore, consumers looking to age wine should store their wine in bottles with an amber hue and out of light.

TEMPERATURE REGULATION

When storing red or white wines of any age, temperature is a crucial factor to consider. All of the reactions during wine aging occur at different rates and are temperature-dependent. In this sense, high temperatures often accelerate oxidation reactions in wine, which causes oxidative browning in white wines. Elevated temperatures may also provide suitable living conditions for otherwise dormant bacterial populations, leading to AAB spoilage in red wines (Ough, 1985). Fluctuating temperatures should be avoided at all times in the storage area because they promote the expansion and contraction of cork material. These changes in the cork shape permit seepage of oxygen into the bottle, resulting in further oxidative browning and AAB spoilage. Lastly, temperatures under 10˚C may impede wines from developing desirable flavours. If wine is stored below the freezing point of water, precipitates form, which may substantially lower aesthetic value and mouthfeel (Butzke, 2008).

As a general rule, wines being kept for longer than four weeks should never have a storage temperature exceeding 16˚C. At temperatures below 10 ˚C, the reactions required to improve a wine's flavour, colour, and mouthfeel do not occur at any appreciable rate. As a result, long-term aging typically means maintaining consistent temperatures in the range of 10-16˚C (Butzke, 2008).

For the majority of consumers, it can be quite difficult to find appropriate wine storage conditions. Underground cellars are far from reality for most city-dwelling connoisseurs. Alternatively, wine cabinets are available for purchase on the market. Storage cabinets keep wine at a temperature suitable for aging, while limiting changes from external temperature fluctuations. A major drawback to these devices is their inability to maintain constant internal temperatures in any given environment. Therefore, keeping the cabinet in an outbuilding such as a garage or shed where temperatures can freely fluctuate may prevent the cabinet from functioning properly (Smith, 1974).

LET THE AGING BEGIN

The aging of wine is truly an art, and its mastery requires great patience and attention to detail. With correct storage techniques, aging can improve some of wine's most appreciable characteristics; particularly colour, flavour, and mouthfeel. Aspiring wine collectors should realize that obtaining the same results as Hugh Johnson would require years of research and large amounts of time and money. Although most people looking to start a small wine collection do not have near the amount of experience, time, or resources as Johnson, aging can still be a manageable and rewarding hobby. A basic understanding of the chemical changes that take place in a wine as it ages, combined with knowledge of proper wine storage techniques can help consumers get the best results from their wine. Perhaps one day, aspiring wine connoisseurs will be able to sell their well-aged Niagara wines with a $9 000 price tag.

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BOTTLE-Y BENEFIT OR BOTTLE-Y HARM?

WINE, HEALTH, AND THE NIAGARA REGION

Matthew Galli, Kerri Kosziwka, Lori Minassian, Pratik Samant, Christina Spinelli, Hanna Stewart

THE GOOD FOOD REVOLUTION

Moving towards a more health conscious world

In recent years, global food markets in North America, Europe, and particularly Asia have undergone a dramatic increase in the volume of commercial health foods and products. In Canada, a combination of government funded healthy eating initiatives and an aging population have made consumers more concerned not only with what food they eat, but how and where it is produced. This shift towards a more health conscious lifestyle has forced food manufacturers to invest heavily in the research and development of natural and healthy alternatives. However, defining a particular food or dietary pattern as 'healthy' is not an easy task, as different clinical studies often yield contradictory results (GoC, 2012). The questions "are these products healthy?" and "which variations are healthiest?" have sparked serious scientific debates that have persisted over many years. One such example is wine (Guilford and Pezzuto, 2011).

