Terroir

|An Integrated Wine Science Publication|

TASTE THE DIFFERENCE

the subtle differences that make wines unique

QUALITY ASSURANCE
the LCBO and wine testing

CLIMATE CONTROL
success in the face of adverse conditions

SUSTAINABLE VITICULTURE
creating a quantifiable measure

A PERFECT PAIRING
icewine production in the Niagara region

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|An Integrated Wine Science Publication|
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ISCI DIRECTOR: Dr. Carolyn Eyles
PROJECT LEAD: Dr. Joseph Hayward
ADMINISTRATIVE LEAD: Sarah Robinson

Authorship by:

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Design by:

ART DIRECTOR: Alexander Young

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 2012

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 or to obtain additional copies of *Terroir* please contact Sarah Robinson at isci@mcmaster.ca

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A good image of the color of red wine with the contrast between the splash color and the color inside the glass. Wikimedia Commons. Francesco Pappalardo. 2010
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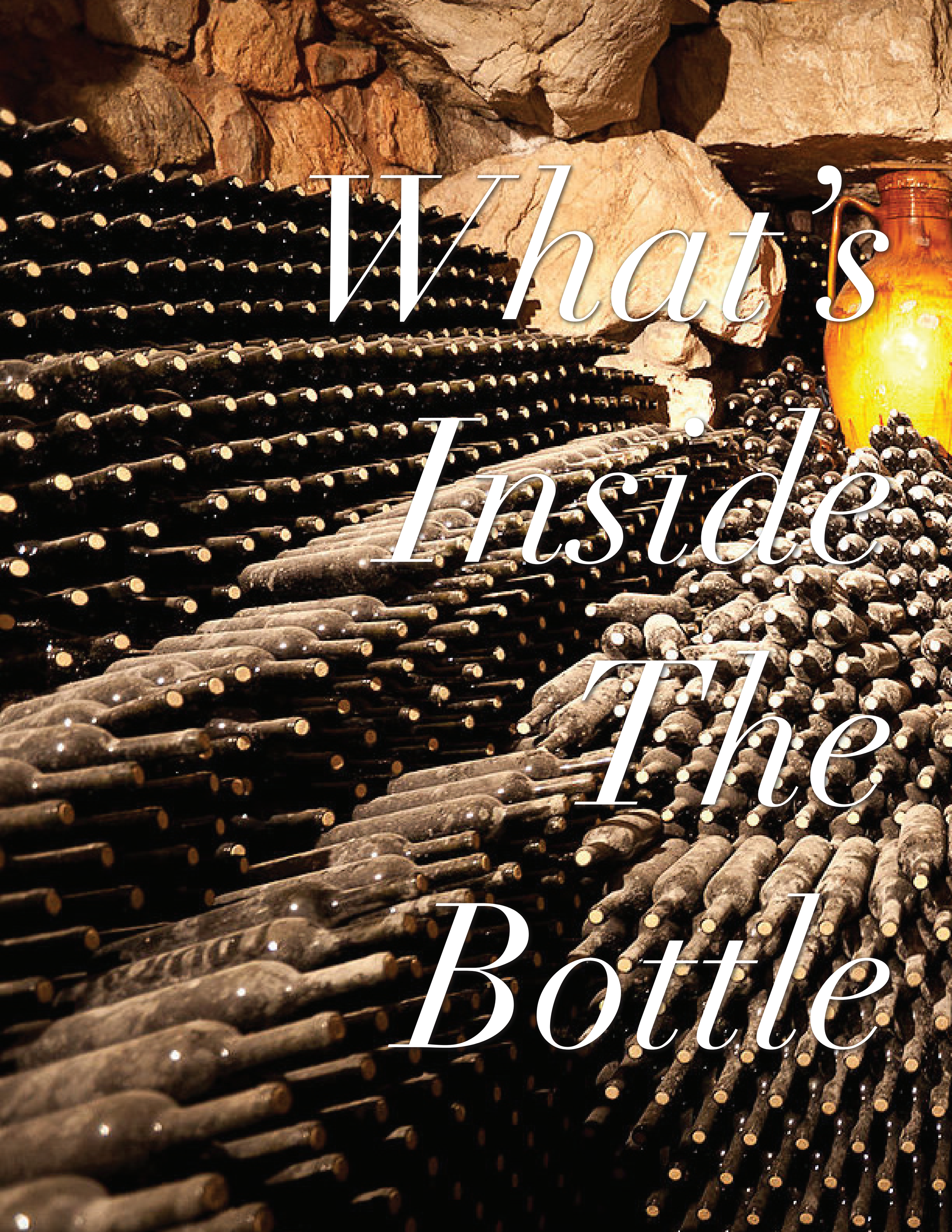
What's Inside The Bottle



Canadian Wine: What is in it, and do we care?

Jonathan Cogle, James Han, Jonathan Hughes, Amna Hyder, Myles Marin

Historically, views on alcohol consumption have varied greatly, from the temperance movement to an influx of evidence that shows that consumption of wine may increase life expectancy. Current research suggests that moderate consumption of wine may prevent various aspects of disease. However much evidence supports that it also may be the cause of disease. With so much focus on the intrinsic nature of wine and its health effects, very little attention is paid to the regulatory agencies that must constantly check for wine quality. In the Niagara region, the LCBO Quality Assurance department is responsible for testing the quality of beverage alcohol. This article outlines the history of the LCBO alongside the practices it implements to test for beverage alcohol contaminants. Further it looks into the current state of LCBO in the public and where it may be headed in the future.

Wine and Health

Wine has been a part of western civilization for over 7000 years, and although its role in society has varied greatly both geographically and historically, it has remained an essential aspect of western culture (Estreicher, 2006). The issue of wine and health has also been a complex and recurring theme in this history. In early times, one of the primary reasons wine was consumed, particularly for early settlers, was that it was a source of clean water and energy. With fifteen percent alcohol content, roughly triple that of beer; it was a sanitary alternative to the contaminated water found in early settlements (Estreicher, 2006). Wine also had its medical uses, and up until the introduction of distillation by Arabs in the 9th century, it was the most effective antiseptic technique for treating wounds (Estreicher, 2006). Moreover, wine was often used to treat a wide range of ailments including digestive complications, lethargy and labour pains during childbirth (Harding 2005).

Current research sheds light on the effectiveness of moderate wine consumption, among other potential health benefits, in retaining bone density, reducing risks of osteoporosis and acting as an anticoagulant to prevent blood clots (Harding 2005). On the other hand, research also demonstrates that chemicals in wine may act as carcinogens, increase blood pressure and increase risks of developing major depressive disorders (Harding 2005). Despite the complex arguments surrounding the intrinsic nature of wine's health effects, the importance of regulations set in place to maintain wine safety are often overlooked. In 2008, researchers from Kingston University, testing a random sample of red wine, found that it contained higher concentrations of several toxic metals than other analogous plant based drinks (Hague et al, 2008). This motivated further studies to confirm that certain red wine samples contained hazardous levels of mercury and other toxic metals (Hague et al, 2008). Such studies highlight the importance of ongoing testing for contaminants that may be present in wine. The policies and systems set in place to regulate the production and sale of wine are often undermined when considering health risks despite the integral role they may play.

Wine regulations in the Niagara Region

The year 1927 marked the end of an 11-year prohibition in Canada outlawing the consumption of alcohol, viewed by the temperance movement as a key source of the tribulations and ills of society (Newman, 2010). However, aspects of this belief system lingered even when the Ontario government removed prohibition laws (Newman, 2010). Thus the sale of alcohol, though legalized, was kept under strict control. As a compromise between prohibition and the unregulated sale of alcohol, the Liquor Control Board of Ontario (Nash, 2010) was created to regulate and monitor the sale of alcoholic beverages within Ontario. Up until the 1960s, the primary purpose of the LCBO was to license drinkers individually by issuing permits after reviewing an application on a case-by-case basis (Bird, 2006). This strict regulation began to slowly subside, and in 1969 the first self-serve LCBO store opened at 10 South Station Street emphasizing the transition to a more consumer based company (LCBO, 2012).

Despite the waning regulations, prior to 1985 the main focus of LCBO remained to control the sale of alcoholic beverages. The institution was significantly undercapitalized with minimal resources invested in upholding its infrastructure, reflected in part by the dreary appearances, bad locations and limited selection of stores (Bird, 2006). However, the 1985 provincial elections spearheaded the reformation of LCBO as Peterson's liberal campaign, elected in Ontario, saw the LCBO as an "embarrassment to the government in its current state" and proposed that it be 'modernized' (Bird, 2006). A new CEO and board of directors was appointed and the proposed changes to LCBO's structure, with recommendations from an external consulting firm, Mercer Limited, were outlined in a proposal termed "Project '87" (LCBO, 2012). In 1989 the LCBO invested 1.7 million dollars into a quality assurance (QA) faculty responsible for tasting, testing and certifying every product sold in the LCBO (LCBO, 2012). The LCBO QA department quickly achieved an invisible reputation for being the world leader in product quality testing, analysis and research (Juzairi, 1994).

This figure demonstrates the hundreds of samples tested by the LCBO Quality Assurance Laboratory on a weekly basis.

Talk of free trade began to emerge in the early 1990s (MacArthur, 2010). This sparked much fear for the Niagara wine industry and many believed that the North American Free Trade Agreement (NAFTA) would allow cheap California wine to wipe out local wineries (Bird, 2006). In fact, one survey conducted in the Niagara region found the public believed that "the entire industry would disappear within five years" (Bramble, 103). Fears escalated when Prime Minister Brian Mulroney's quoted to President Ronald Reagan, "You drink our beer and we'll drink your wine" (Bird, 2006). However all hope was not lost for local wine industries, and this is when the 'Niagara Quality Alliance' emerged; if one could not compete with cost, they could with quality. The Niagara Quality Assurance, now known as the 'Vintners' Quality Alliance' or the VQA, was founded in 1990 and would grant certain wines membership after thorough testing to certify its quality (VQA, 2012).

In 1991, LCBO's QA laboratory, supported by the VQA, performed 138,091 quality tests on 7,341 alcohol products and rejected 14% for failing to meet the standards (Juzairi, 1994). The rejected group can fail due to a labeling fraction, where the manufacturer inaccurately claims quality characteristics and specifications, or a safety violation, where consumer health is at risk (Juzairi, 1994). Apart from comprehensive testing done under the Canadian Food and Drugs act, the QA department also looks at potential contaminants such as glass particles, pesticide residues and dyes that are not permitted in Canada (LCBO, 2012). The breadth of equipment the QA Laboratory has allowed them to test for methanol, ethyl carbamate, OchratoxinA, turbidity, synthetic dyes, and volatile acidity among others (LCBO, 2012).

In 2000, the provincial government of Ontario passed the VQA act and since then, violators of the VQA act are held liable by law (Bird, 2006). The strict regulations coupled with the meticulous testing provided by the LCBO have earned the Ontario wine industry worldwide recognition as a symbol of wine quality and integrity.

Contaminants in Wine: *Is wine safe to drink?*

The LCBO funds a significant amount of resources into determining the health effects associated with contaminants that are introduced in the wine making process. Studies reveal that these contaminants may be introduced in the vineyard (in the form of pesticides), during the wine processing stage (where metals have been shown to leak into the product) and during the packaging stage.

The fermentation of wine is very susceptible to microbial growth and many byproducts of these microbes can be retained, even while the wine is being bottled. It is known that microbial activity plays a role in wine flavor, but some of the byproducts are carcinogenic and must be reduced or removed altogether. Initiating and regulating microbial growth is a wrestling match every winemaker must undergo. Here we highlight one byproduct of microbial metabolism and regulatory factor that are tested by the LCBO's Quality Assurance department.

Ochratoxin A

Ochratoxin A (OTA) is known to be the most potent member of the mycotoxin group. The proliferation of either *Aspergillus* or *Penicilium* species in grapes can often lead to OTA contamination in wine. These strains of bacteria are able to synthesize toxic microbial by-products that are classified as being potentially carcinogenic, nephrotoxic, or immunotoxic in most mammals (Zimmerli & Dick, 1996). Moreover, high OTA concentrations are shown to correlate with an increased frequency of renal tumours, DNA adducts and chromosomal aberrations in kidneys. Researchers have shown that a dietary intake of 1.21μg of OTA per day may lead endemic nephropathy and chronic tubulointerstitial kidney disease (Abouzied et al., 2002).

OTA can be found in various foods ranging from grain products to vegetables. In general, red wine is known to have the second highest concentration of OTA, and the substances are known to have a long half-life of 35 days upon oral ingestion (Petzinger & Weidenbach, 2002). Thus, health risks associated with daily consumption of wine have been thoroughly addressed by scientists and health regulation bodies.

The LCBO and VQA employ various analytical techniques to detect OTA in winemaking processes. Available detection methods include a competitive direct enzyme-linked immunosorbent assay and high-performance liquid chromatography (Reddy & Bhoola, 2010). The systematic regulation and detection techniques assists preventing OTA intake by wine consumers.

Sulfur Dioxide

Sulfur dioxide is used as a disinfectant or preservative in the manufacturing of various foods. In the context of wine, it is used prior to fermentation in winemaking. Sulfur dioxide is known to have antiseptic properties towards microbial proliferation while acting as an antioxidant. Although it has been shown to be beneficial in winemaking process, the use of sulfur dioxide is also implicated in various medical symptoms, including: asthma, itchy skin, headaches, anxiety, cramps, diarrhea and more. As such, the International Organisation of Vine and Wine implemented a strict upper limit of 150-400mg/L of the sulfite in wine. Due to restriction set by the legislation, there has been intensive research to obtain an appropriate chemical replacement for sulfur dioxide. Suggested replacements include electrochemical treatments and the use of dimethyldicarbonate. Outside of using chemicals, other factors, such as packaging, storage atmosphere, ozone and gas treatments, are known to play a key role in reducing the sulfite concentration in wine. In order to detect the sulfite concentration within the final product, the LCBO's Quality Assurance department and other regulatory agencies commonly utilize spectroscopy (Pozo-Bayon et al., 2011).

Techniques used by the LCBO

Wine analysis is a field that is constantly evolving. Many thanks can be given for the analytical techniques developed by the urge to advancement technologies in many other fields. With regards to wine, the LCBO has a constant battle to ensure it keeps up with these advancements to maximize protection towards Canadian citizens from any harmful products that may be present in contaminated wine.

Taint

Wines sold through the LCBO must first be tested by their labs, or at least an endorsed independent one, with this testing repeated every year for as long as the wine is sold. In accordance with this, each vintner must submit three randomly selected bottles of each of their wines to the labs for analysis to ensure it is safe for consumption.

There are several other substances that wine must be checked for besides the aforementioned OTA. One of the foremost amongst these is pesticides, to ensure that those used on the vines to protect them do not get transferred into the wine. If pesticides are applied to the vines properly then there is little risk of subsequent human consumption; however, particularly brutal treatments may lead to excess levels remaining on the grapes at the time of processing (Pozo-Bayón et al, 2001). Such harmful chemicals will may pose significant health risks to anyone that consumes them.

The most common method of checking for pesticides is gas chromatography (GC) using a chromatograph. This is because pesticides are usually in low levels in wine, so a sensitive method of detection is required (Pozo-Bayón et al, 2001). In brief, GC involves the movement of a mobile phase, in this case a vaporized sample of wine, through a stationary phase, which can vary. Interactions between the stationary phase and the various compounds in the wine cause compounds to move at different speeds depending on their properties. This means they emerge from the chromatograph at different times, with each compound having a unique 'retention time.' They are then electronically detected and can subsequently be analyzed for particular properties, such as molecular weight and concentration, to determine how much of which substances are in the wine (Wong et al, 2003).

Metals

Another form of chromatography, ion chromatography, is commonly used to look for a wide range of contaminants, in particular metals. One can easily imagine how the consumption of metals might be detrimental to ones' health. Ion Chromatography is sometimes used in conjunction with GC and HPLC, and has similar principles (Pozo-Bayón et al, 2001). Substances in a sample are separated by species and size as a result of their interactions with an ion-exchange resin. An ion extraction fluid is then used to separate the ions from the resin; the time this takes – known as the retention time – determines the concentration of each ion (Eith et al, 2001).

On the subject of detecting metals in wine, another of several methods of detections is graphite furnace atomic absorption (GFAA) (Pozo-Bayón et al, 2001). GFAA is highly sensitive and designed specifically for the detection of metals in wine and other aqueous samples. A sample is vaporized in the graphite furnace that lends the process its name, and is based on the principle that atoms absorb light at frequencies characteristic of the element they are composed of, hence the 'atomic absorption.' The light absorbed will then related to the concentration of a particular metal, allowing qualitative analysis of the sample (Ajtony et al, 2008).

There are a whole host of other methods of analyzing wines, which is good as there are a great many things to be tested for. Most of these testing methods

This is an image of beverage alcohol combined with other compounds for further chemical analysis.

involve various forms of chromatography and spectrometry, which all have very similar underlying principles (Pozo-Bayón et al, 2001).

Mislabeling

One development in wine analysis both recent and interesting was the discovery of a method of checking that wine labels were accurate: that is to say, that the wine contains the varietals indicated on the label. This method incorporates receptors that respond to the tannins found in grapes. As each grape variety possesses a unique tannin signature they can be identified by a computer program. Developed in 2010 and published in 2011, this was the first means of establishing what grapes go into a wine (Umail A, 2011). In this way blending of inferior grape varieties can now be prevented to ensure the quality of the wine.

Public Perceptions of the LCBO

The LCBO is currently the largest buyer of beverage alcohol, purchasing from more than 80 countries worldwide (LCBO, 2012). Before beverage alcohol is sold in one of the 623 LCBO locations across Ontario, the products must be certified by the LCBO Quality Assurance laboratory (LCBO, 2012). We can look at some questions that may give us insight on how the public views the LCBO: "is the public pleased with how beverage alcohol is sold by the LCBO?" and "how satisfied is the public with health regulations exploited by the LCBO?"

Numerous studies have investigated views of the public towards alcohol policy and availability. Giesbrecht et al. 2004 examined two Ontario surveys, performed in 2000 and 2002, in search of associations between variations in drinking variables on alcohol policy. They found distinct groups to have similar opinions towards specific questions. For example, frequent drinkers, and those with frequent peak drinking events, were more likely to oppose government consultation with regards to alcohol policy among health officials (Giesbrecht et al. 2004).

