Translating Wine Tasting Terminology into Science

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What's the difference between a smooth, dry, full-bodied, fruit-forward Cabernet Sauvignon and a spicy, sweet, medium-bodied, fruity Riesling? Though a wine novice might say, "the colour", a wine expert will likely disagree, giving any number of descriptors to describe the wine. Wine tasting, using a variety of descriptors, seeks to differentiate and describe the complex nature of this most divine of alcohol beverages. However, what quantifiable components of wine gives it these characteristics?

INTRODUCTION

The word 'wine' comes from the Latin word *vinum* and is the product of grape juice fermented by yeast (Clarke and Bakker, 2004). Today, 98% of total grape wine production comes from a single species of grapevine, *Vitis vinifera* (Clarke and Bakker, 2004). The chemical profile of wine is directly influenced by the grape variety used, their growth and harvesting conditions, the treatment of the must (grape juice), the fermentation process, and the maturation of the wine (Styger, Prior and Bauer, 2011). From sweet to dry, and still to sparkling, the individual chemical profile of each wine determines its flavours and aromas.

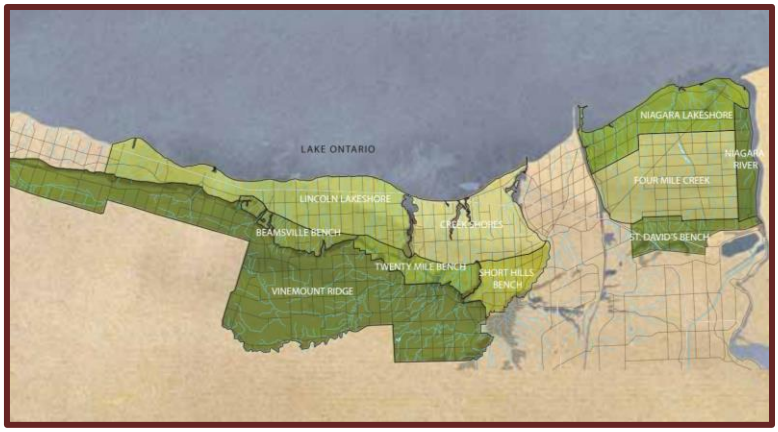

FIGURE 1: NIAGARAN SUB-APPELLATIONS. There are sixteen wine appellations in the Niagara Peninsula, varying in soil type, climate, precipitation, and topography. This allows the Niagara region to produce a variety of wine types (VQA Ontario, 2016).

With the large increase in popularity for wine tourism in the Niagara region (Figure 1), wine tasting has become a significant area of study in viticulture (Carmichael, 2005). Wine tasting allows us to determine the nature of wine, which is a product of the four taste senses (sweet, salt, bitter, sour) and aroma or smell. Taste is detected by the tongue from non-volatile substances, and smell is a product of volatile substances reaching the nose (Styger, Prior and Bauer, 2011). The flavour and aroma of wine is a direct result of a multitude of interactions between numerous chemical compounds and sensory receptors. Both synergistic (enhancing the perception of other compounds) and antagonistic (suppressing the perception of other compounds) interactions can occur. Thus, the multitude of flavour- and aroma-active compounds cause the sensory perception of wine to be highly complex. For example, the presence of sugar, polyol, salt, polyphenol, and flavonoid components account for, respectively, the floral, fruity, peppery, and woody tastes that are often described in wine (Styger, Prior and Bauer, 2011).

The complex composition of wine makes wine tasting and perception largely subjective to individual experiences. Physical and environmental aspects, such as the temperature and shape of the wine glass, can affect the perception of its aroma and flavour (Styger, Prior and Bauer, 2011). Furthermore, since individual consumers' tastes vary, and since peer consumption and marketing can also influence wine enjoyment, what defines the quality of a wine is difficult to understand (Goldstein et al., 2008). Nevertheless, it is important for winemakers and consumers alike to understand the biochemical processes that occur during a wine tasting and the extrinsic cultural factors that influence wine appreciation. As such, this review will examine the cultural history of wine, and conduct an in-depth analysis of the biochemical basis of perceiving and tasting wine, in terms of sweetness, texture, body, and fruit level. In doing so, this article will attempt to translate the language of wine tasting into scientific terminology.