Wine is believed to be the oldest medicine, with uses dating back to 2200 BC. In the past, it was used to treat skin and digestive conditions, and as a painkiller and antiseptic. Despite these historical uses, wine's health benefits did not become a major research focus of the scientific community until the early 1990s. What arguably sparked mainstream scientific interest in wine's health benefits was media coverage of the French Paradox: the observation that the French have a comparatively low incidence of coronary heart disease despite a diet high in saturated fats. Epidemiological studies indicated that habitual, moderate consumption of wine may account for the observed health paradox. Other health benefits observed included protection against cardiovascular diseases, certain types of cancer, type-2 diabetes, and neurological disorders. Many of these benefits are believed to be due to wine's high antioxidant content, such as resveratrol (Guildford and Pezzuto, 2011; Vingtdeux, et al., 2008).

"The questions 'are these products healthy?' and 'which variations are healthiest?' have sparked serious scientific debates that have persisted over many years. One such example is wine (Guilford and Pezzuto, 2011)."

However, critics have in part dismissed the direct link between wine and health, citing other variables that could have impacted the results of these human studies. For example, the average moderate wine consumer is likely to be relatively healthy, a member of a higher socioeconomic class, and well educated. Another critical issue is that the line between excessive and moderate consumption is a blurred one. While the standard suggestion is two glasses of wine per day for men (300 mL), and one for women (150 mL), every individual is different (Guildford and Pezzuto, 2011). Not having a definite distinction between moderate and excessive drinking is dangerous, as excessive consumption can actually lead to health detriments, such as increased susceptibility to stroke, steatosis (fatty liver), and negative changes in brain function (NIAAA, 2013).

Despite these concerns, a large body of evidence supports a link between improved health and regular, moderate consumption of wine. However, every type of wine differs in its chemical composition, leading to the question of which types are healthiest. It has been argued that the higher the antioxidant content, the more profound the health benefits. This is certainly true in the case of red versus white wine, as previous literature indicates greater benefits in the antioxidant rich red wine (Guildford and Pezzuto, 2011). To further test this theory and to determine which wine is healthiest, it is necessary to examine a fruit wine like blueberry wine that also has high antioxidant content and compare it to a red wine.

TOASTING TO THE BENEFITS OF WINE: A RED AND BLUE COMPARISON

Red Wine

Ontario is Canada's largest producer of premium wine, accounting for 90% of wine production and 80% of harvestable grape growth. Good things do grow in Ontario, or more specifically in the Niagara Peninsula. This lush region's proximity to the Great Lakes gives it a moderate climate that is ideal for growing grapes (Carew and Florkowski, 2012). Without this proximity to the Lakes, the region would instead have a mid-latitude continental climate with comparatively hotter summers and colder winters. Instead, a semi-maritime climate is exhibited. Due to water's high heat capacity (the unwillingness to change temperature), water tends to be warmer than the air surrounding it. In turn, this water warms the air and increases the temperature to higher than it would normally be. The opposite occurs during the summer when the temperature of the air tends to be hotter than that of the water. A consequence of this is that viticulture is possible year round (Shaw, 2005).

Wines grown in the Niagara region have varied greatly through the years. The Niagara region's primary indigenous grape varietal or grape variety is *Vitis riparia.* Early settlers would occasionally make wine from this grape, but they found that it was too sour and harsh for consumption. A better grape species for winemaking is *V. labrusca,* as it produces larger grapes that can be cultivated in many environmental conditions. While *V. labrusca* does grow naturally in the Niagara region, French-American hybrids were imported in the 1950s and soon dominated commercial production. This did not last for long. The 1970s brought to fame the grape species *V. vinifera* which by 2004 accounted for more than 58% of the Niagara region's vines (Shaw, 2005).

Red and rosé wines in particular are most beneficial to the Canadian wine industry, accounting for 62% of total volume sales (Carew and Florkowski, 2012). In recent years, red wine has garnered positive media attention as a potentially beneficial addition to a daily diet. As previously mentioned, one of the reasons scientists have become particularly interested in wine is the French Paradox. The French's North American counterparts were tantalized by the thought that by drinking red wine, they could eat diets high in fat without increasing their risk of developing cardiovascular diseases. Further research into the benefits of wine has also shown it has anti-carcinogenic effects and is protective against numerous diseases (Guilford and Pezzuto, 2011).