Furthermore, Giesbrecht et al. 2007 looked at 3 national studies conducted in 1989, 1994, and 2004. More specifically, they analyzed the rules and regulations surrounding the sale and advertising of alcohol in Canada (see figure). Participants over the age of 15 were recruited over the telephone using random number dialling computer systems (Giesbrecht et al, 2007). The participants were categorised into sex, age, province, education and drinking habits to see if any particular group showed trends relating to the regulations of alcohol. One of the most noticeable differences was with people who were classified as heavy drinkers (Giesbrecht et al. 2007). Of all the groups heavy drinkers agreed the least with a group of questions pertaining to price and availability of alcohol. A few of the questions asked were as follows:

- "Should alcohol tax be increased?"
- "Should beer and liquor stores hours be decreased?"
- "Should alcohol not be sold in corner stores?"

These studies corroborated the findings that support of alcohol regulations decreased as alcohol consumption rose. Another interesting aspect of the three studies covered by Giesbrecht et al. is that they suggest that the public is becoming less focused on the need for alcohol regulations. For instance in 1989, fifty one percent of participants believed that the drinking age should be raised whereas by 2004, only thirty five percent agreed with this statement. Participants in 1989 and 2004 were also asked if they thought that the number government run anti-alcohol adverts should be increased; in the time participant agreement dropped from eighty percent to fifty three percent.

Currently both the LCBO, and VQA, invest a significant amount of resources into maintaining the safety of alcoholic beverages. This brings up concerns about whether or not the public even recognizes the work


This image shows a QA Lab assistant preparing samples to be tested.

that is being done to maintain this level of integrity. Further, it begs the question about whether or not the public is even aware of what the LCBO does, and the amount of money spent towards it. Future studies should look into answering such questions, and also determining whether the public should be more informed.

Current Issues

The LCBO has full control on the flow and sale of alcoholic beverages in Ontario. In fact, the sale of beverage alcohol in every Canadian province was within provincial jurisdiction under liquor control authorities up until 1993. A highly controversial topic is the privatization of the LCBO. Nuri T. Juzairi of York University provided a report for the Ontario Liquor Board Employee's Union in September 1994, a year after the Alberta Liquor Control Board (ALCB) became the first board to undergo privatization (Juzairi 1994).

Impact on Ontario Wineries

This report highlighted some pros and cons of the LCBO mirroring Alberta's privatization. For one, Ontario wineries are highly dependent on the LCBO for marketing and they will fall to imported wines under privatization. Imported wines have marketing and cost advantages over domestic. Imported wines benefit from their quality of grape for competitive pricing, government subsidies, and established reputation (Juzairi 1994). Iacobucci and Trebilcock 2003 also stated that Ontario winemakers receive preferential treatment by means of in-store promotions as well as increased product selection, making them vulnerable under LCBO privatization (Iacobucci and Trebilcock 2003, Juzairi 1994).

Overall Economic Impact

One highly controversial issue is the impact of privatization on alcohol sales and pricing. There is public incentive in privatizing alcohol sales to "redistribute the wealth" and reduce the government's control of managing the economy (Juzairi 1994). West (2003) found the number of retail stores in Alberta greatly increased following privatization leading to more communities supporting privately-owned liquor stores (West 2003). Moreover, West 2003 also found retail liquor prices decreased 2.9 percent and product selection increased, leading to an increase in products sold and an increase in revenue for the government (West 2003, Iacobucci and Trebilcock 2003). Contrarily, Juzairi 1994 reported that Alberta's privatization resulted in higher warehousing and distribution costs, smaller product selection, and ultimately higher product prices (Juzairi 1994, SCGA 2012). SCGA 2012 also reports that alcohol markups in Washington State rose 20% after moving towards a privatized system in June of 2012 (SCGA 2012). It is a common public perception that privatization will lead to higher availability of alcohol; however, it is still unclear whether privatization of the LCBO will lead to lower prices of alcohol (Juzairi 1994, SCGA 2012).

Societal Impact

One news report argues that the involvement of the government is a remnant of the past, when the government believed they should help regulate alcohol consumption, and liquor control boards should be privatized (Radia 2012). However, numerous studies have shown that controlling alcohol sales may still be required. Greg Flanagan found a substantial increase in law violations under the Alberta Gaming and Liquor Act and attributed this increase to a higher availability of liquor (Iacobucci and Trebilcock 2003, Flanagan 2003). Furthermore, a study performed by Zalcman and Mann in 2007 found an increase in suicide rates in men and women following the privatization of ALCB (Iacobucci and Trebilcock 2003). Mr. Andrew Murie, CEO of Mothers Against Drunk Driving (MADD) Canada and co-chair of Canada's national alcohol strategy advisory committee, presented some statistics regarding alcohol sales privatization at a Standing Committee of Government Agencies conference (SCGA 2012). In terms of availability of alcohol, private liquor stores stay open longer compared to provincially controlled stores and these extended store hours may cause alcohol related problems because profit is of outmost concern for privately-owned liquor stores (SCGA 2012). For example, police reported increased impaired driving charges and family violence cases when Calgary increased its liquor stores from 23 to 300 between 1995 and 2003 (SCGA 2012). Similarly, Murie reports that extended hours of sale in the United Kingdom raised concern among law enforcement (SCGA 2012).

What have we found?

There is definitely a divide between public perception and what the majority of statistics suggests. It has been said that other factors, like countrywide policy and educational programs present at the time of Alberta's privatization, may have skewed statistics gathered after Alberta privatized alcohol sales (Iacobucci and Trebilcock 2003). However, the statistics based on regions outside of Alberta seem to be congruent and therefore translatable to Alberta's privatization. Since its introduction, there remains much debate and controversy around the issue of the privatization of LCBO and the benefits or costs this may incur to local wineries, health and the Canadian economy.

Alongside the preventative measures taken by the winemakers, LCBO ensures that all wine and beverage alcohol sold in Ontario meets standards set by the Canadian Food and Drug act and the International Organisation for Standardization. It is unclear whether the arguments for privatization will ever outweigh the opposition. Until further consultation, the LCBO will continue to lead regulatory agencies in testing every aspect and ensuring the safety of wine and beverage alcohol for consumers in Ontario.

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VARIETAL MANAGEMENT AND OPTIMIZATION:
A climatic case study of Rosewood Estates Winery

Lee Bardon[1] , Daniel Heggie[1], Rodrigo Narro Perez[1], Paras Patel[1], Meiko Peng[1], & Madison Reid[1]

1: Honours Integrated Science Program, McMaster University, 1280 Main Street West, Hamilton, Ontario

Abstract: Wine making is a prevalent and growing industry in the Niagara Peninsula. Although climatically undesirable, viticulturists have refined their methods in both choosing varietals and managing their site to allow for successful wine development. To assess the factors that impact varietal selection and optimization in the Niagara Peninsula, Rosewood Estates Winery was used as a case study to learn the techniques that wineries use for successful viticulture development. In particular, the growing practices and site selection of their Chardonnay, Riesling, and Merlot varietals were studied in depth. Climatic and anecdotal data provided by the owner, Will Roman, was used in tandem with literature research, resulting in the division of management practices into three principle categories: temperature, sunlight, and precipitation. The accumulated research and data suggested that each varietal requires unique attention attributable to each of these given environmental factors. This solidified the notion that although regional factors must be considered for varietal selection, managing practices are also essential for successful growth in environmentally variable conditions.

In over 40 countries worldwide, wine is produced in significant quantities: indicative of the crop's success in adapting to environmental variation (Howell, 2000). However, its prevalence in some regions and absence from others suggests climatic limiting factors to viticulture, the most obvious of which are extremes of drought or cold. It is essential that viticulturists assess these regional factors when deciding which grape cultivars they want to plant. In Europe, fine wines are distinguishable by their geographic location due to a long history of matching grape types to the varied soils and climates. Terroir is understood as the combination of soil, climate, geographic location and anthropogenic influences unique to each viticultural region. However in the New World which includes the Americas, Australasia and South Africa, wines are instead labeled by varietal names since there is skepticism concerning a varietal's connection to its terroir (Laube and Molesworth, 2012). Although the quality and diversity observed in viticultural products may be attributed to

Figure 1: i) The Niagara Peninsula is located in southern Ontario, **ii)** The location of Rosewood Estates Winery in the Niagara Peninsula is indicated by the red square on the map (Google Earth, 2012).

soil, geographic location and anthropogenic influences, climatic variation between the wine growing regions is highly influential in affecting these distinction (Tonietto & Carbonneau, 2002). Specifically, research has shown that identical varietals grown in the different viticultural regions, or *appellations*, of the Niagara Peninsula region are distinct (Douglas et al., 2001; Schlosser et al., 2004).

Rosewood Estates Winery, a Niagara Peninsula winery located within the Beamsville Bench appellation (**Figure 1**), is an excellent example of how varietal selection and climate management are intertwined. A combination of favourable climatic and topographical influences, as well as unique and dedicated management practices, have culminated in a number of prestigious industry awards being secured by the winery. In this report, we will explore how Rosewood has selected and optimised their varietals for the Niagara Peninsula, taking into account both the natural environment and management interventions.

----------Niagara Climate---------

Climate can be defined, with respect to viticulture, as comprising three main subsections: macroclimate, mesoclimate and microclimate (Robinson, 2006). Macroclimate can be considered as the general, overarching climatic trends of a given region, such as South Ontario; mesoclimate refers to mid-level variation within the region, such as climatic differences experienced by the Beamsville Bench region versus the Iroquois Plain and microclimate may be considered as variation at the level of a vineyard.

The macroclimate of Southern Ontario is characteristic of a cooler, mid-latitude continental climate. The region experiences a great deal of macroclimatic variability, such as humid summers and harsh, cold winters. Damaging temperatures that may be experienced during the freezing winters, late spring and early autumn frosts, can prove to be among the greatest challenges within the region, as they coincide with critical stages in grape development (Shaw, 2005).

As such, in determining the varietals that might be selected for the Niagara Peninsula, the ability of a given species to thrive in a region that tends to suffer frequent and sustained below-freezing winter temperatures, is of paramount importance. This physical characteristic, known as cold hardiness, has been quantitatively described by Howell (2000) and Mills et al. (2006*)*.

Although this broad consideration of common problems within cold-climate oenology is useful

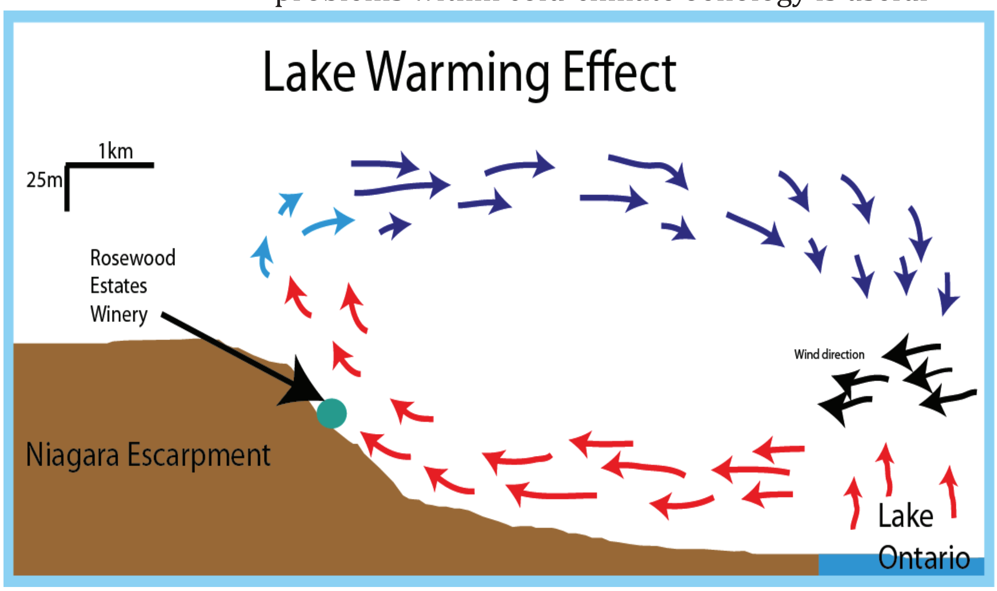

Figure 2: Lake Ontario acts as a heat sink to moderate surrounding temperatures. During the winter, heat is released from Lake Ontario and northern winds carry the warm air over the shore and up the escarpment. As the air cools, the cold air deposits back to Lake Ontario. Similarly in the summer months, the lake heats up much slower and hence a cooling effect is created by the release of cool air (Shaw, 2005, Roman, 2012).

Varietals Under Investigation

Chardonnay, Riesling, and Merlot, all of which are derived from the commonly grown grape vine *Vitis vinifera*, are three successful varietals grown at Rosewood. These varietals are amongst some of the most popular table wines due to both their sensory qualities and their environmental versatility.

Chardonnay: As one of the most widely-planted white wine varietals, it is now commercially grown in vineyards across the world. Even though renowned Chardonnay wines still arise from Burgundy and Champagne – characteristic of their rich full-body aroma, advanced viticulture techniques have allowed successful growth in the Niagara region as well (Bell, 2012).

Riesling: Originating from the Rhine region of Germany, it is a light-bodied wine with refreshing floral aromas. Riesling's hard, woody vines effectively enable its resistance to cold and frost damage, and thus are grown in cooler climates (Laube and Molesworth, 2012). It is highly 'terroir- expressive', meaning that the character of the wine is greatly influenced by the vineyard's location (Bell, 2012).

Merlot: Traditionally used to make red wines, it is one of the most-planted grapes in the Bordeaux region in France. This varietal has been known to be a difficult grape to grow due to its uneven ripening, and high susceptibility to cold damage (Davenport et al., 2008).

when considering varietal selection for a region, it fails to account for the great deal of mesoclimatic and microclimatic variation between major wine-producing regions and single vineyards, respectively. For example, a major mesoclimatic moderating influence, particularly for the Niagara Peninsula comes from the nearby Lake Ontario and Lake Erie. During the cold winters, north or north-easterly winds passing over the lakes are warmed to above the overall damage threshold temperatures for *V. vinefera* vines before they reach the Niagara Peninsula on the southern shore. This is known as the lake warming effect (**Figure 2**). By way of illustration, consider an example of a neighbouring vineyard located at the top of the escarpment, approximately three kilometres away from Rosewood. According to Will Roman, owner of Rosewood, it inhabits a less sheltered position than his vineyard, in terms of its level of temperature moderation and exposure to cold, strong winds. This is thought to be a major contributing factor in the high level of success that Rosewood enjoys with its Merlot crop: a notoriously cold-sensitive varietal that is unsuccessful in the adjacent vineyard (Davenport et al., 2008)

At the microclimatic level, Rosewood illustrates how the variable climates within a vineyard can help enable the success of a wide range of varietals (**Figure 3**), even before any anthropogenic intervention. Topographical variation within Rosewood creates varied microclimates, primarily in terms of temperature moderation. For example, the relatively high gradient of the slope on which the Merlot is placed, allows high-velocity, cold north and northeasterly winds to travel over the Merlot site, decreasing the likelihood of cold damage (Roman, 2012).

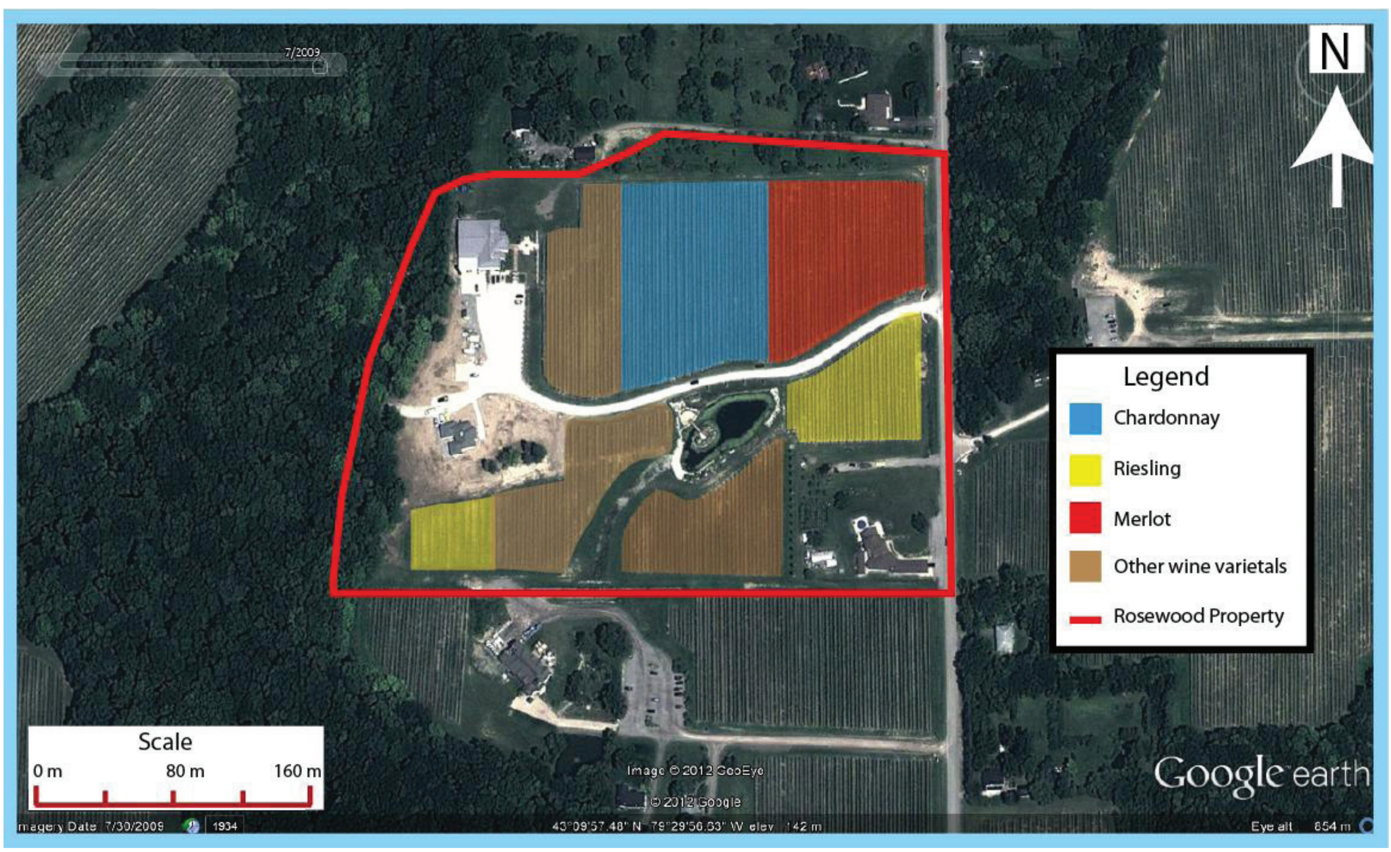

Figure 3: Geographic location of the three varietal blocks under examination (Chardonany, Riesling, and Merlot) within Rosewood Estates Winery (Roman, 2012).