THE DRINK OF THE ELITE

Wine is an interesting beverage, in that it not only appeals to the senses, but also symbolizes wealth and class (Valentin, 2001). Few other foods or drinks have been described in such detail, or their taste so thoroughly researched. Some of the earliest wine taste research dates back to 1535, from a Veronesi physician named Giovanni Confalonieri (Holt, 2006). Confalonieri published on the differences of opinion on the taste of wine: whether it was hot or cool, moist or dry. He found 'tannic' wines were 'drier' and that the location of the vineyard, its exposure to the sun, and the properties of the soil were important factors in determining flavour. Confalonieri refused, however, to make bold, general statements about all wines, deeming such an attempt futile given wine's incredible diversity. It is likely that many of today's wine tasters would agree with him (Holt, 2006). But where did wine tasting begin? Why does it have such a strong connection to class structure?

Europe in the 16th century had a Roman Catholic, largely wine-drinking culture in the south. This connection of geography, religion, and drink preference can be understood through the relationship between wine and the Catholic church. The doctrine of the Eucharist states that the wine of the Mass turns into the blood of Christ when consecrated by an ordained priest. Wine was thus considered so holy that 'common folk' were not allowed to drink it (Holt, 2006). In fact, many spaces in which wine was sold were not accessible for lower class citizens, as the powerful elite (the church, the bourgeoisie, and the nobility) made wine cheapest and attainable only to themselves (Holt, 2006; Crawford, 1977). This was done through the establishment of laws allowing the ruling class to buy wine cheaper wholesale, sold by vintners, while the poorer classes bought wine retail from taverners, when it was affordable (Crawford, 1977). For example, Henry II of England, reigning from 1154 to 1189, established the right of 'prisage', entitling the king to a certain amount of all imported wine. He could also purchase any additional wines at a reduced, fixed price. Through this, and a host of other regulations throughout history, the elite classes monopolized the market, associating wine with wealth and superiority (Crawford, 1977). As wine became easier to make with new techniques, the quantity of wine available increased, and the price became more accessible to the middle and lower classes. This removed the upper-class monopoly on wine, and it was no longer an automatic indication of wealth. Because of this, modern wine tasting may have arisen as a way for the upper class to maintain a niche market. This emphasized the importance of having expensive wine from specific regions, prized for taste characteristics (Crawford, 1977).

Wine tasting is also connected to insuring bottles have not been poisoned or gone bad, as some could turn to vinegar, or potentially dissolve a rotting cork (Loubere, 1978). The various phases of inspection used in wine tasting may have come from simply assuring oneself that the wine was fit to drink. Taverners who wanted to prove they weren't swindling their customers might also have adopted this practice. There is certainly 'initial tasting' done in restaurants today to ensure drinkability (Loubere, 1978). The more recent rituals of wine tasting could also

have been driven by the growth of high-end commercial wineries in California (Holt, 2006). By the late 1800's, California vineyards realized they had to cultivate a sense of connoisseurship to establish a sizable American market for themselves. They started aggressively promoting how 'real' vintners taste tested, and how to become a wine tasting 'expert', effectively tying their names to large European wineries (Holt, 2006).

The historical precedent for the current cultural practices surrounding wine tasting is complex. Due to the push for wine to remain sophisticated and refined, there is now an intricate means of classifying taste in wine. But, what does it mean when we say that a wine is smooth, spicy, sweet, dry or any number of other terminologies?