While the health benefits of wine are well researched, the components of wine responsible for them still puzzle scientists (German and Walzem, 2000). Some research has found moderate alcohol intake may be beneficial to preventing atherosclerosis (plaque build-up in the arteries that can lead to heart attacks). Alternatively, others argue that it is the polyphenolic (antioxidant) compounds in wine that contribute to these benefits. Red wine is unique among wines in its abundance of polyphenols (Nigdikar et al., 1998). Found in the skin and seeds of grapes, they are likely responsible for the protective effects against cardiovascular diseases, as well as its anti-carcinogenic and insulin-like properties (Su, Hung and Chen, 2006; Soleas, et al., 2002; Nigdikar, et al., 1998). There are many different types of polyphenols, the most famous of which is resveratrol. Wine's high resveratrol content is the most popular explanation for the French Paradox.

Regardless of the uncertainty as to where these benefits originate, it is clear that there are many benefits to consuming red wine. The question that remains is how they compare to the health effects of blueberry wine.

FIGURE 1: WINE GRAPES GROWING IN ONTARIO'S NIAGARA-ON-THE-LAKE. Good things grow in the Niagara Peninsula. Ontario accounts for 90% of wine production and 80% of harvestable grape growth in Canada, making it Canada's largest producer of premium wine (Carew and Florkowski, 2012; Graham., 2010).

Blueberry Wine

Typically, popular wines are made from red and white grape varietals. Non-traditional fruit wines do not seem to have as much success. This is easily seen in any LCBO (Liquor Control Board of Ontario) where Pinot Grigio, Cabernet Sauvignon, and Merlot stack the majority of shelves, with non-traditional fruit wines holding a minority. However, this was not always the case. Historical evidence shows that the earliest wines were made from honey (mead) and fruits, such as plums. Today, for many berry growers in Ontario, wine production is a beneficial alternative for the use of produce that cannot be sold due to over-ripeness or slight imperfections. There are 15 fruit wineries in Ontario, and one of the more popular fruits to use is blueberries (Fruit Wines of Ontario, n.d.).

Canada has almost 3 000 blueberry farms and represents 33% of the world's blueberry production. It is important to note that blueberries must grow in slightly acidic soil with a pH around 5.0 to 5.3 depending on the variety (Agriculture and Agri-Food Canada, 2010). Many geographic locations across Canada are optimal for growing blueberries. The climate is very important in this regard, with adequate rainfall and sun during summer months, and mild winter conditions being the key factors. In 1993, the first winery in Canada to specialize in fruit wine, Sunnybrook Farm Estate Winery, was opened in the Niagara Region. Since then, more fruit wineries have opened including the notable Scotch Block Winery in Milton, Ontario which produces blueberry wine in addition to strawberry, currant, raspberry, and many other berry wines (Fruit Wines of Ontario, n.d.).

Blueberries in particular are known to be very beneficial to health, and are often proclaimed to be one of the healthiest foods due to their high levels of Vitamin K and C, manganese, and fibre. Studies have shown that blueberry consumption can aid in disease prevention and promote healthy aging. Their high level of anthocyanins has been shown to help dilate arteries to counter the build-up of atherosclerotic plaques. Also, regular consumption of blueberries has been shown to positively affect brain health. Studies show that blueberry consumption decreases memory loss and improves motor skills in people genetically predisposed to Alzheimer's. Furthermore, blueberries can help improve night vision, prevent urinary tract infections, and reduce the risk of developing diabetes (The George Mateljan Foundation, n.d.). Many of these health benefits are consistent with those found for red wine consumption. Though there is much ongoing research on the topic, the amount of data present regarding blueberry wine is limited relative to data present on grape wines.