-------------**Temperature Management**-----------

Temperature is essential to the growth of healthy grapes, and ultimately the craftsmanship of quality wine. As alluded to in the previous section, frost damage is of particular concern to the Niagara Peninsula wineries. This is because frost damage can be economically threatening, with potential to occur most of the year (Evans, 1999). Using Rosewood as a case study, various techniques to maximize varietal efficiency will be investigated.

The first and often most effective frost protection technique is site selection (Evans, 1999). First, the site of the winery within the larger region is important. The Beamsville Bench, where Rosewood is located, is situated just below the top of the Niagara escarpment. As such, it is protected from most major cold winds and is significantly warmer than locations on top of the escarpment (Roman, 2012) (**Figure 4**). In addition, the predominant slope direction of Rosewood maximizes sun exposure, optimizing hillside warmth.

Within a vineyard, different varietals are planted in different locations, which optimizes efficiency and minimizes frost damage. A prime example of this technique is the placement of Merlot and Chardonnay in Rosewood (**Figure 3**).

They are planted adjacent to each other, but the Chardonnay is planted at a lower elevation than the Merlot. This can be explained by looking at the varietals' cold hardiness. Mills et al. (2006) assessed various cold hardiness and found that Chardonnay is more cold resistant than Merlot;

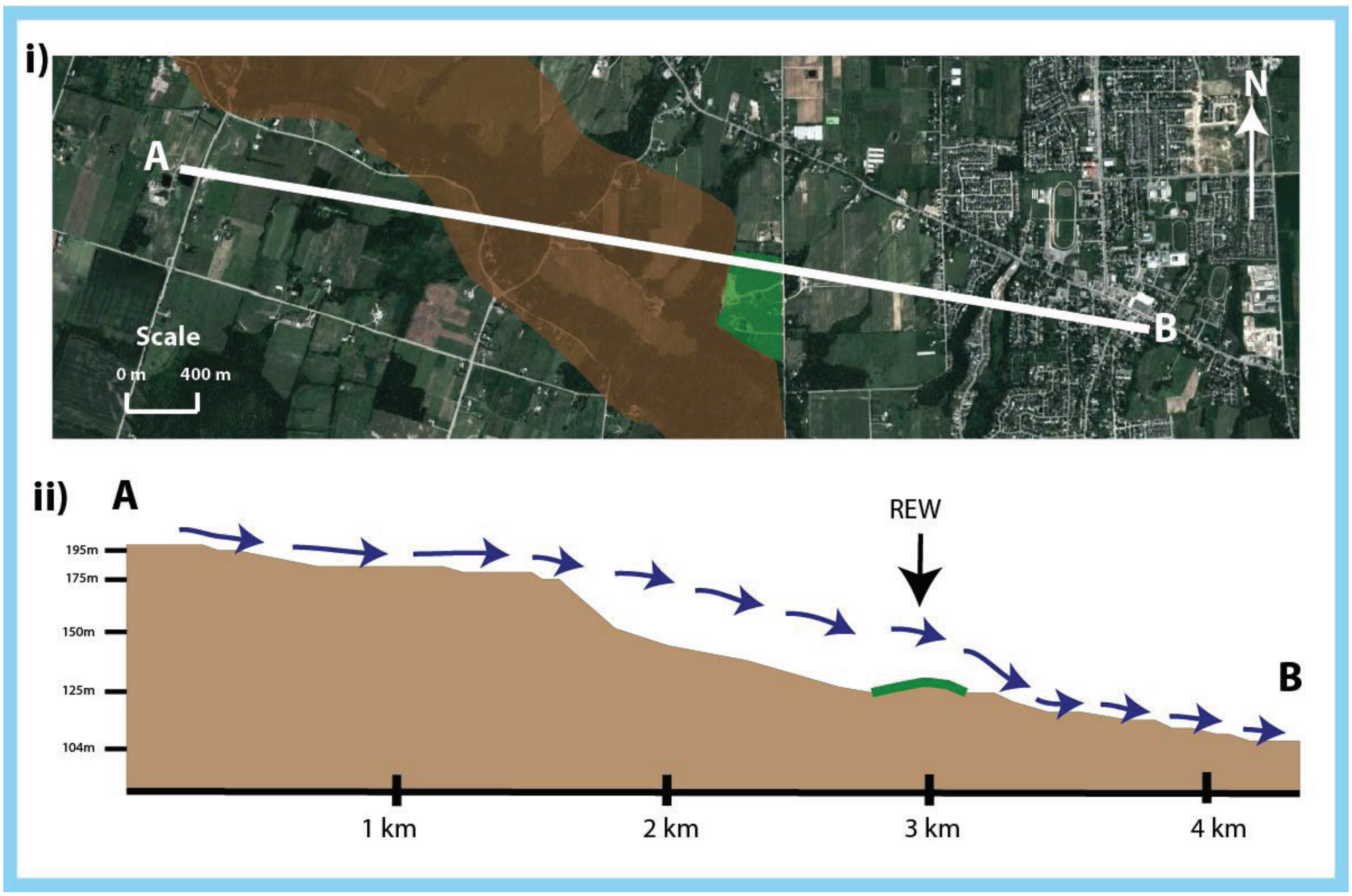

Figure 4: i) A transect going from west (A) to east (B) that crosses both the Niagara Escarpment and Rosewood Estates Winery; **ii)** A cross section of the transect from A to B, north-west winds go over Rosewood, decreasing the potential cold damage the varietals can go through (Google Earth, 2012).

thus it is planted in the lower and colder area of the site to maximize the overall chance of success. Although not specifically linked to temperature moderation, another consideration for the site selection for Merlot in Rosewood are the iron rich soils present where it was planted, which is a internationally known practice (Blue Poles Vineyard, 2006). It is important to note that although Merlot is a cold-sensitive varietal, its location on the escarpment slope allows for protection from the cold air (Davenport et al., 2008).

There are several maintenance techniques that can be used to regulate temperature and protect against frost damage after a vineyard is established. Although many of these methods are very useful, it is important to remember that cost effectiveness is usually the primary concern. As such, these methods are generally used as sparingly as possible (Streigler, 2007). The two major temperature moderating methods are stratification limiting techniques and irrigation techniques (Davenport, 2008).

The effect of denser, colder air falling, while warmer air rises, has been discussed earlier in the paper. This layering is called stratification, and it is detrimental to vineyards because it reduces the air temperature surrounding the plants. To limit stratification, wind machines can be used (**Figure 4**). These machines pull down the warm upper air to mix with the cold air surrounding the plants (Evans, 1999). Although this method can be very effective, it is often too expensive for many small wineries. This is the case for Rosewood; however, their ideal slope location allows them to sidestep this problem. As an alternative solution to wind machines, small wineries can rent a helicopter to hover over the vineyard to mix the air (Davenport, 2008).

Irrigation techniques include dampening soil and spraying crops with water. The general concept behind this technique is that water has a very high specific heat capacity, and as such acts as an

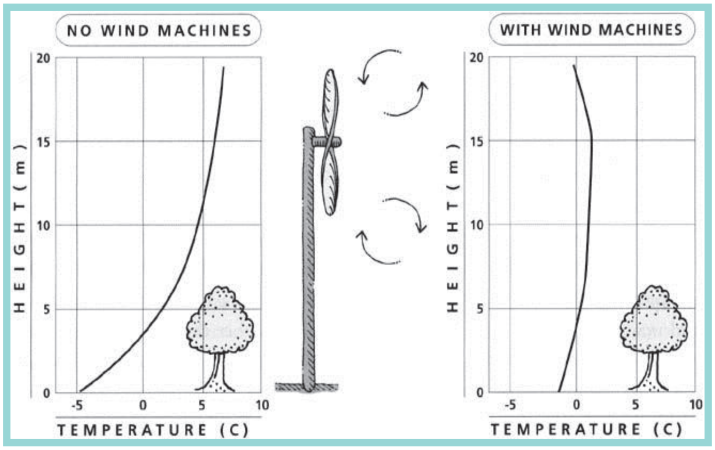

Figure 4: Wind machines prevent thermal stratification of the air, and help moderate the temperature at ground level near crops (Davenport et al., 2008).

excellent insulator (Evans, 1999). In addition, latent heat of vaporization and fusion are often used to release heat into the vines and grapes (Streigler, 2007). Although there are many unique irrigation techniques, such as spraying and misting, these fundamental principles apply to all. Many of the wineries in the Niagara Peninsula, including Rosewood, do not use these techniques because soil saturation and drainage is often a significant issue, and adding more water is undesirable.

----------------Sunlight Management---------------

Although varietal selection is critical when trying to produce a quality wine, there are various properties unique to each varietal that can be optimized depending on the growing system and practices selected in the vineyard. Exposure to sunlight, the leaf area to crop ratio, and shoot density are only some of the many factors that can affect the grape, and the resulting wine's composition, both in terms of volatile compounds and sensory responses (Zoecklein et al., 2008). Rosewood's success in growing many different varietals can be attributed to their management of all of these factors, unique to each varietal.

One of the first concerns when growing a varietal is deciding which growing system to utilize. During the winter months, grapevines often grow four canes, which posses no leaves or buds

(Roman, 2012). Chardonnay, Merlot, and Riesling are managed using the vertical shoot-positioned (VSP) systems at Rosewood, which generally involves tying the two healthiest canes along a single fruiting wire (ensuring vertical growth come spring), while cutting off the two remaining canes (Roman, 2012). However, Rosewood adjusts this individual method dependent upon the varietal. For example, all four arms are left to grow for Riesling around two fruiting wires. **Figure 5** demonstrates a typical VSP system at Rosewood.

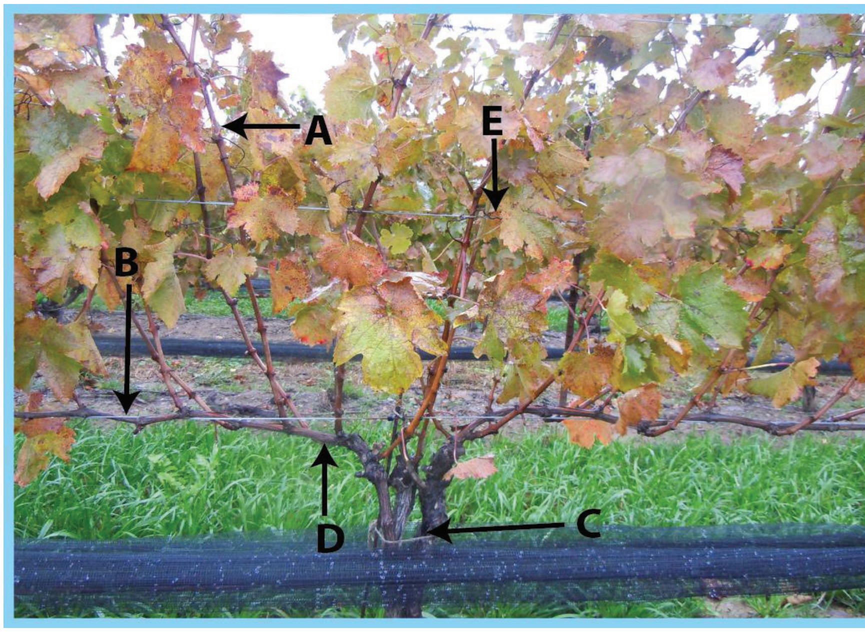

Figure 5: Vertical shoot positioned (VSP) system at Rosewood winery. The parts of the growing system are labeled: **A)** vine shoot, **B)** fruiting wire**, C)** rootstock, **D)** canes, **E)** catching wires (used to further encourage vertical growth).

There are various motivations when deciding which growing system to use, but most revolve around sunlight exposure. Variations in light interception through the canopy can affect productivity, yield, and subsequent wine quality (Louarn et al., 2008). High irradiance from sunlight has been shown to affect berry composition, particularly with increased levels of anthocyanins and flavonols. These can alter sensory qualities of the grapes, affecting the final wine product (Louarn et al., 2008). Conversely, low irradiance helps mitigate growth, especially in varietals with high vigour**,** but can also affect the pH and potassium content of the wine. Shaded grapes have lower fruit sugar content, less tartaric acid and malic acid, and sensory tests have found that wines produced from shaded grapes receive lower scores for fruit characteristics (Smart, 1985).

There is a subtle balance between shade and sunlight that needs to be carefully adjusted to each varietal, and alternative growing systems are employed depending on the growing conditions. One study found that positioned systems (such as VSP), achieve lower canopy surface area, and as a result, allow for greater sunlight penetration to the inner canopy compared to non-positioned systems (Gladstone & Dokoozlian, 2003). Another study found that positioned systems had reduced levels of sunlight reaching the berries during midday compared to non-positioned systems, which could potentially limit the detrimental effects of high temperatures and sunlight on the fruit composition (Louarn et al., 2008). Essentially, viticulturists need to anticipate their particular vine's vigour prior to choosing the appropriate growing system in order to either maximize sunlight for low vigour vines, or increase shade for high vigour vines. Rosewood puts this notion into practice with its Riesling vines, by using 4-arm rather than 2-arm VSP (Roman, 2012). Riesling is highly vigorous, but by growing twice as many shoots, they increase canopy density, reduce sunlight, and thus manage the vines' intrinsic vigour.

Sunlight can also be managed for by subtle means within each growing system, such as shoot positioning and leaf pruning. Shoots that are closely spaced will result in greater leaf density of the canopy, increasing the shading of the interior.

Shoot positioning reduces crowding, thereby increasing radiation on leaves and ultimately the yield of the vines (Smart, 1985).

VSP inherently allows for well-spaced shoots that interact little with each other by ensuring vertical growth; however, spacing may be increased through shoot removal to reduce crowding depending on the growing conditions (Smart, 1985). At Rosewood, as a general rule they employ a four-finger space between given shoots.

Although growing systems are designed to increase sunlight exposure to the inner canopy, mechanical leaf removal may become necessary if the grower wishes to further increase irradiance (Bledose et al., 1988). Excessively vigorous plants may require repeated prunings during growth to increase sunlight exposure to the inner canopy (Zoecklein et al., 2008). Rosewood also spatially distributes its pruning, removing more leaves from the western side of the vineyard than the eastern side, as it receives less sunlight (Roman, 2012). Although leaf removal will increase light to the inner canopy, regrowth of the cut shoot tips will often compete with fruit development for carbohydrates, resulting in delayed sugar accumulation in the berries (Bledose et al., 1988). Bledose et al. (1988) found that although leaf removal did not significantly reduce crop weight, it did reduce the concentrations of malate, potassium, and the pH of the berry. Thus the resulting wine can vary greatly depending not only on the varietal selected for, but also by its exposure to sunlight.

-------------Precipitation Management-------------

The Niagara Peninsula is located far inland and thus should technically be a dry region; however, its proximity to Lake Ontario and Lake Erie transforms what would be a continental climate into a maritime one. As such, Niagara generally has a very humid climate, with the average relative humidity being around 80%, as seen in **Figure 6**.

High humidity is often correlated to large amounts of rain. According to the available data from Rosewood, this is the case for the Beamsville Bench, with the exception of the year of 2007 where the Ontario region suffered from a drought (**Figure 7**). Surprisingly, this reduction in overall rainfall had a positive impact on the

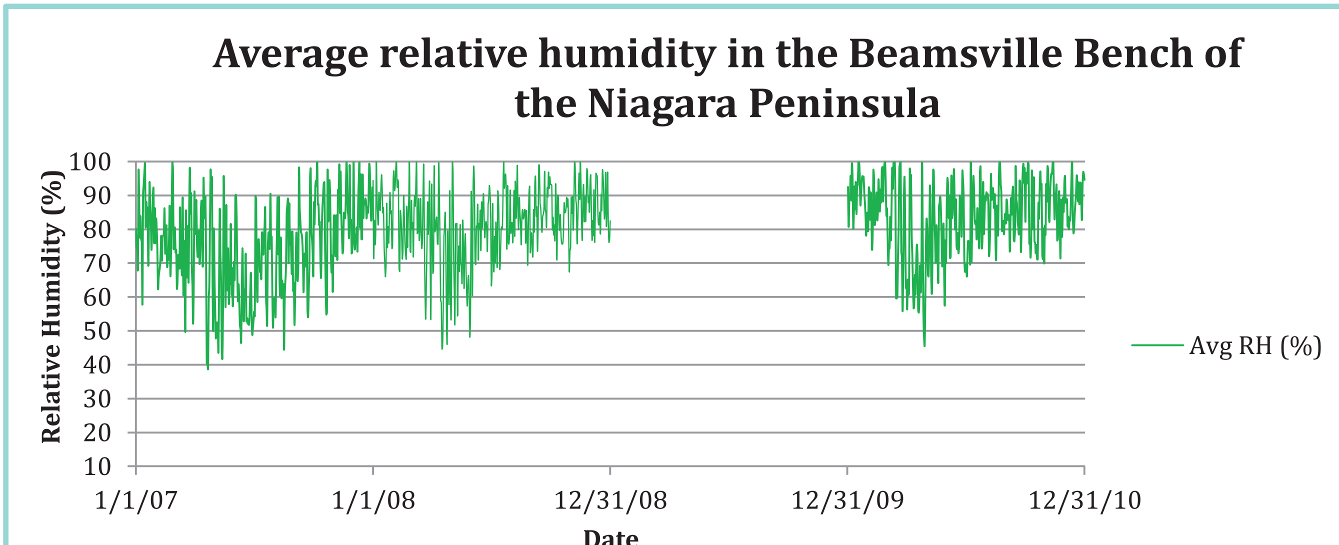

Figure 6: The relative humidity of the Beamsville Bench appellation. No data was available for 2009 (Roman, 2012).