A SWEET NECTAR

Perhaps the most ubiquitously identifiable component of a wine's taste is its sugar content, or sweetness. In wine tasting terminology, the sweetness of a wine is described on a scale of dryness, ranging from bone dry to sweet, with off-dry, and semi-sweet in the middle. The perceived dryness and sweetness of the wine is characterized by the residual sugar, which is comprised of glucose and fructose. The residual sugar level in dry wines is 0.2-0.8 g/L of glucose and 1.2 g/L of fructose, while the residual sugar level in sweet wines is 30 g/L and 60 g/L of glucose and fructose, respectively (Stevenson, 1999).

FIGURE 2: NOBLE ROT ON RIESLING GRAPES. The rot can be seen on the grapes pictured, where some have already shriveled due to loss of water (Maack, 2005).

The high residual sugar level in sweet wines usually comes from the sugar that is not consumed by the yeast during the fermentation process (Clarke and Bakker, 2004). Therefore, to produce a sweeter wine, the fermentation process can be stopped early. Drier wines can also be sweetened with specially prepared sweetening wine. For example, Süssreserve (unfermented grape must) is used as a sweetener in various German wines.

Wine can also be sweetened using sun-dried grapes or late-harvest grapes infected with *Botrytis cinerea*, a mould which attacks grapes, causing 'noble rot' (Figure 2). *Botrytis* creates a desirable grape rot in areas near river valleys, where mist develops at night, lingers in the morning, and clears up by the sunny afternoons. The mould causes a drying effect, removing water from the grape. This results in concentrated sugars creating juice that will have a sugar content of 30-40% sugar weight per volume. The drying effect also makes the grapes less susceptible to a second invasion by bacteria and fungi. Late ripening grapes have thick skins and are also susceptible to noble rot. Riesling and Semillon are the main varieties used, but Furmit, Chenin Blanc and often Gewürztraminer are used as they are also susceptible to a 'noble rot'. When used properly, the Botrytis cinerea can create some of the most remarkable sweet wines (Clarke and Bakker, 2004).

The sweetness of wine can also influence other characteristics of the wine. For example, high levels of sugar have been associated with reduced bitterness of wine (McRae and Kennedy, 2011). Sweeter wines also tend to suppress wine acidity. In fact, when compared to other fermented drinks such as beer, the high acidity of wine is tolerable as it counterbalanced by the high residual sugar levels (Stevenson, 1999).

IT GOES DOWN SMOOTH

The sense or perception of wine after swallowing, referred to as the texture or finish of wine, is another term frequently used when assessing the taste of wine. Various chemical factors can affect the unique finish of each wine produced. The presence of tannins and polysaccharides, ethanol concentrations, and the acidity level are the greatest contributors to the finish of wine (Jones et al., 2008).

Tannins (Figure 3), a naturally occurring compound extracted from the seeds and skin of grapes, are one of the most significant factors pertaining to the mouthfeel and texture of wine (Vidal et al., 2004). Tannins interact with salivary proteins, causing the formation of tannin-protein complexes, which increase friction in the oral cavity (McRae and Kennedy, 2011). These complexes influence the astringency of wine, a tactile sensation on the palate, resulting in loss of lubrication in the mouth (Vidal et al., 2004). This can be described as a dry or rough sensation in the mouth, and is commonly associated with an undesirable wine (Vidal et al., 2004). Tannin compounds alone are structurally very stable, and thus create a grittier taste in the wine. This further influences tactile sensation and increases the astringent effect on the finish of wine. The effects of tannins on astringency levels in wine are directly correlated, and dependent on the concentration of tannin compounds in the wine. Therefore, an understanding of tannin interactions is significant in controlling the texture of wine. Methods such as micro-oxygenation or fining techniques are commonly used to control the finish and texture of wine. Micro-oxygenation adds oxygen to wine, which improves aroma while changing the structure of tannins to more structurally flexible compounds, thus reducing astringency (McRae and Kennedy, 2011).

FIGURE 3: TANNIN POWDER. A mixture of various tannic compounds, this component of wine gives it its bitterness (Eugster, 2009).