Since it is difficult to determine individual antioxidant components of complex mixtures like wine, resveratrol itself has not been directly extracted out of blueberry wine nor has its concentration been quantified. However, Oxygen Radial Absorbance Capacity (ORAC) and Trolox Equivalents (TE) are techniques that can be used to measure total antioxidant levels. The process of producing blueberry wine has been shown to not have a significant impact on ORAC values when compared to pure blueberry juice. Blueberry wine yielded greater ORAC values than 80% of red wines and 100% of white and rose wines. Although total phenolic content of red wine is generally higher than blueberry wine, both have similar anthocyanin content (Yang et al., 2012). These results indicate that blueberry wines contain a higher overall antioxidant content than most red

FIGURE 2: MATURING BLUEBERRIES. With their high antioxidant, Vitamin K and C, and fibre levels, blueberries are considered to be one of the healthiest foods. Blueberry wine contains these same benefits (The George Mateljan Foundation, n.d.; Anon., 2006).

and white wines (Yang et al., 2012).

While more research must be conducted, it is encouraged that consumers branch out of their comfort zone to try and enjoy non-traditional fruit wines. The benefits associated with blueberries and blueberry wine are highly dependent on antioxidants. As such, understanding antioxidants and their benefits will aid in the overall understanding of wine-related health benefits.

THE POWER OF ANTIOXIDANTS

The health benefits of wine are generally attributed to the presence of antioxidants: molecules that inhibit the oxidation of other molecules. In wine, most of the antioxidative effects come from the presence of polyphenols. Polyphenols can be split into two main categories: flavonoids and non-flavonoids. There are many examples of flavonoids, including anthocyanins and flavan-3-ols, which are the most abundant polyphenols found in wine. Anthocyanins are the molecules that are responsible for the colour of red wine (Brouillard, et. al, 1997). Non-flavonoids include gallic acid, cinnamates and resveratrol. The antioxidant effects of polyphenols include a reduction in the oxidation of low-density lipoprotein (LDL) cholesterol, modulation of cell-signaling pathways, a decrease in oxidative damage to DNA, and a reduction in platelet aggregation (Guilford and Pezzuto, 2011).

The majority of cholesterol is present in two forms in the body: low-density lipoprotein (LDL) or high-density lipoprotein (HDL; also known as "bad" and "good", respectively). High levels of LDL are associated with an increased risk of atherosclerosis, obesity and type-2 diabetes. Oxidation of LDL cholesterol has been linked with cardiovascular disease. Studies have shown that certain flavonoids can reduce the amount of LDL cholesterol oxidation by binding to the lipoprotein. In addition, wine polyphenols can preserve the activity of an enzyme called HDL-associated paraoxonoase. This enzyme can break down oxidized lipids, reducing oxidative stress. Wine polyphenols can also accumulate in certain cells, such as macrophages (cells that ingest foreign particles or dead cells) in the artery walls, protecting them from lipid peroxidation (Sandler and Pinder, 2003). Interestingly, procyanidins, a type of flavonoid, can prevent the oxidation of fats from food during digestion, indicating that drinking a glass of wine with your meal may benefit you more than having a drink on its own (Guilford and Pezzuto, 2011).

"Drinking a glass of wine with your meal may benefit you more than having a drink on its own (Guilford and Pezzuto, 2011)."

Moderate consumption of wine has also been shown to have positive effects on the cardiovascular system, reducing the risk of atherosclerosis, hypertension and hypercholesterolemia (high amounts of cholesterol). The endothelium (inner layer) of blood vessels regulates the vascular diameter. The release of nitric oxide (NO) from these cells relaxes the blood vessel and the release of endothelins constricts them. Long-term constriction of blood vessels leads to higher blood pressure and a higher chance of clotting. Wine polyphenols such as catechin, quercetin and procyanidins enhance the production of NO by the endothelium. They also increase the long-term expression of endothelial NO synthase, the enzyme that generates NO. This increased NO production leads to lower blood pressure (Guilford and Pezzuto, 2011).