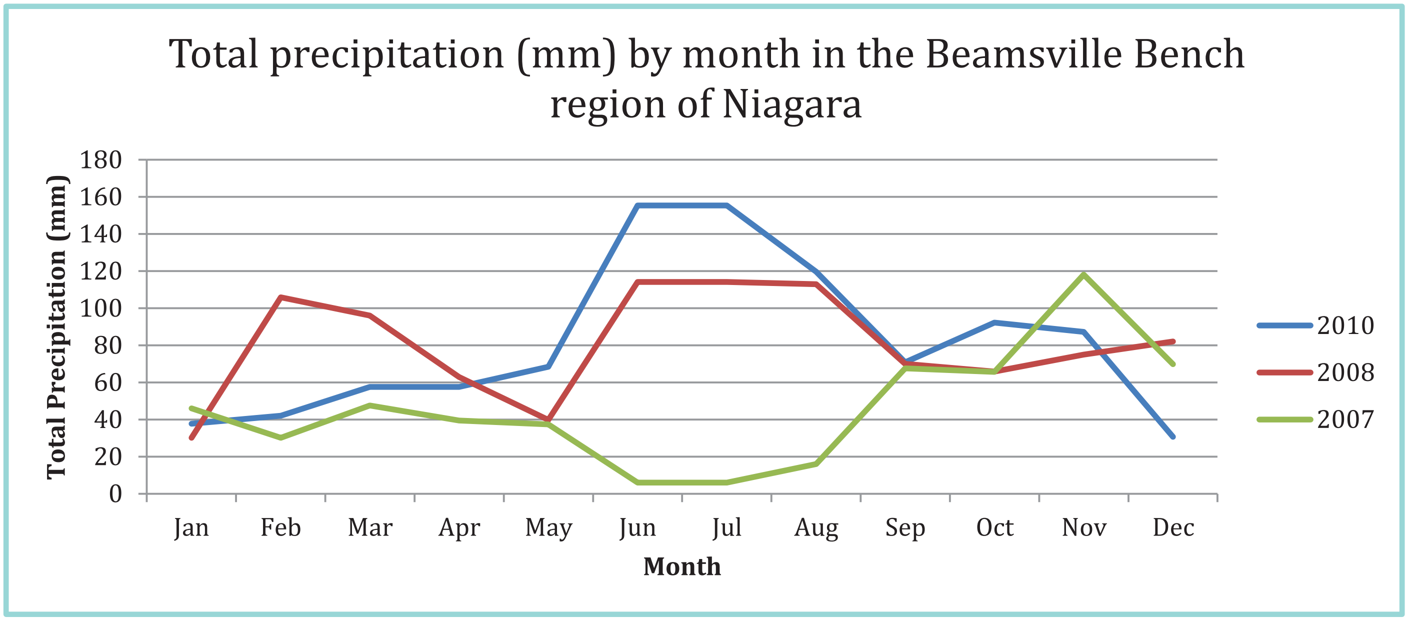

Figure 7: Monthly precipitation by year in Beamsville, there is no data for 2009 (Roman, 2012).

wine industry, as vines directed more energy to grape production rather than vine growth due to increase water stress (VQA, 2007).

High levels of humidity and precipitation are also problematic as it increases vigour and result in large diluted grapes. In addition, the excess water dilutes the sugar content of the grapes, which leads to large and poor quality grapes. This is a common problem in the Niagara Peninsula, as the largest amount of rainfall occurs during the growing season from budding (June) to harvest (September) (Davenport, 2008). High humidity also encourages the growth of rot and mold on plants, where rainfall then aggravates the problem by facilitating the dispersion of mold spores (White, 2006).

There are several ways to deal with these problems, the first of which is varietal site selection. For example, at Rosewood, Riesling is grown within the South Block, situated close to the on-site pond (**Figure 3**). This is in an effort to maximize effective land usage given Riesling's relative resistance to water damage (Roman, 2012). Diagnosis of vine water status, and thus determination of water resistance, can be performed by measuring the $^{13}C/^{12}C$ ratio. The ^{13}C isotope is determined by the gradient of CO_2 between the atmospheric and intercellular CO_2 concentrations; the main factor that affects this ratio is water stress (Gaudillere et al., 2001). Riesling exhibits a high ^{13}C concentration, indicative of its water stress-resistant property (Gaudillere et al., 2001). In red varieties, Merlot has been shown to have a lower ^{13}C concentration compared to Cabernet Sauvignon and Cabernet Franc. This explains why Merlot is unsuitable, in the case of Rosewood, at regions near the pond or in a depression in case of water accumulation during rain season.

Soil permeability is also very important. In particular, highly permeable soils are desirable as they allow the flow of air and water to and from the roots. Low permeability soils, on the other hand, are more susceptible to water saturation, which limits the flow of nutrients to the roots and blocks the roots' access to air (Unger & Kaspar, 1994). One of the most permeable soils, although somewhat rare, are chalks; the only varietals currently grown on pure chalk are Chardonnays of the Champagne region, which are some of the most highly regarded grapes in the world (Bohmrich, 1996).

The last technique to mitigate problems caused by excess precipitation and/or low soil permeability is artificial drainage. The most common drainage method employed in the Niagara Peninsula is drainage tiles: a series of connected pipes underneath the soil. The drainage tiles used at Rosewood are perforated tubes around 24-36 inches below the surface (**Figure 8**). They allow efficient water drainage when the soil reaches its water-holding capacity. This prevents ponding from occurring, thereby protecting vines from water damage.

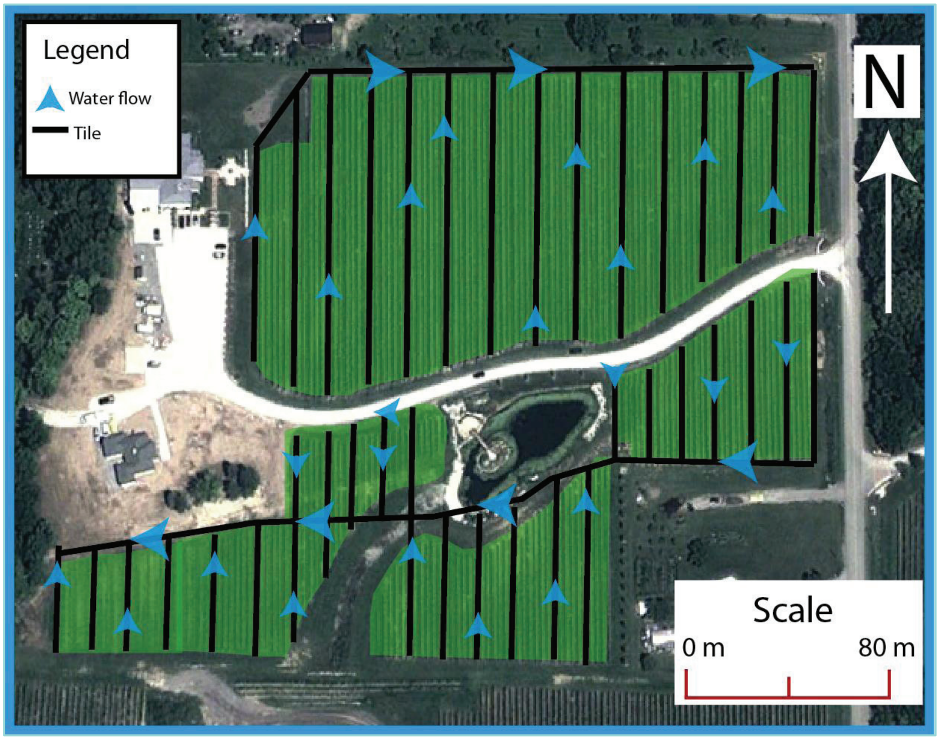

Figure 8: The tile drainage system of Rosewood Estates Winery. The north block has the draining system draining to the north. The south block has the main tile running through the middle, eventually draining to the west.

Drainage tiles can have significant positive effects on plant growth during particularly wet years, specifically by preventing plant death from water saturation. Additionally, drainage promotes varietal growth by providing circulation of air and nutrients to the roots, thus these tiles can overcome many limitations of poor draining soils (Brown, 2001).

For example, Merlot, a less water resistant varietal, can be grown successfully even in poor draining soils if there is a mechanical intervention. Evidence of the effectiveness of drainage tiles can be seen in **Table 1**, where they increased the live weight, berry cluster weight, berry weight and yield for the Pinot Gris varietal. It should also be noted that the level of acidity was increased (lower pH) in the Pinot Gris, as well as an increase in the Total Soluble Solids (TSS) – both indicative of increased grape quality.

Although drainage systems are very effective, they are expensive and troublesome to install. They must also be planned well in advance before vineyard development as Rosewood, for example, had to install the drainage tiles two years before planting any vines (Roman, 2012). Thus despite the drainage system's many

Table 1. A table showing the affect drainage tiles can have on different factors (Brown, 2001).

Treatment	Pruning[z] Live wt (lb)	Pruning[z] Dead wt (lb)	Avg cluster wt (lb)	Yield (lb/vine)	Berry wt (g)	Fruit composition TSS[y] (%)	Fruit composition pH	Fruit composition TA[x] (g·L^{-1})
				'Chambourcin'				
Nontile	1.04	0.07	0.37	27.3 b	1.90 b	20.7	3.14	10.4
Tile	1.62	0.10	0.42	37.2 a	2.10 a	20.7	3.14	10.4
1998	0.94b	0.03 b	0.34 b	20.7 b	2.03	22.0 a	3.17 a	11.1 a
1999	1.72a	0.13 a	0.45 a	44.6 a	1.97	19.4 b	3.10 b	9.8 b
				'Pinot Gris'				
Nontile	0.53b	0.03 b	0.20	19.9	1.45	17.8	3.33	06.0
Tile	1.04a	0.07 a	0.20	22.3	1.50	18.4	3.29	06.2
1998	0.32b	0.03 b	0.19 b	15.6 b	1.68 a	18.7	3.28 b	06.2
1999	1.25a	0.07 a	0.22 a	26.6 a	1.27 b	17.5	3.35 a	06.1

beneficial contributions to a varietal's success, it is important to consider the topographic and geographic properties of the site before installation.

-----------------------Conclusion-----------------------

By studying Rosewood's success with their Chardonnay, Riesling, and Merlot varietals, it is clear that site selection and microclimate considerations, as well as specific management practices are important factors to consider in optimizing varietal growth. Rosewood's location on the Niagara escarpment slope allows the vineyard to sidestep the cold-climate limitations of the Niagara macroclimate. Additionally, their carefully planned placement of each varietal and dedicated management techniques that both mitigate and optimize regional temperature, sunlight, and precipitation variability contribute to their success. Comparison of the vineyard's practices to that of the literature confirm that even though there are various limiting factors, with hard work and proper consideration of potential challenges, one can establish a successful vineyard.

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WINE SCIENCE

From Terroir to Tongue

An examination of how wines express the tastes of their regions.

By Sheridan Baker, Hannah Dies, Clark Eom, Angela Huynh, Piotr Roztocki, and Kaian Unwalla

Sheridan Baker is a 3rd year Honours Integrated Science student at McMaster University, concentrating in biology. He hails from St. Catharines, Ontario.

Clark Eom is a 3rd year Honours Integrated Science student at McMaster University. He is originally from Pohang, South Korea.

Angela Huynh is a 3rd year Honours Integrated Science student at McMaster University, concentrating in biochemistry. She calls Ancaster, Ontario home.

Hannah Dies is a 3rd year Honours Integrated Science student at McMaster University, concentrating in physics. She is from Toronto, Ontario.

ASK ANY CONNOISSEUR OF FINE WINE AND THEY WILL tell you that every winemaking region produces wines of distinct flavours. From Chardonnay to Pinot Noir, Merlot to Gewürztraminer, the differences in each type of wine are quite evident, even to the unrefined palette. However, it is the subtle differences within the same varietal between vineyards that give the winemaking regions their unique quirks and character. Limited work has been done into investigating which factors give each region their distinct flavour; however, below we outline a study that we conducted to analyze the factors affecting the taste of Niagara wine and answer the question: **why does Niagara wine taste the way it does?**

Wine is a delicacy that has been enjoyed by humans for thousands of years, over which it has become integrated into cuisine, culture, science, and society itself. Though many viticultural aspects are preserved across the industry, each bottle that is produced contains a unique mélange of sensory attributes that are determined by the varietal, vinification process, climate and geology of the region. In Canada, the Niagara Peninsula is known for producing superior quality wines, renowned worldwide for their crisp flavour, which is often attributed to the cool climate growing conditions of the region. However, the exact effect that the Niagara climate and geology have on producing this distinct wine flavour is still uncertain, although various studies have examined correlations between certain climatic factors of a region and the chemical properties of wine (Douglas et al., 2001; Kontkanen et al., 2005). In European viticulture, a large emphasis is placed on the effect that climate and geology have on the flavour of wines from a particular region, resulting in the classification of **terroirs**: regions which impart unique effects on the character of the wine they produce.

The concept of terroir is loosely defined within the world of viticulture and enology. At its most basic definition, terroir is comprised of all of the environmental factors which influence the character of grapes and their subsequent wine product. Terroir usually includes, but is not limited to, climate, soil, topographical, and geographical factors (Kontkanen et al., 2005; Jackson and Lombard, 1993). A good winemaking terroir allows for slow but complete maturation of grapes, and is stable enough to produce wine with consistent characteristics each year. This can be achieved by the terroir having adequate but not excessive soil nutrients, sufficient

EXPAND YOUR KNOWLEDGE

In the past five years, consumption of wine has increased while the consumption of beer and spirits has decreased (Le Cordon Bleu, 2012)

Viticulture is the study of grape growing.

Enology is the study of wine-making.

Vinification refers to the process of winemaking through fermentation.

The **degree days** of a season for grapes is defined as the total number of hours where the temperature is above 10 degrees Celsius (Oliveira, 1998).

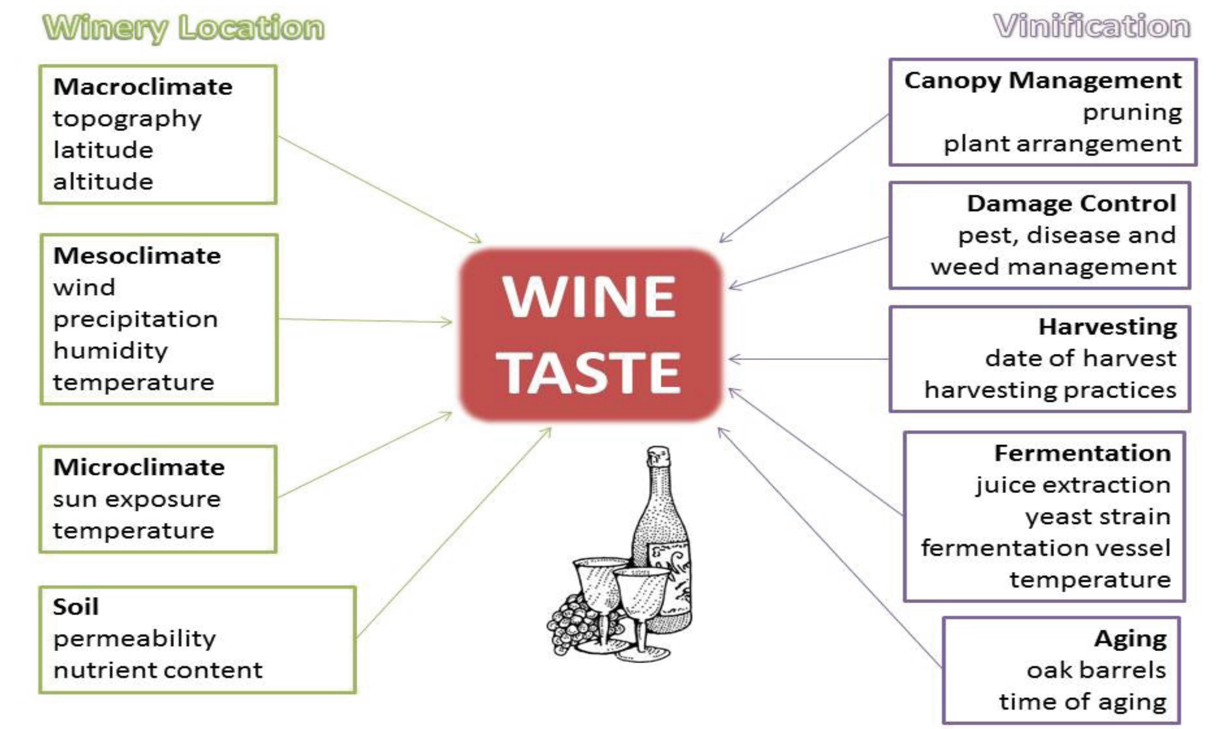


Figure 1: Factors affecting the taste characteristics of wine. These factors are often summarized into a general statement about the terroir of a region. Note that while these factors are separated here into Winery Location and Vinification, often Winery Location plays a large role in determining the required vinification processes.

drainage, and the ability to withstand drought (Jackson and Lombard, 1993). Soil and climate are believed to be the two largest factors contributing to terroir; however, their exact influence on wine taste is largely unknown (Reynolds et al., 2007). In order to investigate this influence, it is necessary to build a foundation of the geological factors that affect the climates of differing wine regions, as well as the biochemical factors that eventually impact the taste of wine. **Figure 1** summarizes the main factors that have been identified to influence the taste of wine. In this figure, a clear distinction is made between geological factors that depend on the vineyard location, and the processes involved in winemaking. However, it is important to note that often geology necessitates certain vineyard management processes such as irrigation or pruning, thus the two are intrinsically linked. It is therefore reasonable to hypothesize that most of the differences between wines produced in different locations are a result of the unique terroirs of the regions. Here, the terroirs of two differing regions, the Niagara Peninsula and California, are investigated and compared in order to understand the differences in the wine they produce.

DEFINING THE NIAGARA TERROIR

THE NIAGARA PENISULA, which produces over 80 percent of Canada's wine grapes, is a region with unique geological features including its proximity to the Great Lakes, the presence of the Niagara Escarpment, and its exposure to weather systems from across the continent. These features combine to produce a distinct semi-continental climate, despite its similar latitude to many of the principal European winemaking regions (see **Figure 2**) (Shaw, 2005). One of the main features of the Niagara region is its proximity to the Great Lakes, specifically Lake Ontario to the north and Lake Erie to the south (as

Piotr Roztocki is a 3rd year Honours Integrated Science student at McMaster University, concentrating in physics. He was born in Krakow, Poland.