Higher ethanol levels of wine (11% – 20%) can alternatively result in a smooth texture and finish to wine (McRae and Kennedy, 2011). This is primarily due to the structural changes that result from decreased protein-tannin binding as well as changes in the solubility of protein-tannin complexes in the presence of higher ethanol concentrations. Furthermore, increased ethanol may also reduce the roughness in texture perceived, due to the onset of increased lubricity in the mouth (McRae and Kennedy, 2011).

The pH levels of wines typically range from 3.2 to 3.8 (McRae and Kennedy, 2011). The slightest change in pH can affect the astringency and therefore texture of wine. A lower pH has been shown to increase the tannin-protein association resulting in an increase in astringency of wine (McRae and Kennedy, 2011).

A SENSATION OF WEIGHT

Unlike other descriptors for wine, body is a more imprecise term, and the specific characteristics that contribute to it are difficult to define. In wine tasting, body is a function of the tactile weight or richness of the wine in the mouth (Jackson, 2009). A high amount of body makes a wine "full-bodied", and an absence of body makes a wine "watery" or "light-bodied". But what does this actually mean? What quantifiable characteristics of wine give it its body? The answer comes from the products of fermentation by yeast, and their effect on wine viscosity.

Perceived viscosity of a wine has been found to be the most significant factor influencing wine body (Runnebaum, Boulton, Powell and Heymann, 2011). One study, conducted on the properties of white wines and their composition in relation to body sensation, found that typically light-bodied wines like Sauvignon blanc were found to have lower viscosities, and full-bodied wines such as Chardonnay tended to have higher viscosities (Runnebaum et al., 2011).

The components of wine that influence viscosity are mostly produced by yeast. *Saccharomyces cerevisiae* converts the sugars in grape juice to ethanol and carbon dioxide, and produces many secondary metabolites, including various acids, alcohols, carbonyls, esters, and sulfur compounds (Pretorius, Curtin and Chambers, 2012). Ethanol is thought to have the greatest effect on perceived viscosity, and has also been found to increase other subjective mouthfeel sensations, such as intensity and harshness of taste (Demiglio and Pickering, 2008; Yanniotis, Kotseridis, Orfanidou and Petraki, 2007). A potential explanation for these effects of ethanol may be its inhibition of salivary protein binding to polyphenolic constituents of the wines (Demiglio and Pickering, 2008). Glycerol, a major by-product of yeast fermentation, has also been found to have a positive effect on the viscosity of wine, but it is generally present in a very low concentration, rendering its effect negligible (Yanniotis et al., 2007).

FIGURE 4: RED AND WHITE WINE. Red wine is generally more full-bodied, whereas white wine is lighter. However, light-bodied reds like Pinot Noirs can be lighter than full-bodied whites like Chardonnays (Public domain).

A secondary type of fermentation, malolactic fermentation, is catalyzed by the lactic acid bacterium *Leuconostoc oenos* (Versari, Parpinello and Cattaneo, 1999). Lactate, the major product of malolactic fermentation, has also been shown to increase perceived viscous mouthfeel, and is associated with viscosity and thus wine body (Runnebaum et al., 2011).

However, products of fermentative processes in wine are not the only components which influence wine body. In both red and white wine, dry extract (defined as the total content of a wine that is not water or alcohol) has been found to positively correlate with viscosity (and therefore body) (Yanniotis et al., 2007). It has been found that dry white wines have the lowest viscosity, followed by dry red wines, and finally sweet wines (red or white) with the highest viscosity (Figure 4) (Yanniotis et al., 2007). Finally, the most abundant amino acid found in grapes, proline, is unused by yeast in fermentative processes (unlike arginine, alanine, glutamate, and glutamine), and has also been positively correlated with wine body (Skogerson et al., 2009).