Polyphenols in wine have also been shown to have anti-cancer effects and decrease the risk of type-2 diabetes. Cancer cells rely on a process called angiogenesis to proliferate. This process involves the production of new blood vessels to feed the growing tumor. Polyphenols in wine have been shown to inhibit angiogenesis through two mechanisms: 1. They decrease the production and migration of smooth muscle and endothelial cells required for blood vessel formation; 2. They reduce the expression of factors needed for angiogenesis. Type-2 diabetes is characterized by high blood sugar concentrations. This can be due to insulin resistance, or reduced insulin production by the beta cells of the pancreas. Studies have shown that antioxidants found in wine can increase the amount of beta cells and their efficiency (Guilford and Pezzuto, 2011).

Antioxidants found in wine have also been shown to have positive neurological effects, reducing the risk of dementia, Alzheimer's disease and stroke. Oxidative stress is a characteristic of aging and generation of age-related neurological disorders. Oxidative stress is a chemical imbalance between the production and breakdown of reactive oxygen species (ROS). Neurons are thought to be more at risk of oxidative stress than other mammalian cell types due to their low amount of antioxidants (Higgins et al., 2010). Antioxidants in wine break down these reactive oxygen species and thus reduce oxidative stress. In addition, some wines contain hydroxytyrosol, a dopamine metabolite and antioxidant. Dopamine is a molecule used by the brain for signaling thus suggesting that hydroxytyrosol may be involved in brain signaling (Guilford and Pezzuto, 2011).

There is still debate regarding whether or not it is the alcohol or the antioxidant content of wine that makes it so beneficial. However, most studies seem to conclude that the effects of alcohol and antioxidants are additive. Experiments comparing wine, dealcoholized wine, grape seed extract and grape juice have shown results suggesting that alcohol is not the key to the health benefits of wine. It should be noted that the alcohol component in wine does play a role in amplifying the antioxidant effects and in other health benefits such as increasing HDL cholesterol, and inhibiting platelet aggregation (Guilford and Pezzuto, 2011). In addition, there is evidence that the antioxidants in wine and food work synergistically to positively affect health. Green olive oil consumed in conjunction with wine has been shown to have positive effects on cardiovascular disorders (this is known as the Mediterranean diet). The key to harnessing the best health effects from wine is moderate, consistent consumption. Studies show that one or a few doses of wine have no effect. However, health benefits become apparent when approximately 200mL of wine is consumed daily for a span of weeks (Guilford and Pezzuto, 2011).

Within the realm of antioxidants, resveratrol stands out as a prominent contributor to the benefits of wine. Not only does it carry the benefits that other polyphenols have, resveratrol has other special properties that further increase the health benefits to the consumer.

"Wine's antioxidants have been found to have a vast number of health benefits. The key to harnessing them all is moderate and consistent consumption along with a healthy lifestyle (Guilford and Pezzuto. 2011)."

Resveratrol: The phytoalexin that's good for your health

Resveratrol is a phytoalexin, an antioxidant compound naturally formed in plants that protects it from ultraviolet radiation, and bacterial, fungal, and parasitic infestations (Campagna, 2010). Produced in the skin and seeds of grapes and blueberries, resveratrol contributes to the health benefits of wine. The average concentration of resveratrol within red wines is approximately 7 mg/L (Shishodia and Aggarwal, 2005). Though it is not known exactly how much resveratrol is present in blueberry wines, it is likely lower than red wines given that unprocessed blueberries have less than 10% of red grapes' resveratrol content (Lyons et al., 2003). Chemically classified as a polyphenol stilbene, the –OH group on ring B is responsible for resveratrol's powerful antioxidative properties like preventing free radicals (unstable molecules) from causing cell damage (Refer to Figure 3; Baxter, 2008).