Kaian Unwalla is a 3rd year Honours Integrated Science student at McMaster University, concentrating in psychology, neuroscience, and behaviour. She currently resides in Oakville, Ontario.

shown in **Figure 3**). In general, the high heat capacity of water relative to air means that the lakes retain heat in the winter, and remain cool in the summer, resulting in a temperature moderating effect on the surrounding land (Haynes, 2000). This effect is similar to that provided by the Atlantic Ocean on wine-growing regions in Europe, as well as the Pacific Ocean on California. However, the moderating effect on the Niagara Peninsula is slightly more complex, as the two surrounding lakes do not have identical impacts. Lake Ontario has the smallest surface area of any of the Great Lakes, yet it is the second deepest. This results in an extremely large capacity to retain heat, meaning that the lake rarely freezes over completely. Lake Erie, in contrast, is the shallowest and most southerly of the Great Lakes, resulting in more annual temperature fluctuations of the water (Shaw, 2005). The distinct properties of these two bodies of water mean that vineyards that are close to Lake Ontario experience greater temperature moderation in the winter, as northerly winds blowing over the unfrozen water are warmed before passing over the land to the south. Additionally, the cloud cover that results from evaporation of the warm lake water causes lower daytime temperatures, along with higher nighttime temperatures. This evaporation results in greater snowfall during the winter, which has an insulating effect on vines and prevents frost damage (Shaw, 2005). In the spring, cool winds off of both lakes result in lower temperatures on land, which is beneficial for vineyards, as it prevents buds from breaking while there is still the risk of damage from unpredictable late spring frosts. Throughout the summer, the slightly cooler temperature of Lake Ontario slows down the ripening of grapes, and reduces humidity above vineyards which is preventative against fungal infection (Shaw, 2005).

CONTRASTING VINEYARD LATITUDES

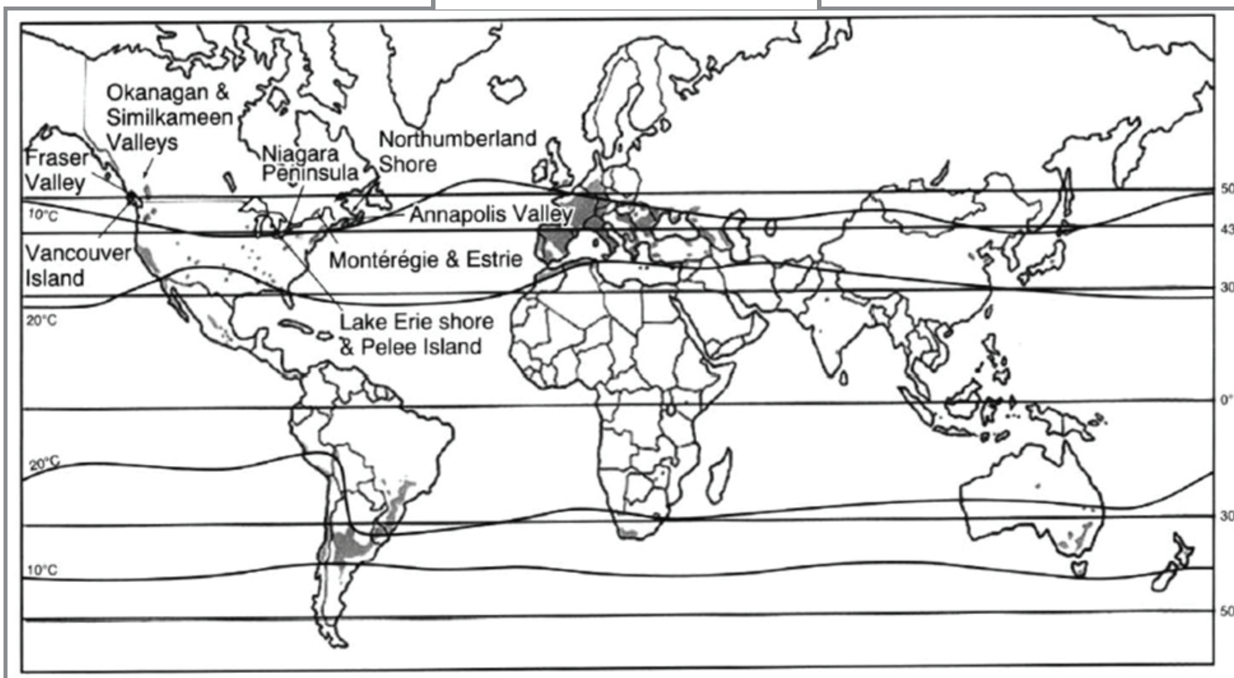


Figure 2: The latitude of various global winemaking regions (shaded areas). Note that while the Niagara Peninsula is generally classified as a cool climate wine region, it is almost identical in latitude to many of the primary European winemaking regions, such as Provence in France, and Chianti in Italy (Haynes, 2000).

Figure 3: The Niagara Escarpment, shown in red, runs across southern Ontario, ending just east of the Niagara Peninsula. Lake Ontario and Lake Erie, which border the Niagara Peninsula to the north and south respectively, have a large moderating effect on the climate of the region (Wikimedia Commons, 2010; Featherstone, n.d.).

The Great Lakes, while having a large effect on the Niagara region, are not the only geological features that influence the climate. The Niagara Escarpment, a dominant landform that is approximately 90 metres in height and stretches 725 kilometres across Ontario, creates a microclimate in Niagara that is essential to the agriculture and viticulture of the region. The escarpment was formed at the end of the last ice age, from retreating glaciers which carved away at Paleozoic limestones and dolostones from an ancient inland sea, leaving steep cliffs (Sendzik, 2005). The escarpment acts to shelter the land from icy winter winds, and the slopes of the escarpment drain cold air away from vineyards on clear, still, winter nights (Shaw, 2005). Areas on top of the escarpment are generally avoided for crop production, due to their lack of wind protection and resulting cooler temperatures (Shaw, 2005).

The first 100 percent Canadian Chardonnay was produced in 1955 by Bright's Winery (Le Cordon Bleu, 2012)

The air masses from both the cool Arctic and the warm Gulf of Mexico bring a wide range of weather conditions, resulting in large annual temperature fluctuations. As Niagara lies under a major storm track from the northeast to the west, there are occasional warm spells from unstable subtropical air streams that arrive in early winter, sometimes causing a spontaneous early thaw (Shaw, 2005). The highly variant spring weather caused by these jet streams generates conditions that are hazardous for undeveloped buds. While the escarpment and Great Lakes are somewhat effective in moderating these conditions, there is still a large degree of variability of climate that acts as the largest challenge to viticulture in the Niagara region.

GEOGRAPHY OF CALIFORNIA WINE REGION

Figure 4: A topographical map of California, in which the blue areas are lower in elevation compared to the red areas. The wines used in this case study are from Monterey and Paso Robles, which are located in Monterey County and San Luis Obispo County, respectively (State of California, 2009).

CALIFORNIA: A CONTRASTING TERROIR

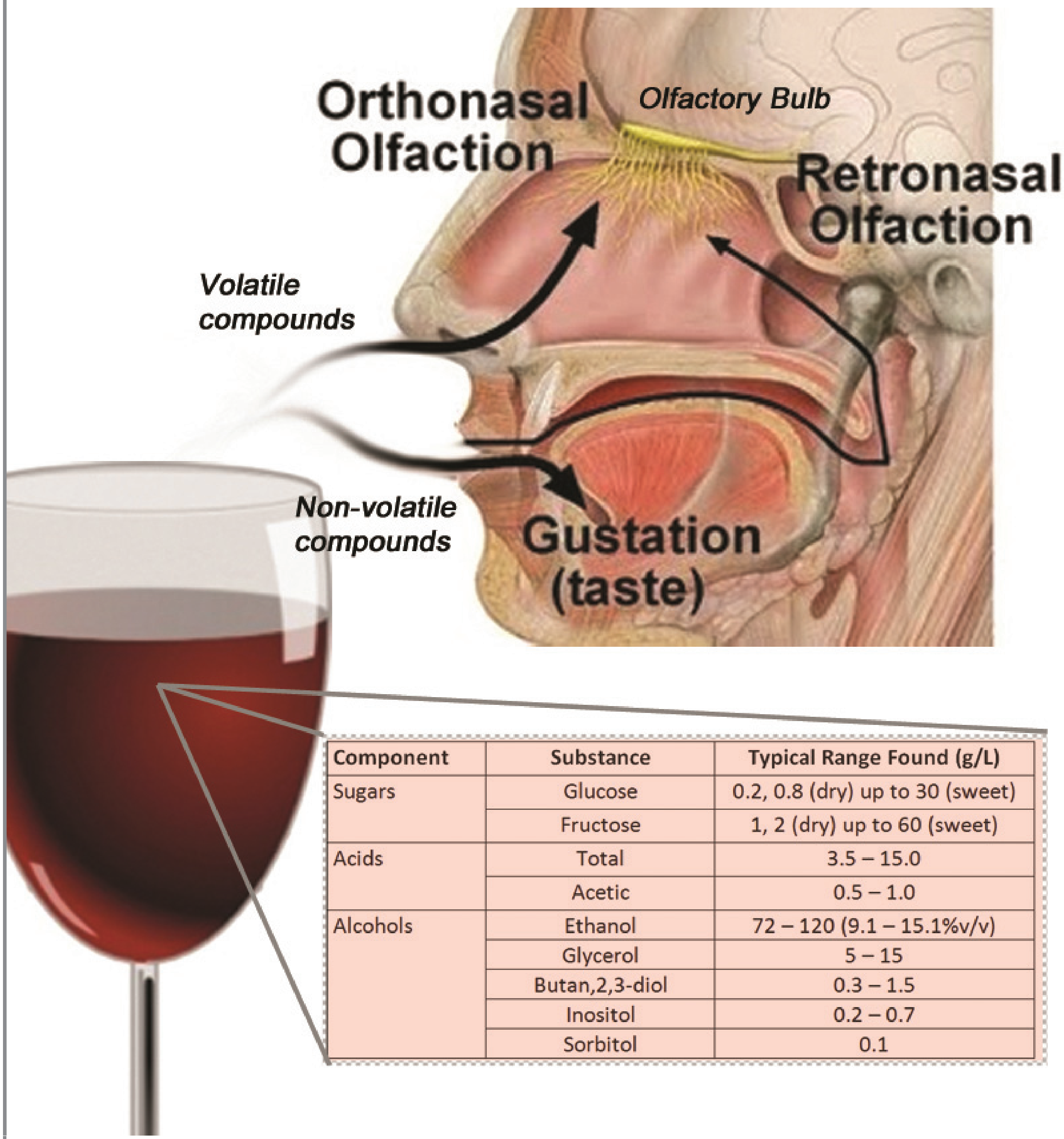
CALIFORNIA PRODUCES over 90 percent of the wine made in the United States (Nemani et al, 2001). The geology and location of California define various unique terroirs which are well suited to the production of quality wine. The west coast of California borders (see **Figure 4**) the Pacific Ocean, which has a large moderating effect on the temperature, increasing temperature stability throughout the year. One major factor contributing to the success of the California wine region is its relatively high number of degree days. California also experiences high amounts of sunlight due to its southern location, which is a crucial factor for vine growth (Wilson, 2001). There is plentiful precipitation which, combined with the warm, stable climate, allows for an excellent grape growing region (Sullivan, 1998). The coastal valleys of California have a Mediterranean climate with moderately wet winters and warm, dry summers. The northern coastal areas experience colder winters with significantly more precipitation and are classified as West Coast Maritime. Most of the Central Valley of California has a desert climate, rendering irrigation essential to grape cultivation (Sullivan, 2008).

While both the California and Niagara wine growing regions are situated next to large bodies of water, the moderating effects experienced in these regions are very different, creating contrasting climates. Coastal California experiences a greater moderating effect from the ocean, while the Niagara region has larger annual fluctuations in temperature. California, due to its southern location, also experiences higher average annual temperatures, resulting in a lower risk of frost damage to vines. The different climates of these regions mandate different viticultural practices as well, resulting in wines with flavours unique to their region of origin.

A CHEMICAL COCKTAIL

WHILE TERROIR is a major contributing factor to the development of fruit while it is on the vine, flavour is ultimately a property that arises from the wine chemistry. Flavour in itself is a psychological construct - the integration of sensory inputs from wine aroma and taste which is done by the central nervous system. Non-volatile wine compounds at and above concentrations corresponding to human detection limits give rise to the five basic taste sensations: bitter, sweet, sour, salty, and umami, the latter two being less pronounced in wine (see **Figure 5**). Conversely, volatile wine compounds reach the olfactory organ through the nostrils and back of the mouth, the nasal and retronasal routes respectively, and are ultimately perceived as smell. Multiple

When a white wine is dyed red, consumers perceive the taste to be that of a red wine (Morrot et al.,



Component	Substance	Typical Range Found (g/L)
Sugars	Glucose	0.2, 0.8 (dry) up to 30 (sweet)
	Fructose	1, 2 (dry) up to 60 (sweet)
Acids	Total	3.5 – 15.0
	Acetic	0.5 – 1.0
Alcohols	Ethanol	72 – 120 (9.1 – 15.1%v/v)
	Glycerol	5 – 15
	Butan,2,3-diol	0.3 – 1.5
	Inositol	0.2 – 0.7
	Sorbitol	0.1

Figure 5: Wine is a complex chemical cocktail containing thousands of different compounds. Compounds that are easily associated with a certain taste sensation, such as a sour taste for acids, and a bitter taste for alcohols, are listed here and their typical concentrations in wine are given (Clarke and Bakker, 2008; Gray, 2007; Summit Brewing Company, 2010).

Multiple flavor components are perceived simultaneously at varying intensities (Clarke and Bakker, 2008). Wine is therefore valued by its consumers not so much for its consistency across the market, but rather the subtle breadth and complexity of sensation that it offers (Conde et al., 2007). Overall mouth feel, as induced by bubbles or the dry, puckering feel of wine, also contributes to this complexity and appealing descriptions of such sensations, causing various wine flavour notes to form a cornerstone of wine marketing (Clarke and Bakker, 2008).

Wine has a diverse chemical makeup, with thousands of compounds ranging in concentration from a few parts per billion to a few percent. These compounds arise from the grape juice, fermentation and the vinification process, and wine aging (Conde et al., 2007; Clarke and Bakker, 2008). The chemical content of grape juice varies between grape varietals, as it does also for grapes of the same varietal grown in unique terroirs and harvested at varying times. Winemakers may exercise further control during the vinification process over yeast type, temperature, acid and sugar adjustments, wood type for barrel aging, and other conditions, which further affect compound presence and concentration in the final product in a complex manner (Clarke and Bakker, 2008).

Different wineries have unique growing conditions and processes; yet despite this fact, many wineries agree on similar standard amounts of compounds for which they strive. The reason for this arises from the interplay of different wine components in determining the final flavour (Jones et al., 2008). For example, acidity is paramount in determining wine tartness and has to be balanced against the wine sugar level. Titratable acidity (TA) and pH are measures of organic acid concentration – TA is the amount in equivalent concentrations of tartaric or malic acid, which are the most abundant acids found in the grapes at harvest, and pH is a measure of the strength of all the acids present (Jackson and Lombard, 1993; Conde et al., 2007). Tartaric acid is one of the strongest components that affect the taste of wine. It is a compound almost unique to grapes, and along with malic acid (also found in apples) forms 69-92 percent of all organic acids in the grapes and leaves. Other acids found in wine at smaller concentrations include citric acid (also found in lemons and oranges), lactic acid from the fermentation process, and volatile acetic acid, which is perceived as vinegar-like. Acidity is different between grape varietals and is also determined by grape growing conditions and maturity at harvest (Clarke and Bakker, 2008).

Did you know that the human olfactory threshold for detecting volatile substances such as acetic acid is as low as two parts per billion (Wise et al., 2007)? That's like being able to find Waldo in the entire Chinese population.

With a pH in a favourable range (3—4), wine is better prepared to mould its flavours and maintain its freshness and colour, and is less likely to spoil (Fontoin et al., 2007). If a wine has a pH above the acceptable range, it is more likely to taste dull and flat, and with too low of a pH, it tastes overly tart and sour (Fontoin et al., 2007) The pH also has influence over how other flavour components, such as wine astringency (the puckering sensation also characteristic of tea and coffee), are expressed—at lower pH the wine expresses more of this astringency. Although sugar plays an important role in wine sweetness, it is the balance between acidity and sugar that brings out the full flavour so that the wine tastes neither too sour nor sickly (Clarke and Bakker, 2008).

The initial sugar level of the grapes affects many characteristics of the wine including alcohol content and sweetness. Yeast is used for alcoholic fermentation of grapes to produce wine (Bisson and Karpel, 2009). At the time of harvest, there are usually equal amounts of glucose and fructose present in the grapes.

Sucrose is not present in the grapes at harvest as it is converted into glucose and fructose while the grapes are still on the vines. However, sucrose is sometimes added to increase the alcohol content in a process called chaptalization (Mietton-Peuchot et al., 2002). Perceived sweetness of these three sugars differs – glucose is 0.69 and fructose is 1.14 times as sweet as sucrose (Clarke and Bakker, 2008). Brix levels represent the sugar (glucose and fructose) content of the grapes when harvested (Jackson and Lombard, 1993). While quantifying wine taste is an extremely challenging goal, the various chemical compounds introduced here provide useful metrics for both determining when to harvest, and assessing the taste quality of a finished wine product.

Canadian grapes naturally produce more of the chemical compound resveratrol because of the cooler climate. Resveratrol is an antioxidant that reduces fat and cholesterol in human blood, reducing the risk of heart disease (Le Cordon Bleu, 2012).

CASE STUDY

The Impact of Niagara and California Terroirs

In order to determine whether there is a significant difference in the flavour of wines from the Niagara region compared to those from other regions, wine composition data on two different types of wine from two different locations was obtained and analyzed. The two varietals selected were a Chardonnay and a Pinot Noir, from both Niagara and California. The winery selected in Niagara was the Rosewood winery located in the Beamsville bench. This is one of the regions most protected by the escarpment, causing it to be a highly competitive area for vineyards (Shaw, 2005). Two wineries were selected for comparison in California, one located in Paso Robles and the other in Monterey. Paso Robles has a warmer climate than Monterey, and is therefore mostly suited to the production of red wine (Sullivan, 1998). Wine Brix levels, titratable acidity (TA) and pH for each of the wines were obtained and compared over a period of six years (Eberle, 2012; J Lohr, 2012; Roman, 2012).