FRUITY AND AROMATIC WINE

When individuals refer to the fruitiness of wine, terms such as 'savoury' or 'fruit-forward' arise. These terms are more indicative of the aroma of wine rather than its actual taste. Why is it that some wines tend to be fruitier, and others herbaceous? Many important processes and compounds play a role in the aroma of wine, and work together to result in multiple different odours.

Yeast metabolism is very important when it comes to the aroma of wine, as various volatile compounds, including esters, co-exist to create complex aromas individual to each wine (Pretorius and Lambrechts, 2000). Volatile fatty acids are some of the aroma compounds that contribute greatly to the smell of the wine (Pretorius and Lambrechts, 2000; Styger et al., 2011).

Long-chain fatty acids and medium-chain fatty acids contribute to the aroma of each wine (Pretorius and Lambrechts, 2000; Swiegers et al., 2005). Long-chain fatty acids, particularly those with 16 and 18 carbon atoms (C16 and C18), are commonly found in esters and are precursors for lipids that are found in the yeast used for fermentation, including phospholipids, glycolipids, and acylglycerols (Pretorius and Lambrechts, 2000). These long-chain fatty acids, found in the yeast plasma membrane, allow for the regulation and movement of molecules into and out of yeast cells during fermentation (Pretorius and Lambrechts, 2000). Medium-chain fatty acids, such as C8, C10, and C12, are produced as intermediates during the synthesis pathway of long-chain fatty acids (Pretorius and Lambrechts, 2000). Both long-chain and medium-chain fatty acids determine the aroma of the wine (Pretorius and Lambrechts, 2000; Styger et al., 2011). For example, the presence of fatty acids such as acetic acid, propionic acid, butyric acid, and valeric acid result in an unpleasant, pungent smell; tridecanoic acid and decanoic acid give a citrus smell; while acids such as hexanoic acid and isovaleric acid give almost a cheesy aroma to wine (refer to table 1; Pretorius and Lambrechts, 2000).

Along with fatty acids, higher alcohols, known as fusel alcohols, also affect the aroma of wine (Swiegers et al., 2005). Higher alcohols consist of alcohols at a higher boiling point and molecular weight than ethanol, and these give wine an unpleasant, pungent smell when present between the concentrations of 300-400 mg/L (Pretorius and Lambrechts, 2000). Amino acids found in the grape juice, most commonly valine, leucine, and isoleucine, greatly influence the yield of higher alcohol formation (Styger et al., 2011). The

concentrations of these high alcohols in wine are dependent on the presence of the aforementioned amino acids, therefore affecting the intensity of unpleasant aromas of the wine (Pretorius and Lambrechts, 2000; Styger et al., 2011).

Unlike fatty acids and fusel alcohols, esters are volatile compounds that give a pleasant aroma to wine (Lilly et al., 2000; Pretorius and Lambrechts, 2000). The mixture of esters produced during fermentation gives a fruity, floral aroma to wine, where the most prominent are acetate esters, which are classified as fermentation compounds (Lilly et al., 2000; Pretorius and Lambrechts, 2000). Table 1 shows some of the aromatic acetate esters formed during fermentation that produce various smells, from different fruits, to honey and flowery aromas (Pretorius and Lambrechts, 2000). Carbonyl aldehydes, specifically volatile aldehydes, are also important compounds in the production of higher alcohols from amino acids (Liu and Pilone, 2000). These aldehydes, when interacting with keto-acids, also contribute a fruity aroma to wine that varies from fruit-forward, to herbaceous and coffee-like (refer to Table 1; Liu and Pilone, 2000).

Not all compounds affecting aroma are produced during yeast fermentation. Some wines tend to undergo malolactic fermentation, as previously mentioned (Styger et al., 2011). Since many malolactic fermentation steps occur within oak barrels (Figure 5), the lactic acid bacteria that is involved in this process chemically reacts with the oak and produces oak-derived compounds (Styger et al., 2011). These compounds give off a vanilla aroma as lactic acid bacteria modify a vanillin precursor within the oak barrels, releasing vanillin into the wine (Styger et al., 2011).