Resveratrol has been shown to interact with many different cell and tissue types, including the heart, liver, kidneys, and brain, to produce a diverse range of systemic health benefits. Scientists now recognize that many diseases are the result of a combination of both environmental factors and dysregulation of multiple genes, meaning that compounds capable of enacting positive effects on multiple biological targets have a higher therapeutic potential (Campagna, 2010). Returning to the French Paradox, resveratrol (like other antioxidants) plays a key role in the reduction in incidence of cardiovascular disease. Like other polyphenols, resveratrol up-regulates the production of NO, though it also reduces the formation of plaque by affecting platelets (cells responsible for forming blood clots; Smoliga et al., 2011).

Furthermore, the ingestion of resveratrol has been shown to mimic the effects of caloric restriction, which gives it the potential to be used as a therapy for metabolic disorders. High calorie diets in humans cause augmentations in glucose and insulin levels, which can ultimately lead to diabetes (Smoliga et al., 2011). Resveratrol has been shown to reverse the detrimental health effects of prolonged high caloric intake in obese humans. These effects include a reduction of fat content in the liver, a reduction in blood pressure, and an increase in insulin sensitivity (Schrauwen, 2011).

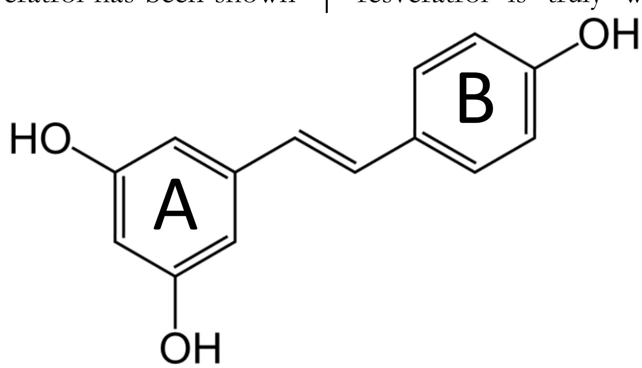

FIGURE 3: RESVERATROL MOLECULE. The specific arrangement of the hydroxyl (-OH) groups on resveratrol in Ring A is called a meta-configuration, and allows for the antioxidative effect seen in phenolic compounds. However, the presence of an additional hydroxyl group on Ring B raises the potency of resveratrol's antioxidative effects. In fact, research has shown that the more hydroxyl groups a phenolic compound contains, the better able it is to prevent damage caused by free radicals (Baxter, 2008; Anon., 2007).

Resveratrol's therapeutic potential also extends to its anticancer properties. It has been shown to inhibit the growth and spread of breast, melanoma, and intestinal cancers in a cell-specific manner, meaning its toxicity towards cancer cells is higher relative to normal cells (Baxter, 2008). Furthermore, it has shown potential in the realm of cancer prevention. Through its ability to alter enzymatic activity in the liver, resveratrol has been shown to prevent the transformation of pro-carcinogens into carcinogens. Interestingly, it has also demonstrated effectiveness in both enhancing cancer-killing abilities of drug and radiation treatment, while attenuating their toxic side effects. Unfortunately, not all research has led to positive implications. In the laboratory, resveratrol has been shown to augment angiogenesis and prevent programmed cell death, activities which would promote the spread of cancer cells (Pervaiz and Holme, 2009).

Although resveratrol's therapeutic potential looks promising, more research is needed to validate its effects in humans, as most research was conducted in animal models. Searching "resveratrol" through *ClinicalTrials.gov* reveals only 72 clinical studies have been conducted on resveratrol while thousands of studies have evaluated resveratrol's effects in laboratory models. It is apparent that human clinical trials are the minority within resveratrol research. Additionally, a key concern is the apparent contradiction between resveratrol's low bioavailability (amount ingested that enters systemic circulation) and its widespread positive effects. The question that remains is whether resveratrol is truly what exhibits the observed health benefits, or if they are the result of resveratrol's metabolites (Schrauwen, 2011).