A factorial analysis of variance (ANOVA) has the ability to determine whether groups of data are different enough to come from distinct populations. Factorial ANOVAs can test the effects of multiple independent variables and also determine whether there is an interaction between them. Factorial ANOVA was thus well suited to find out whether the average values for Brix levels, TA, and pH for location and wine type were significantly different and could be attributed to the wines originating from unique terroirs. The results showed that the Brix levels obtained were significantly higher in California compared to Niagara, regardless of the type of wine. By looking at **Figure 6**, it is evident that in Niagara, Brix levels are greater in the Chardonnay than the Pinot Noir, which is opposite to the trend observed in California. This difference however, is not statistically significant. In regards to TA and pH, no significant difference was observed between the two locations.

To control for individual differences in winemaking practice, all the data used was collected at the time of harvest. The biggest contributor to different grape compositions is generally considered to be varietal; however, this was controlled for by comparing identical varietals. It is hypothesized that the next greatest contributing factor to the differing grape chemical composition is terroir. By examining two separate locations, two different terroirs were analyzed, and the data collected shows that location, and thus terroir, has a significant effect on the composition of the grapes. It is worth mentioning here that the data was obtained from only one winery in the Niagara region and two wineries in California. While these two wineries have differing microclimates, they have the same macroclimate, which is determined by the latitude and geology of the region. For this reason it would be unreasonable to assume that the results apply to the whole of Niagara and California. The results do suggest that different terroirs exist between the wineries studied, and that these terroirs ultimately influence the taste characteristics of the wine produced. Thus, Niagara wine tastes the way it does because of its unique terroir.

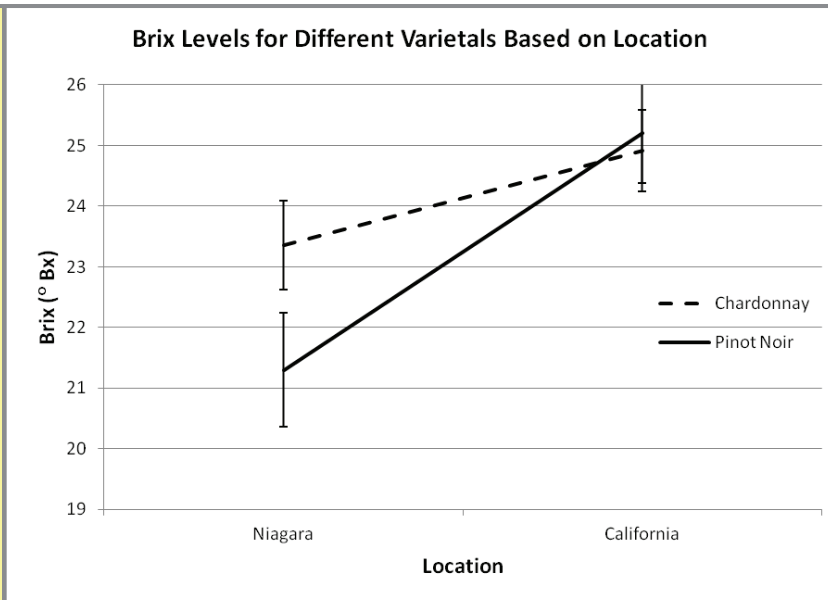


Figure 6: Graph showing the Brix levels for the two different varietals, broken down based on location. It shows that Chardonnay has a greater Brix level than Pinot Noir in Niagara, yet the opposite is seen in California.

FROM TERROIR TO TASTE

NIAGARA WINE has a unique flavour due to the distinct terroir of the region. Here, this is represented by its reduced sugar levels compared to wines from the California region. However, the case study was limited in its data set, thus larger scale studies can provide insight into other characteristics of taste that are unique to the Niagara region, as well as how these are ultimately influenced by the climate of the region. A 2010 study by Orduna, investigating the effects of climate change on wine quality, analyzed temperature data over almost a century, and showed that increased annual temperatures generally resulted in increased sugar content of the wine vintages. This result, similar to the trend observed between the Niagara and California regions, is likely due to the fact that photosynthetic efficiency of grapes increases, to a certain threshold, with increasing temperature and sunlight exposure. The increasing sugar concentration may also be due to evaporative loss of water from the grapes in hot conditions. In general, acid levels follow an opposite trend to sugar levels; there is an observed decrease in acid levels with higher temperature vintages. Thus, Niagara wine would generally be expected to be higher in acid and lower in sugar levels than California wine. In addition, some vegetative flavour components of white wines, such as pyrazines, have been shown to develop more favourably in cool climate growing conditions. In contrast, monoterpenes, which impart fruity, floral, or spicy tastes to wine, are generally lower in concentration in wines from cool climate regions (Orduna, 2010). As stated by Becker (1985), “In cooler climates, white wines are fresher, more acidic and finer in bouquet and aroma, warm region wines are high in alcohol and short on taste and aroma.” Even from these limited observations, one can already see that climate has a complex effect on the flavour of wine. While it is difficult to pinpoint specific climatic parameters as being solely responsible for defining the flavour profile of wine from a particular region, an understanding of geology, along with how it affects plant physiology and ultimately the biochemical composition of the resultant wine product, is certainly the right starting place to begin answering this question.

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Striving for Sustainability in the Niagara Region

Sustainable agriculture involves the integration of practices in the production of plants and animals that satisfy the current needs of the human population and ensure the long term environmental viability of the region. In recent years, sustainable agriculture has risen in popularity across the Niagara region. Although wine is a luxury product, the Niagara wine industry is no exception to this trend. While the majority of wineries in the Niagara region do not promote themselves as utilizing sustainable practices, there are a handful which heavily advertise their eco-consciousness. The most common ways in which environmental impacts are reduced include water management, pest control, and energy conservation. In 2004, the Wine Council of Ontario (WCO) developed a program called *Sustainable Winemaking Ontario* in order to further promote these practices. This program consists of a voluntary self-assessment that winemakers can choose to complete in order to receive an approximation of their sustainability. Unfortunately, voluntary ratings like this are pvulnerable to exploitation. Therefore, it is our suggestion that an independent auditing method be implemented to ensure an unbiased view of the sustainability in the region. This method must include a quantifiable measure of environmental impact, namely a Life-Cycle Assessment (LCA). An LCA is a technique that utilizes quantifiable measures to determine the environmental consequences associated with the entire process of creating and selling a product. In order to conduct an LCA of the Niagara wine industry there are four steps. First, the goal and scope of the assessment must be determined. Second, an analysis of the data inventory must be conducted. Third, an evaluation of the potential environmental impact of the industry must be performed. Lastly, the results must be interpreted to determine the final recommendations for improving sustainability. The implementation of this metric would be beneficial for creating long term sustainability in the Niagara region while demonstrating a product's actual environmental quality, especially in a luxury market such as wine.

INTRODUCTION

The concept of sustainability is one that is hard-to-define. With over 100 definitions created in the mid 1990s alone, it has been applied to a variety of scenarios, some of which have a questionable claim to the term (Marshall and Toffel, 2005). The first formal attempt to define this concept came in 1987 by the World Commission on Environment and Development (WCED). WCED defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bader, 2008). While this definition was hailed as being quite intuitive, it was also highly criticized for being unhelpful when making practical decisions (Marshall and Toffel, 2005). One other important explanation of the term came from the European Union's 1997 Copenhagen summit, which established the three-pillar model of economic, social, and environmental sustainability as shown in **Figure 1** (Bader, 2008). This was also criticized, this time for being arbitrary and "lacking any meaningful foundation" (Marshall and Toffel, 2005).

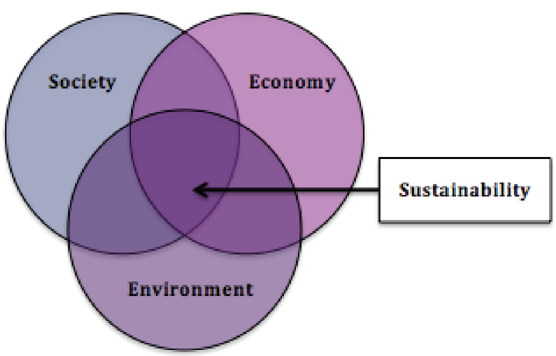

Figure 1: The three pillar model takes into account the social, environmental and economic aspects of sustainability (Wikimedia Commons, 2009).

In conjunction with this confusion over the definition of sustainability, the usage of this term has skyrocketed in recent years as shown in **Figure 2** (Marshall and Toffel, 2005). The widespread adoption of this word by large corporations is a recent cultural phenomenon closely related to the 'greening' of advertising. Being seen as environmentally friendly is an effective way of capitalizing on the flourishing environmental movement. As a result, putting a 'green' spin on the marketing of products has become incredibly popular (Dahl, 2010). The high usage of terms such as 'green', 'sustainable', and 'organic' has led some to suggest that sustainability is simply a buzzword without any real meaning (Marshall and Toffel, 2005).

While the word sustainability is commonly used arbitrarily and insubstantially in marketing, the field of industrial ecology is one that takes a more quantifiable approach to the term. Concerned more by the environmental side of sustainability rather than the economic and social ones (as detailed by the three-pillar model), this field views industrial activity as an analogue to biological ecosystems (Hess, 2010). It seeks to trace the flow of energy and materials through industrial systems with the aim of reducing environmental impacts (Garner and Keoleian, 1995). The industrial ecological approach to the term sustainability is one that is based on a verifiable, scientific foundation (Garner and Keoleian, 1995). An industrial ecological slant to the term sustainability will therefore be used within this article.

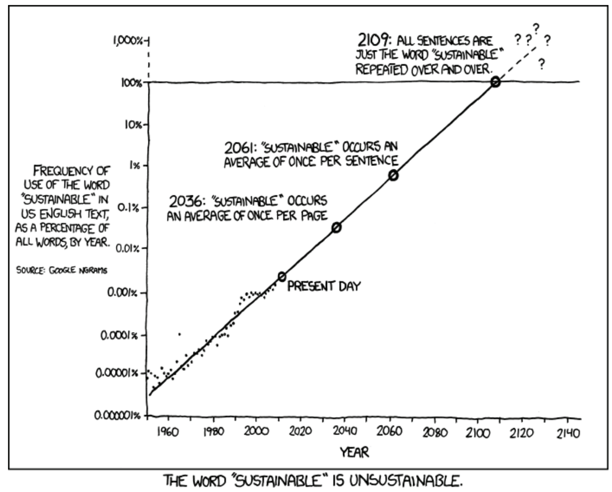

Figure 2: This comic humorously depicts the overuse of the word sustainable.

A variety of metrics can be used to measure sustainability. As with definitions, there are a copious number of metrics available, each with a different objective (Marshall and Toffel, 2005). A variety of categories including material, energy and water consumption, solid wastes, and land use are typically measured (Tanzil and Beloff, 2006). One well-known indicator is the ecological footprint. It is typically used to highlight inequalities in resource utilization by framing ecological impact in terms of the capacity of the Earth (Tanzil and Beloff, 2006). The International Organization for Standardization (ISO) has also helped in the development of metrics used in environmental management, including emergy analysis and Life-Cycle Assessments (LCA; Marchettini, et al., 2003). This latter tool is one that is highly favoured in the field of industrial ecology (Garner and Keoleian, 1995).

SUSTAINABILITY IN THE NIAGARA WINE REGION

Sustainable agriculture in particular has risen in popularity over the past two decades (Gold, 2009). This trend is largely due to the potential to mitigate the risks associated with global warming and the growing human population (Gold, 2009). Although wine is a luxury product, parts of the wine industry have enveloped the ideals associated with environmentally friendly agriculture. This can clearly be seen in the Niagara wine industry (see **Figure 3**). This region accounted for over 338 million dollars in retail wine sales in

2001 and is the country's leading grape producer (Niagara Region, 2003).

Figure 3: Five of the sustainable wineries in the Niagara region.

While the majority of wineries in the Niagara region do not promote themselves as utilizing sustainable practices, there are a handful which heavily advertise their eco-consciousness. Stratus Vineyards, Diamond Estates, Tawse Winery, Jackson-Triggs, Southbrook, and Hinterbrook have incorporated sustainable methods into their winemaking processes. The most common ways in which environmental impact is reduced are water management, pest control, and energy conservation as shown in **Figure 4** (Wineries of Niagara on the Lake, n.d.).

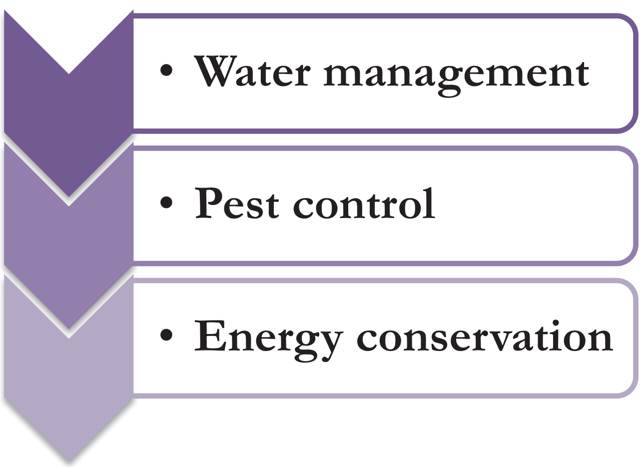

Figure 4: There are three common ways in which environmental impact is reduced.

The Earth's supply of fresh water is limited and shortages could pose a severe environmental threat. In addition, the resources used to purify, store, and transport water contributes to its carbon footprint. Conserving and managing water usage is thus incredibly important when there are concerns about environmental impact (Larson and Gujer, 1997). For example, Hinterbrook collects rainwater and uses it for winemaking as well as watering the lawn (Hinterbrook, 2012). Broadening this idea, Southbrook controls water usage with low-flow fixtures and treats waste water with an onsite wetland filtration system. This filtration system mirrors the natural purification which results from plants and rocks in a wetland (Southbrook, 2012). Furthermore, Diamond Estates has claimed to have instituted a pigging system, an insert in pipelines, which reduces their water usage by 50 percent (Diamond Estates, n.d.).

As in all agriculture, pest management is vital to the success of the business. Pesticides are commonly employed to increase yield, however over 98 percent of insecticides and 95 percent of herbicides spread past their target pest to other species, and cause air, water, and soil pollution. Pesticides also reduce biodiversity, decrease nitrogen fixation, and destroy habitats (Miller, 2004). Rather than using these dangerous chemicals, several wineries in the Niagara region, such as Tawse Winery and Southbrook, raise sheep and other livestock to control insects and unwanted plants (**see Figure 5**). Cover crops grown in between vines can also help increase biodiversity and provide additional pest control (Southbrook, 2012, and Wineries of Niagara on the Lake, n.d.).

Figure 5: Some wineries raise livestock for the purpose of pest control

In general, eco-conscious methods involve reducing the quantity of electricity consumed. This can be done in a multitude of ways and a large variety of practices are employed across the sustainable wineries in the Niagara region. For example, Stratus Vineyards uses a true gravity flow system to eliminate pumping of wine (Wineries of Niagara on the Lake, n.d.). Hinterbrook and Diamond Estates both use solar panels on the roofs of their buildings to reduce the amount of energy they must purchase from the grid (Hinterbrook, 2012, and Diamond Estates, n.d.). Many of the wineries listed above also have Leadership in Energy and Environmental Design (LEED) certified buildings and warehouses. Some even use lightweight glass in order to reduce transportation costs. Outside of the viticulture and processing, several vineyards encourage the use of local food, biking or public transportation for wine tourism, and the use of biodegradable materials (Wineries of Niagara on the Lake, n.d.).

It should be noted that the methods mentioned above are only the ones which these specific wineries advertise in material accessible to the public. The validity of these claims cannot be verified. Nonetheless, it is evident that efforts are being made within the Niagara wine industry to promote sustainable winemaking.

Sustainable Winemaking Programs

In 2004, the Wine Council of Ontario (WCO), a non-profit trade association representing 81 winery properties, developed a program, called *Sustainable Winemaking Ontario* with the goal of evaluating the sustainability of wineries. This included incorporating many of the methods already employed by several wineries as described above (Wine Council of Ontario, 2011). It was designed with industry input using existing research on reducing environmental impact. As of 2008, 17 wineries were participating in the project and the WCO hopes to use the data gathered to eventually create benchmarks. It is currently the only evaluation of sustainability in the Niagara wine industry (Insight Environmental Consulting, 2008).

The program is based on a voluntary self-assessment which covers topics such as water management, waste management, materials handling, energy efficiency, and pest control. Interestingly, the program takes into account all three pillars of sustainability: environmental, economic, and cultural. The assessment takes the form of an interactive spreadsheet with yes or no questions that wineries can complete and then add up their total scores for each section. Answers are weighted using scoring from -20 to +20 where a negative score indicates significant harmful environmental and economic impacts and a positive score indicates leadership in environmental practice (Insight Environmental Consulting, 2008).

The WCO states that its goals for *Sustainable Winemaking Ontario* include improving environmental performance, adding value to the wine industry, and long term improvements in the region's air and water quality. This may seem to be a hefty goal and unfortunately the program is new enough that no publicly accessible data has been published to evaluate its efficacy (Wine Council of Ontario, 2011). It should be emphasized that this program is entirely voluntary and since it is a self-assessment, sustainability scores are not independently audited. Nonetheless, it shows an important step in promoting sustainable winemaking in the Niagara region.

The WCO's efforts to increase the sustainability practices of wineries in Ontario through the use of the voluntary assessment show that the organization understands the long term benefits of supporting sustainability. However, due to the 'self-assessment' nature of the test, there is still much to be desired in terms of actually classifying wineries based on their sustainability. In other primary winemaking regions around the world, municipal governments and watchdog groups have implemented more rigorous sustainability guidelines, which serve as excellent examples of how the WCO should progress. Perhaps the best example of this type of program is the *Sustainable Winegrowing Program*, which was implemented by the California Sustainable Winemaking Alliance (CSWA).

In addition to a self assessment program that is very similar to that of the WCO's, the CSWA also hosts seminars, runs sustainable winemaking workshops, and, most importantly, offers a 'sustainable' certification system (CSWA, 2012). In order to obtain this certification, wineries must pass yearly, third party inspections that evaluate their water, energy, and nitrogen uses, in addition to their yearly greenhouse gas emissions (CSWA, 2012). If the winery receives a passing grade on each of the 58 scored metrics, they can use the CSWA Certified label to market their product and additionally receive free advertising through the agency (CSWA, 2012). This program, which was introduced in 2004, has seen incredible success as over 62% of all wine cases produced in California in 2009 met the sustainable threshold (CSWA, 2009). A program like this, which uses economic incentives to push sustainable development, could go a long way to increasing the sustainability practices in the Niagara region.