FIGURE 5: OAK BARRELS. Wine undergoes further malolactic fermentation in oak barrels, pictured here in the cellar of Jackson Triggs Winery (Raisa Ahmed, 2016)

The aroma of wine is affected by many factors, including the types of fermentation, as well as which metabolic compounds are found in the grape juice and used in the fermentative process. However, the aroma of wine is also more dynamic than it is static, as the ageing of wine and its means of storage could result in an altered taste in the designated wine (Styger et al., 2011). As such, the aroma of wine is a result of complex interactions between many volatile compounds, and gives specific wines their fruit profile.

TABLE 1: VARIOUS COMPOUNDS AND THEIR SIGNIFICANCE TO WINE AROMA. (Pretorius and Lambrechts, 2000).

Classification of Compound	Compound	Odour
Fatty Acids	Acetic Acid	Vinegar, pungent
	Hexonic acid	Sour, vinegar, cheese, sweaty, rancid, fatty, pungent
	Octanic acid	Oily, soapy, sweet, faint fruity, butter
	Tridecanoic acid	Fatty, citrus, unpleasant
Higher Alcohols	Tyrosol	Bees wax, honey-like
	Phenethyl alcohol	Floral, rose
Esters	Ethyl acetate	Varnish, nail polish, fruity
	Isoamyl acetate	Banana, pear
	2-Phenethyl acetate	Rose, honey, fruity, flowery
Aldehydes	Isobutanal	Slightly apple like
	Pentanal	Cocoa, coffee-like, slightly fruity
	Isovaleraldehyde	Warm, herbaceous, slightly fruity, nut-like

THE NIAGARAN TERROIR

Over the past centuries, the Niagara Peninsula has rapidly grown into the New World Wine Route, an area where the favourable microclimate and proximity to the Niagara Falls has led to the development of one of Ontario's major tourist destinations (Hakimi, Rezaei, and Reynolds, 2010). The unique environmental aspects of the Niagara region vastly influence the characteristics and quality of the wines produced there. In fact, the Niagara region is known to be the Fruit Belt of Canada due to its adequate temperature and soil types to produce high quality wine and fruit (Telfer, 2000). Due to this ideal location, irrigation in the Niagara region tends to increase the acidity of must in the process of producing wine, which increases the overall quality of these wines (Reynolds, Lowrey, and De Savigny, 2005). Nutrient uptake, a factor associated with the quality of wine, is highly efficient in these wineries as the Niagara Peninsula provides ideal conditions for transpiration, metabolic activity and warming temperatures (Reynolds, Lowrey, and De Savigny, 2005).

Wines produced in the Niagara river and lakeshore area are identified to have a higher green bean and bell pepper aroma, due to the cool temperatures associated with the presence of large water bodies nearby, an environmental influence referred to as Buis (Rezaei et al., 2010). Studies conducted in the Niagara Peninsula have further identified increased red fruit, black currant, black cherry and black pepper aromas, specifically in the Henry of Pelham and Château de Charmes sites. Similarly, this is due to a close proximity to Lake Ontario. Overall, the various aspects of each wine produced, the hue, colour intensity, and ethanol content vary from site to site as the chemical and sensory components of wine are affected by a vineyard's proximity to large bodies of water and growing conditions (Rezaei et al., 2010).

CONCLUSION

From historical wine to wine in modern society, it is fascinating to see how wine tasting has changed throughout the years and how the focus has shifted from the taste of a wine to the reasoning behind its taste. Factors ranging from wine texture, to sweetness, to its aroma and body profile, all work together to produce their own unique taste for every individual wine. However, despite attempts by the scientific community to chemically analyze wine components, the quality of a wine will always be defined by each individual's tastes. The interaction between the various components of wine and the outcome of this interaction is such a delicate, intricate process that it should not be considered just a science, but also an art.

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