Although there are questions that still need to be answered about resveratrol's connection to health, it is clear that resveratrol is capable of exerting a wide range of beneficial effects. It is for this reason that extracting and comparing the resveratrol content in red and blueberry wines may be a guide in determining which type is healthiest.

Quantifying Antioxidants in Red and Blueberry Wines

The argument presented thus far is that antioxidants, like resveratrol, play a key role in the health benefits exhibited by both red and blueberry wines. One method for attempting to answer the question of which type of wine is healthiest would be to conduct an experiment comparing extracted polyphenol content from a model red and blueberry wine. Such an experiment was recently conducted at McMaster University and compared two wines from the Niagara region: Pinot Noir (a red wine) and Blueberry Sensation (a blueberry wine).

Only basic extraction techniques were used in this investigation - polyphenols were separated from the wine samples using solvent extraction (technique for separating components of a mixture based on their differential solubilities in two solvents), and the resulting extracts were purified using chromatography (technique for isolating and purifying target compounds). This investigation found that the total concentration of polyphenolic compounds in the Pinot Noir was 0.3 ± 0.1 mg/mL, and 0.7 ± 0.1 mg/mL in Blueberry Sensation. The reported value for the Pinot sits nicely within the range of 0.2 to 0.71 mg/mL cited within the literature for red wines (LeBlanc, 2005). However, since this experiment is novel in the sense that blueberry wine's polyphenol content has never been physically quantified, there are no values to compare it to.

Although this experiment showed that the Blueberry Sensation wine had a higher polyphenol content than the Pinot Noir, this does not conclusively prove blueberry is 'healthier' than red. For one thing, it is possible that not all of the polyphenolic compounds present in blueberry wine have antioxidant activity, thus leading to a greater ORAC value but with lower quality polyphenols. Unfortunately, this investigation was unable to determine what percentage was specifically resveratrol, so the relative concentration of this important antioxidant is not known (Guilford and Pezzuto, 2011).

FIGURE 4: PINOT NOIR AND BLUEBERRY SENSATION. These two bottles of wine were compared for their polyphenolic content. Blueberry Sensation was found to have a greater total concentration of polyphenolic compounds that Pinot Noir.

Another important consideration is that only a single variety of each wine was tested. A wide variety of factors affect the chemical profile of a wine, including the specific grape varietal, the climate and soil type the grapes were grown in, and the particular techniques used in fermentation and aging. Previous studies have even found considerable variations in the antioxidant content of red wines made from the same varietals and grown in the same location (Siemann and Creasy, 1992). Ultimately, one bottle of Pinot Noir and Blueberry Sensation cannot be taken to represent red and blueberry wine as a whole.

A GLASS OF WINE A DAY KEEPS THE DOCTOR AWAY

Despite the appeal of such a statement, the true value of it should be taken lightly. When it comes to answering the questions "is wine healthy?" and "which one is healthiest?," the most honest answer is that there is no right one. The benefits and detriments of both red and fruit wine tread on a very thin line and what has been presented by no means advocates for or against wine consumption. An individual who already has a healthy diet and lifestyle can see benefits from a daily moderate consumption of wine, but heavy drinkers or alcohol abstainers are not encouraged to drink simply for health reasons. Wine consumption also does not replace a healthy lifestyle or pharmacotherapy (Guildford and Pezzuto, 2011).

However, the body of evidence in favour of wine's benefits will have significant impacts on Ontario's wine industry. In the past two decades, the wine industry of Ontario has undergone drastic changes and is now widely recognized for its high quality products. With Canadians moving towards healthier lifestyles that support local and organic goods, Ontario wineries should see more Canadians purchasing Niagara wines (Carew and Florkowski, 2012).

In the end, most reasons for consuming wine go beyond health, as wine is fundamentally something to be enjoyed. So whether it is red, white, fruit, or any other variation, drink up the succulent and fragrant tastes of all the Niagara region has to offer.

Cheers to good health, good taste, and good wine.

MORE TO EXPLORE

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