Life-Cycle Assessment as a Sustainability Metric

An LCA is a technique that uses quantifiable measures to determine the environmental consequences associated with the entire process of creating and selling a product (SAIC, 2006). LCAs assess the product's overall environmental impact and aim to avoid a narrow outlook by identifying the goal of the assessment, collecting data from all energy inputs and environmental outputs, and evaluating the impact of all of these inputs and outputs, as depicted in **Figure 6.**

The end goal of the assessment is to produce metrics that accurately and definitively show the environmental impact of a product, and the stages of development that are the primary causes of the impact (Duda and Shaw, 1997). These assessments have been used by a wide range of businesses including those in the manufacturing, agricultural, and retail industries. There are several forms of LCAs, most of which vary by the extent of the product development considered. Some of the most popular of these variants are the Cradle-to-Grave, which looks at the entire process from extraction to disposal, Cradle-to-Gate, which looks at extraction through the manufacturing process, and Gate-to-Gate, which looks at the value adding portion of the products development (Duda and Shaw, 1997). LCAs have proven to be extremely valuable through their ability to look behind the initial first impressions of a product, but because of the nature of the tests, they do have several limitations.

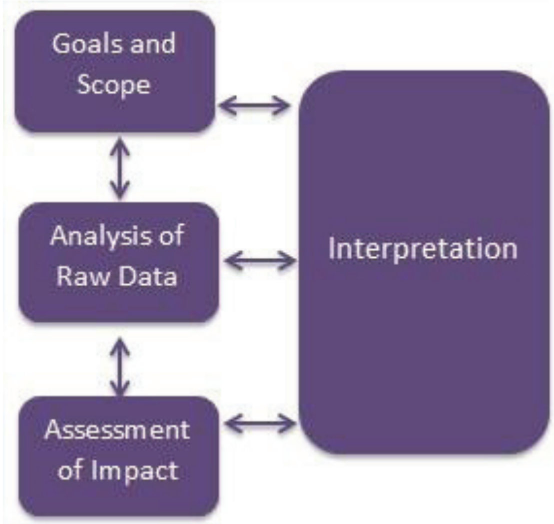

Figure 6: A depiction of the LCA process, which includes deciding on the goals of the test, collecting all relevant data, and evaluating the impact of the data retrieved (modified from (SAIC, 2006).

There are both benefits and disadvantages that result from the application of LCAs for winemakers and environmentalists alike. Recall that an LCA systematically assesses environmental impact and allows for the analysis of exchanges with the environment for a specific product or process (Gaines and Stodolsky, 1997). It quantifies certain factors, such as outputs into air, water, and land that occur for each step of the cycle in product development (Gaines and Stodolsky, 1997). This allows for the detection of environmentally detrimental parts of the manufacturing process. These 'hot spots' can therefore be targeted, allowing the producer to modify or replace the steps in question, enhancing the product's environmental performance. The implementation of this evaluation serves to provide comparative data among wineries for their production methods, encouraging the establishment of environmentally acceptable methodologies and policies (Gaines and Stodolsky, 1997).

In addition, LCAs can enable the distribution of quantitative information between stakeholders such as industries, customers, government, local committees, and other organizations. It can be of internal use to an industry for process management, technology reporting and selection, as well as externally to inform stakeholder groups and to support marketing (Gaines and Stodolsky, 1997). Through the sharing of this information, winemakers can take effective measures pertaining to environmental protection (Gaines and Stodolsky, 1997).

As with other assessment techniques, there are disadvantages to an LCA. Ardente et al. (2006) reviewed European winemakers' experiences in using LCAs. They suggested that small-and-medium enterprises (SMEs) in the wine industry generally found it difficult to perform an LCA because of the sheer amount of information needed. Also, highly specialized skills are required to use LCA databases and software, and the process is very time-consuming. This is because a holistic LCA is a data intensive process, and the more comprehensive the LCA, the more expensive it is to conduct (Gaines and Stodolsky, 1997). As echoed by Cordano et al. (2010), SMEs typically lack the complex organizational structures, and culture of formally documenting the procedures required to implement and utilize LCAs. Only larger wineries have the capital required to cover the increased operating, and implementation costs.

There are also inherent limitations in LCA studies, such as subjectivity in boundary selection and impact assessments depending on the quality and availability of relevant data (Gaines and Stodolsky, 1997). A boundary defines where energy or matter enters or exits the system. The boundaries of the life-cycle of a product are based on a set of assumptions, which may differ according to each LCA (ISO, 2006a). For example, the energy required for the consumer to wash the glasses used to drink wine is typically excluded, as is the energy and materials required to build factories producing auxiliary consumables.

An LCA For the Niagara Wine Industry

As Cordano et al. (2012) demonstrated, programs like LCAs are perhaps best implemented as part of a voluntarily adopted scheme supported by trade-associations. Building upon the WCO's Sustainable Winemaking Ontario: An Environmental Charter for the Wine Industry, there is perhaps scope for the development of a consortium between the WCO, LCBO, and other stakeholders. The consortium could develop a program whereby the challenges faced by SMEs in the Niagara region in adopting LCAs are addressed through the pooling of their resources. Most importantly, a database of environmental data used in LCAs could be developed specific to the needs of Niagara winemakers.

Also, the consortium could work towards an LCA methodology for the community, based on international standards (ISO, 2006a, b), which could be continually improved. LCAs could be performed specific to the region's winemakers, encouraging innovation of winemaking methods with lower environmental impacts. The LCA procedure itself is iterative; "every successive phase of the study focuses on aspects to be investigated in more detail: the old data will be replaced with new ones leading to a more realistic evaluation" (Pizzigallo et al., 2008, p. 397). A simplified LCA could also be developed in the short term, which could be limited to a cradle-to-gate approach. Meanwhile the consortium could provide the funds needed to gain access to appropriate expertise and equipment.

Incentives need to be given, especially for winemakers and their suppliers to provide data, such as quantities of consumables used in production for a given product. The potential for eco-labelling also offers incentives for winemakers in reaching an environmentally conscious market. We argue that environmental self-assessments, and LCAs performed by the enterprises themselves should not be the basis for eco-labels. The potential for abuse remains with self-assessment or accreditation. Whilst obtaining an eco-label can be voluntary, its allocation should be based upon independent auditing.

Useful knowledge relating to LCAs can also be gained from the academic literature in the field. For example, in a case study of a bottle of wine produced in the similar cool-climate environment of Nova Scotia, Canada, it was shown that "nutrient management activities and consumer shopping trips were the largest relative contributors to wine's life cycle impacts. Non-trivial impacts also arose from the manufacture of glass bottles, winery activities, and transport of wine to retail" (Point et al., 2012, p. 19).

The ISO 14040:2006 document provides a standardized framework through which an LCA can be implemented. An LCA study is comprised of four phases: goal and scope definition, inventory analysis, impact assessment, and interpretation.

Goal and Scope

The goal of an LCA study in the wine industry is typically to quantify the life cycle emissions of one 750ml bottle of wine, and to determine the environmental impacts of each step of the wine's life-cycle. Other goals may also be desired with each particular LCA. Boundaries are also set in this phase. In the wine industry these are usually "all major material and energy flows associated with grape growing, wine making, glass bottle production, transport of wine to retail, consumer transport, refrigeration and bottle recycling" (Point et al. 2012, p. 12). Point et al. reviewed how boundaries were defined in the wine industry of Nova Scotia. Some of their suggestions included disregarding capital goods such as wine making equipment, farm and winery buildings due to their negligible impacts to a single bottle of wine. Defining these boundaries, along with environmental categories to be prioritized, and quality of data would be some of the most important tasks of the proposed Niagara consortium.

Life-Cycle Inventory Analysis (LCI)

Inventory analysis involves data collection and calculation procedures used to quantify inputs and outputs of matter and energy at the system's boundaries. This data includes "energy inputs, raw material inputs, ancillary inputs, other physical inputs, products, co-products and waste, emissions to air, discharges to water and soil, and other environmental aspects" (ISO, 2006a, p. 13). This information is compiled through questionnaires given to winemakers, surveys, other forms of personal communication, analyses of industry reports, and 'grey' literature from Niagara, all of which may need to be independently audited for certification. Following data collection, calculation procedures are performed to translate this data to a form useful for further analysis, from material and energy inputs into environmentally relevant inputs and emissions (Point, 2008).

Life-Cycle Impact Assessment (LCIA)

In this stage, the LCI results are simplified to globally significant impact categories, such as global warming potential, and cumulative energy demand. Those results may comprise hundreds of different inputs and emissions, and so must be organized and integrated into a quantitative form for a particular global environmental impact. LCIA is aided with LCA-specific software packages, which use embedded scientific models to sort LCI data. Point (2008) used a leading package, SimaPro developed by PRé Consultants (PRé Consultants, 2012), which is a popular package in the field of LCA. Another software program that the consortium could consider is GaBi, developed by PE International (2012). The LCIA results, in terms of the globally significant impact categories are highly relevant to eco-labelling and may be particularly useful in the consumer market of Niagara's wines.

Interpretation of Results

The final phase of an LCA involves refining, assessing and presenting the results of the study. This allows general conclusions to be made along with specific recommendations as to how the product's environmental impact may be reduced (ISO, 2006a). For example, 'hot spots' may be identified, and options for potential improvements evaluated. This evaluation is performed using what is referred to as scenario modelling, whereby potential alterations to the life-cycle may be considered by altering the life-cycle model in the software producing LCIA data. A potential alternative scenario which may be performed in an LCA is the impact of switching to lower mass wine bottles. Furthermore, if specified in the goals, the impacts of these scenario models may be assessed so as to quantify their effects (known as sensitivity analyses). This can help determine the robustness of the LCA results (Point, 2008).

The Importance of Independent Auditing

The implementation of LCAs or a similar metric in the Niagara wine industry would have a number of positive implications. The rising trendiness of the green movement has caused words such as 'sustainable', 'green' and 'organic' to be used abundantly in popular advertising (Dahl, 2012). The claiming of such terms by corporate entities can lead to the well-characterized phenomenon of greenwashing. Greenwashing, similar to whitewashing, is the marketing of a corporation as being environmentally friendly when in reality they are not (Parguel, Moreau and Larceneux, 2011). Corporate incidents of greenwashing can range from ingenuous and seemingly harmless to pervasive and highly damaging (Dahl, 2012). The appeal is easy to see; a company could, in theory, reap the benefits of being 'green' without putting in any of the work.

While the Niagara wine industry consists of SMEs rather than large corporations, it is still susceptible to greenwashing attempts. It has been found that corporations at this size still widely participate in this phenomenon (Cordano, Marshall and Silverman, 2010). Implementing environmental certification programs has been found to significantly deter corporations from engaging in greenwashing (Parguel, Moreau and Larceneux, 2011). However, care must be taken to ensure that these ratings are not determined through voluntarily submitted information. Voluntary ratings, such as Energy Star (see **Figure 7**), are vulnerable to exploitation by unscrupulous companies (Dahl, 2012). It is therefore ideal that independent auditing of such enterprises occurs for an unbiased view of how 'sustainable' or 'green', an organization is in reality.

Figure 7: Energy Star is a rating system for electronics.

Recommendations and Next Steps

Implementing such an independent rating system would have positive impacts on both the environment and on the Niagara wine industry. The over-usage of 'green' buzzwords has led a growing number of consumers to become cynical about corporate 'greening' (Dahl, 2012). However a highly regulated, independent sustainability metric would be beneficial for demonstrating a product's actual environmental quality while increasing its marketability, especially in a luxury market such as wine (Marchettini, et al., 2003).

As the Niagara wine industry has grown in terms of both the quality and quantity of its product, so too has the potential for a significant environmental impact. During this same time period, consumers have become increasingly interested in the environmental consequences of the products they purchase. This piqued interest has led to the greenwashing phenomenon, whereby businesses market their product as being environmentally friendly without actually developing sustainable practices (Dahl, 2012). To counteract the increasing environmental issues associated with the Niagara wine industry, the WCO developed a set of sustainability guidelines and a self assessment test for the wineries (Wine Council of Ontario, 2011). Unfortunately, this test offers very little incentive for wineries to become more environmentally friendly, and will likely result in minimal changes.

To create any kind of change in the practices of wineries, it has become clear that the WCO must implement an independently audited sustainability certification program. This type of program, a model for which was implemented by the CSWA, offers financial incentives like an eco-label, to wineries that begin to implement sustainable winemaking practices (CSWA, 2012). Differing from the program implemented by the CSWA, we recommend that an LCA, or life-cycle assessment, be the means by which wineries are classified based on their sustainability. An LCA would look at all of the energy inputs and varying outputs, and produce numerical values that will easily allow the winery's level of sustainability to be determined (SAIC, 2006). This type of LCA driven, third party certification system could significantly increase the desire for wineries to become environmentally friendly, and improve the long-term sustainability of the Niagara wine making region.

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ICEWINE AND THE NIAGARA REGION: AN IDEAL PAIRING

Thilakshan Arulnesan, Gillian Criminisi, Eric Hempel, John Kim, David McDonough, Lori vandenEnden

Icewine is an expensive late harvest luxury dessert wine produced from naturally frozen grapes. Very few regions in the world have the climate to support icewine production, making the product rarer than most other table wines. The most notable countries that produce icewine include Germany, Austria, and Canada. Each country has its own rules and regulations that govern the production and labeling of icewine. For example, the Vintners Quality Alliance (VQA) in Canada places strict laws on the production of Canadian icewine, and bestows the trademarked name 'Icewine' to those wineries that meet the standards. The following review details the history and reputation of icewine, methods by which it is produced, the rules surrounding its production in various regions, and considerations for the product and its market in the future.

INTRODUCTION

Icewine in its earliest form was first produced in the late 1700s by a German winemaker who was desperate after a cold spell caused his grapes to freeze earlier than usual. After harvesting and pressing these frozen grapes, the winemaker found that instead of a sensory disaster he had created a rich, sweet, and unique wine (VQA Ontario, 2012). Following this discovery, other wineries in Germany and Austria also began to produce icewine. However, icewine can only be made if temperatures become cold enough for the grapes to freeze and to stay frozen throughout harvesting and pressing processes. Germany and Austria did not have consistently cold winters and as a result, the decision to produce icewine in these countries was risky (VQA Ontario, 2012). In the 1970s, a German immigrant who was living and making wine in British Columbia created the first known Canadian icewine. The industry grew and they produced the wine with moderate success until 1991, when Ontario's Inniskillin Icewine won the highest award given at Vinexpo, one of the most prestigious wine exhibitions in the world. Following this, Canadian icewine became known internationally, and the demand for it increased significantly. As of today, Canada is now the leading producer of icewine worldwide (Jones and Hirasawa, 2007).

Icewine grapes still frozen on the vine. The grapes will remain frozen during the harvesting and pressing processes (Rivard, 2005).

Icewine is an alcoholic dessert wine renowned for its high concentration of sugar and flavour compounds. The wine is created with grapes that have naturally frozen on the vine, resulting in a rich and smooth wine with bouquets such as peaches, apricots, tropical fruits, honey, toffee, caramel, maple and nuts, depending on the varietals used (Agriculture and Agri-Food Canada, 2011). It is regarded as a luxury drink, typically costing between thirty and eighty dollars per 375mL bottle (LCBO, 2012). Because it is so sweet and rich, it is often consumed in smaller dessert wine glasses. At the moment, the Niagara icewine industry is promoting the brand and solidifying their place in the global market. There are select niche markets in countries such as China and Japan where it has become well established, but more brand awareness and widespread distribution would be a boon to the Niagara icewine industry (Jones and Hirasawa, 2007).

In Canada, a majority (about 75%) of icewine is produced in Ontario, particularly in the Niagara region. The rest is made mostly in British Columbia, with smaller quantities being produced in Quebec and Nova Scotia (Nurgel, Pickering and Inglis, 2004). These areas have the optimal climate for this type of wine, with warm, sunny summers and reliably cold winters, allowing Canadian wineries to produce high-quality icewine year after year (Nurgel, Pickering and Inglis, 2004). Canada consistently makes excellent icewine due to regulations set out by the Vintners Quality Alliance (VQA), an organization recognized by the government of Canada. The VQA has a strict set of regulations that winemakers must follow if they want to label their wine as Icewine, a trademarked term owned by the alliance (Soleas and Pickering, 2007). Approval from the VQA guarantees quality and authenticity to icewine consumers.

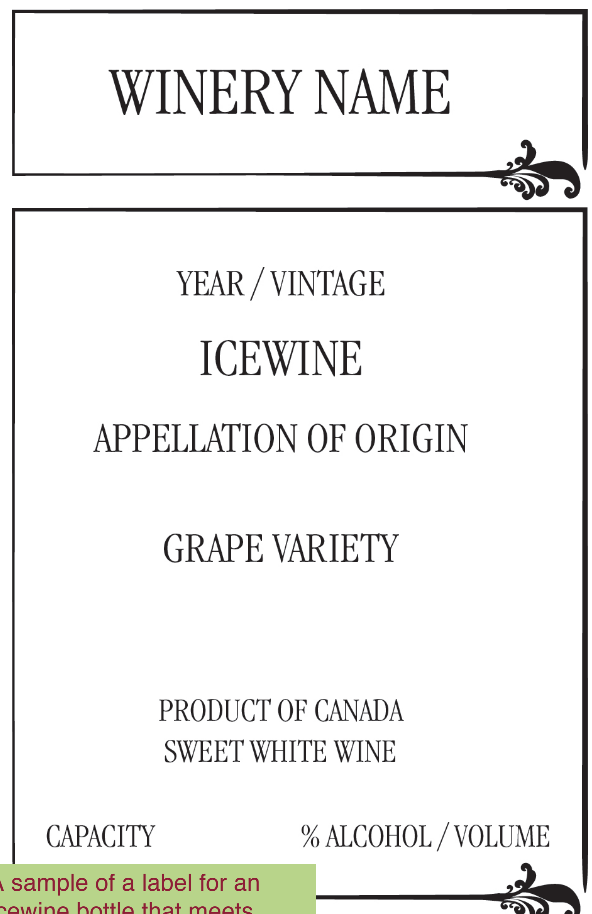
The processes involved in creating icewine are somewhat different from table wine production. Since the grapes are harvested while frozen, much of the grape volume has been lost due to dehydration by the time they are harvested. In addition, much of the water content in the grape is frozen. As a result, the same amount of berries will yield much less icewine in comparison to table wine (Jones and Hirasawa, 2007). It is also much more difficult to harvest, as there are

Inniskillin's Vidal Icewine, priced at CDN $55 per 375 mL bottle, alongside a typical icewine glass. Image used with written permission from Inniskillin winery (Inniskillin 2008).

typically only one or two nights in a season to harvest the berries in accordance with VQA standards. This is typically done early in the morning when it is coldest (VQA Ontario, 2012). These factors cause icewine to cost considerably more than table wines.

WINE REGULATIONS

Icewine couldn't boast its impressive price tag if not for the strict regulations surrounding its production. The VQA, an agency of the Canadian government, regulates the production and sales of Icewine in Canada, and is often credited as having the most stringent laws associated with winemaking in the world (Ziraldo and Kaiser, 2007). In other northern hemisphere countries such as Germany, Austria and Switzerland, different organizations, both governmental and non-governmental, regulate ice wine production. In Germany, legal revisions as recently as 1971 govern the classification of wine (Robinson, 1974). The highest quality German wines, including ice wine, or Eiswein, fall under the Prädikatswein designation as outlined by the European Union. In addition to the EU Prädikatswein designation, the Verband Deutscher Qualitäts-und Prädikatsweingüter (VDP; The Association of German Quality and Prädikat Wine Estates), a collective of some of the oldest and most famous wineries in Germany, give further guidelines to Eiswein production provided the producer desires their stamp of approval (Robinson, 1974). A similar system exists within Austria, where in addition to the Prädikat system, the Districtus Austriae Controllatus (DAC; Latin for Controlled District of Austria) gives their own designations to regions and varieties of wine (Robinson, 1994). Despite all of these various quality control organizations, Canadian wineries produce Icewine harvested at the coldest temperatures with the highest sugar content, and are required to do so by law (Ziraldo and Kaiser, 2007).



A sample of a label for an Icewine bottle that meets strict VQA standards.

Country/Region	Minimum Sugar	Minimum Cold (°C)	Added Acids
Germany	29.58 °Brix	-7 or colder	• EU regulations: citric acid up to 1.0 g/L • in 2003, up to 1.5 g/L of tartaric acid was allowed for that year only
Mosel	26.40 °Brix	-7 or colder	
Austria	29.58 °Brix	-7 or colder	
Canada (BC and Ontario)	35.0 °Brix	-8.0 or colder	• added tartaric and citric acids up to a total acid content of 4 g/L

A comparison of the icewine regulations in different regions of the world. Notice that Canada requires the sweetest grape must and the coldest harvest temperature (data from Kaiser and Ziraldo, 2007).

The VQA regulates the quality of all certified wine produced in Canada, including Icewine (VQA, 2012). The usage of the term "Icewine" with an uppercase "I" is trademarked within Canada, and this term may only be applied to wines that meet very strict conditions. Grapes used for the production of Icewine must freeze naturally on the vine, and must be harvested at a temperature of less than -8 °C (VQA, 2012). This temperature must be maintained artificially throughout the entire pressing process. The must produced from the pressed grapes must have a final average sugar content of 35 °Brix (a measure of the dissolved solids in a liquid in grams per 100 grams, spelled "degrees Brix"), and no individual pressing may contain less than 32 °Brix (VQA, 2012). Canadian icewinemakers are allowed to add up to 4 g/L of a variety of acids, such as citric acid and tartaric acid, to improve the quality of wine, while European ice wines may only have up to 1g/L of added citric acid, hence Canadian Icewine is known for its balance of high acidity with high sugar content (Ziraldo and Kaiser, 2007).

A Canadian winemaker who wishes to make icewine must first register with the VQA and attend a yearly VQA Icewine Standards seminar. The icewine grape harvest may not begin until after November 15th of each year. Before harvest, the winemaker must inform the VQA of the temperature of the harvest(s), the amount of grapes that will be harvested, the Brix level of each must, the date and time of the harvest and the pressing capacity of the harvest. Each vineyard producing icewine is subject to inspection by the "icewine police." These third-party investigators randomly select vineyards and measure the must, juice and wine to ensure they meet the standards set by the VQA (Kaiser and Ziraldo, 2007). If the wines do not meet the standards set by the VQA, they must be reclassified as a Select Late Harvest wine and sold at a significantly lower price point.

Icewine Production

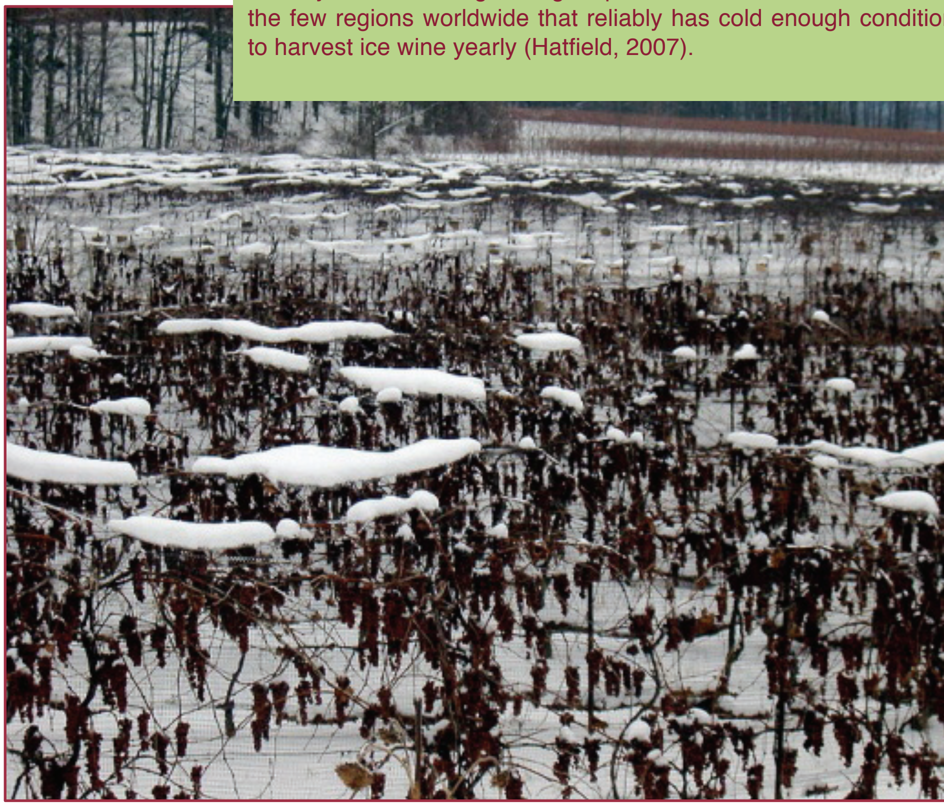
Icewine production involves many challenges that are not present in the production of other wines. However, it is overcoming these challenges that contribute to the unique sweet taste of icewine. We will discuss key steps in the making of icewine that differs from the production of table wines.

GRAPE VARIETAL SELECTION

Wines are often classified by the varietal or the type of grapevine used in the winemaking process. As with other wines, varietal selection in icewine production influences the chemical composition of the wine, affecting the sensory perception of the finished wine (Nurgel et al., 2004). In icewine, varietal selection is especially important as not all grape varietals can withstand the freezing and thawing that is involved in producing the wine. Winemakers are still experimenting with various varietals to find ones that can withstand the conditions required for icewine harvest yet complement the taste of the wine. Usually, *Vitis vinefera* grape vines are used to produce icewine (in fact, Canadian Icewine is required to be made from *Vitis vinefera* varietals) (VQA, 1999). In Canada, the majority of icewine is produced from Vidal and Riesling varietals. Both varietals have thick skins, which provide protection from disease and withstand the stress involved in freezing and thawing throughout the winter season (Nurgel, Pickering and Inglis, 2004).

GROWTH, HARVEST, AND PRESSING OF GRAPES FOR ICEWINE

Pest control and harvest date are both parameters that must be controlled to ensure a good harvest. Grapes used for table wines are often harvested between late August and early October, whereas icewine grapes must be harvested in colder conditions, ideally between December and January (Zirlado and Kaiser, 2007). Consequently, the grapes are exposed longer, and are more susceptible to predation (Harvey, 2012). In fact, typically 30 percent more grapes are lost as a result of the late harvest (Inglis, 2012). Wineries often require additional defenses, such as bird nets and sound cannons in order to reduce predation.



A vineyard in the Niagara region prior to harvest. Canada is one of the few regions worldwide that reliably has cold enough conditions to harvest ice wine yearly (Hatfield, 2007).

As outlined above, unlike grapes used for other wines, icewine grapes grown in Canada must be harvested at temperatures below -8 °C. Grapes harvested at different points during the season have been reported to have varying sugar and phenolic compound concentrations, affecting the taste, mouthfeel, and smell of the wine (Zirlado and Kaiser, 2007; Tian et al. 2009). Mechanical equipment or hand picking can be employed to collect the grapes, as with table wine.

After harvest, the grapes are destemmed and then pressed into a juice with a high solute concentration (measured in °Brix). The grapes often go directly to pressing after being picked in order to maintain their low temperature. The temperature at which the icewine is pressed requires some balance. If the temperature is too high, excess water from the grapes will enter into the juice, diluting the sugar concentration (Inglis, 2012). The opposite effect is also true, where juice yield is too small if the temperature is too low. The optimal range for pressing grapes is between -8 °C and -14 °C (Zirlado and Kaiser, 2007). Typically, the yield of icewine juice is 5-20% of typical table wines (Jones and Hirasawa, 2007).

Once pressed, the juice is left to settle and warm before fermentation, and individual winemakers add chemical agents (e.g. bentonite) to remove unwanted substances from the wine. In addition, the winemakers may also add agents that will acidify (e.g. tartaric acid) or deacidify (e.g. calcium carbonate) the grape juice to enhance the flavour profile. For icewine in particular, since the berries are pressed while frozen, some of the acidic compounds precipitate out of solution and do not enter into the juice. As a result, icewine juice often requires additional acidic compounds to compensate for this loss (Kaiser, 2012).

FERMENTATION

Prior to fermentation, the winemaker creates different blends with the different Brix-rated juices at temperatures within the range 37-42°C. The juice is then brought to a temperature at which the yeast (*Saccharomyces cerevisiae*) can ferment (13-25°C). Icewine fermentation is challenging because high sugar concentration is an extremely stressful environment for yeast cells (Pigeau and Inglis, 2005). Thus, the winemaker adds a large amount of yeast using correct rehydration procedures. Yeast cells lose water by osmosis, shrink in size, and some die as a result of fermentation (Pigeau and Inglis, 2005). Yeast respond to this stress by producing glycerol to protect against further water loss (Pigeau and Inglis, 2005). Glycerol production is important for increased mouthfeel (Ziraldo and Kaiser, 2007). However, it is biochemically coupled with the formation of acetic acid, which leads to higher levels of volatile acidity in icewine (Pigeau and Inglis, 2005). Swiss researchers showed that a fermentation temperature of 15°C is ideal for good glycerol production and low acetic acid production for the Swiss yeast strain (W15 and W27) (Klaus, Hoffmann-Boller und Jurg Gafner, and Wadendswil, n.d.).

A horizontal pneumatic press used to extract juice from grapes. Equipment used in the pressing of table wine and icewine grapes does not differ, though the juice yield of icewine is much less (Agne, 2011).

Icewine fermentation is often slow, taking months to reach the desired ethanol level. There are several factors that can affect the fermentation process. Yeast inoculation at a lower rate results in an insufficient amount of sugar consumed to yield the target ethanol concentration of 10% by volume (Kontkanen et al., 2004). Addition of yeast nutrient during yeast rehydration increases the rate of biomass accumulation, and reduces the fermentation time, ethanol concentration, and the rate of acetic acid production (Kontkanen et al., 2004). Furthermore, the selection of yeast strain can have an impact on the production of acetic acid, glycerol, and sensory characteristics. Canadian researchers showed that the yeast strains ST, N96, and EC1118 were most suitable for the production of icewine when compared to other commercially available strains of yeast. The researchers found that these yeast strains adapted more quickly to the high osmotic stress (resulting in faster fermentation rates), and were able retain more glycerol inside the cytoplasm (Erasmus, Cliff, and van Vuuren, 2004).

LONGEVITY AND STORING CONDITIONS

It is unknown how the longevity of icewines compares with the longevity of other wines. The aging process of icewine depends on the initial sugar concentration of the juice and the total acidity. It is estimated that icewines with low pH, high acid, and reasonable alcohol could be stored for 50 years or more at temperatures between 10-13°C (Ziraldo and Kaiser, 2007).

COUNTERFEIT ICEWINES

Like all valuable luxury goods, icewine is subject to imitation brands. There are two types of imitation icewines: those that are produced synthetically, and counterfeit copies of established brands (Jones and Hirasawa, 2007). Synthetic icewines are manufactured by artificially freezing the grapes, while counterfeit copies are made from a blend of grape juices and often contain no alcohol. Fake icewine is particularly prominent in Asia, where up to 60% of icewines sold are counterfeit (Jones and Hirasawa, 2007).

To combat the production of counterfeit icewines, Canada, Austria, and Germany signed an agreement in 2000 that set international standards for the production of icewine (Jones and Hirasawa, 2007). This agreement was designed to protect consumers from a number of fake icewines that were being sold. The agreement was also beneficial to Canadian icewinemakers, as it allowed the sale of Canadian icewine in the European market (Jones and Hirasawa, 2007). In order to stop the artificial freezing of grapes prior to pressing, the United

A typical icewine bottle is smaller than a wine bottle. Icewine is subject to counterfeiting which may include exact duplication of the label and bottle. This strategy is designed to fool the uneducated consumer and inferior counterfeit products often give a negative impression of icewine (Er, 2008).

States passed legislation shortly after the 2000 agreement stating that wine made from grapes frozen by means outside of nature cannot carry the Icewine designation (Ziraldo and Kaiser, 2007). In support of this ruling, the Office International de la Vigne et du Vin (OIV) in France also revoked the label of Icewine, Eiswein, or Vin du Glace from wines made from artificially frozen grapes (Ziraldo and Kaiser, 2007).

The presence of these imitators reinforces Icewine's status as a luxury good, yet these counterfeit icewine products threaten the worldwide status of icewine, as consumers who are exposed to lower-quality imitation products are left with a bad impression (Jones and Hirasawa, 2007). This counterfeiting also cuts away from the market of icewine sellers.

FUTURE CONSIDERATIONS

NEW METHODS FOR ICEWINE AUTHENTICATION

Presently, a great deal of research is being performed on icewine authentication, to counter the threat of counterfeit icewines. Researchers at Brock University have developed a method for identifying imitation icewines based on biochemical markers. Near the end of the growing season, grapes begin to produce large amounts of a certain metabolite, called Metabolite A (DeLuca, 2012). Metabolite A concentrations are four times greater in December than in the early fall. By measuring the concentration of this metabolite, it can be determined when the grapes that were pressed into icewine were harvested. This makes it possible to differentiate between icewine juice from grapes that were harvested in September and then artificially frozen and pressed, and juice from grapes that were frozen naturally on the vine in the winter months (DeLuca, 2012). Additionally, another potential method for determining icewine authenticity and quality is the use of electronic nose (EN). This analytical instrument mimics the human nose to detect changes in the microbiological and chemical quality of foods and beverages (Dickinson et al., 1998; Barlett et al., 1997). An EN comprises a sensor array that selectively reacts with volatile compounds such as hydrocarbons, aldehydes, amines, and aromatics. Recently, eight fruit wines (blueberry, cherry, raspberry, blackcurrant, elderberry, cranberry, apple, and peach) and four grape wines (red, Chardonnay, Riesling, and icewine) produced in Ontario were successfully characterized using EN (McKellar et al., 2005).

CLIMATE CHANGE AND ICEWINE

As icewine grapes must be harvested in a very narrow temperature window, the climate of the growing region is an important consideration. In general, the Niagara region meets these temperature requirements, with typical yearly temperatures ranging from mid twenties in the summer growing season, to sub-zero temperatures ideal for harvest (Environment Canada, 2012). However, climate change has been ongoing worldwide, and the steadily increasing temperatures and more extreme weather presents a concern for icewine growers (Davison, 2012). Harvest dates are being pushed to later in the season, increasing the susceptibility of grapes to pest damage and rot (Grape Growers of Ontario, 2012a). For example, during harvest in 2012, individual wineries have reported reductions in icewine production of up to 60% due to milder conditions (Allick, 2012). Wetter fall weather means that fewer grapes are left on the vine to freeze, resulting in yields that have been steadily decreasing over the past few years (Grape Growers of Ontario, 2012a). Some winemakers do like the freeze-thaw pattern as they feel it results in an icewine with a more concentrated flavour. Some wineries are considering moving their icewine growing regions further north, or switching to more resistant varietals (Davison, 2012).

NEW VARIETALS FOR ICEWINES

In addition to searching for more weather-hardy varietals, icewine makers are investigating new varietals to introduce new icewine flavours (Soleas and Pickering, 2007; Grape Growers of Ontario, 20012b). For example, varietals such as Chardonnay and Gerwurztraminer are less popular for icewine production than Vidal and Riesiling, but these new varietals are high in sugar and volatile acidity, consistent with a typical icewine (Soleas and Pickering, 2007). As well some new varietals, such as *Vignoles,* introduce pineapple aromas to icewine (Grape Growers of Ontario, 20012b). However, this varietal is not approved for Icewine production under VQA regulations and cannot be sold as an Icewine. In the future, the VQA may approve these wines, which would be an interesting addition to the icewine palate.

CONCLUSION

The Niagara region offers a prime growing location for icewine grapes, with warm summers and cold winters. But does Niagara icewine really stand out from the competition? A sensory and chemical comparision of icewine from different regions revealed that Niagara icewines have more late harvest characteristics than other icewines (Cliff et al., 2002). In particular, Niagara icewines have a more intense colour and a fruiter taste than the oily, nutty German icewines. These taste differences arise from the specific volatile organic compounds that are responsible for taste and aromas found in wines from these regions.

The unique taste of icewine drives its continued success, despite threats from imitation products and climate change, which make icewine production risky for winemakers. The Niagara icewine industry is growing, especially since it is one of the the only regions in the world that can consistently produce an icewine harvest. Recent expansion of the icewine market into Europe and Asia has proven successful. Niagara icewines owe their worldwide success to the region itself, which is perfectly suited for growing icewine grape varietals. An ideal climate combined with stringent VQA regulations means that Niagara icewine is not only delicious, but of the highest quality.

Niagara icewine is a delicious beverage that is enjoyed worldwide (Hatfield, 2008).

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