Packaging Type and Wine

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This is a mini-review that looks at how different types of packaging can impact the sensory characteristics of wine. This mini-review compared glass bottles, polyethylene terephthalate (PET), Bag-in-box (BIB), aluminum cans, and Terta Pak. Some of the most common packaging types used by the wine industry at the moment. This mini-review looked at the history of wine packaging, the impact packaging type has on the flavor profile of wine, and consumers attitudes towards the different types of packaging. While glass is still the dominate packaging material within the wine industry and by consumer demand however, economic and environmental concerns are driving the industry and consumers to investigate and adopt alternative packaging materials.

Keywords: wine packaging ; flavor ; sustainability ; wine bottles

1. Introduction

Since the Neolithic era, humans have utilized the fermentation process as a means of extending the shelf life, increase the safety, as well as produce desirable flavors for foods and beverages [1][2]. Beer and wine have been around for tens of thousands of years. The discovery of wine is likely to have only been by accident when damaged grapes spontaneously fermented within a storage vessel. Farmers tried it and enjoyed the taste of the fermented product compared to the unfermented. The rest is history as they say [1]. Wine production is one of the oldest economic sectors in the world and presently is one of the most profitable agricultural products today [3][4]. The wine industry plays an important role in the global economy in terms of production and distribution [5]. In 2018, the International Organization of Vine and Wine (OIV) estimated that 292 million hectoliters of wine were produced worldwide. The international wine trade is estimated to be worth USD 36 billion (29.5 Euro) [6].

Wine packaging has drastically changed over the years from clay amphorae to single serving plastic bottles. The belief that only premium wine can be packaged in glass bottles with a natural cork has slowly been changing over the years [7] [8]. Despite glass being an inert material, most consumers are not aging wine longer than a few months thus opening up the wine industry for alternative packaging [9]. As the industry adopts alternative packaging options, it is accepting the potential that the product packaging can have an impact on the consumer experience. The purpose of this literature review is to look how packaging type impacts wine flavor stability and flavor.

History of Wine Packaging

Several thousand years prior to the rise of the Roman Empire, winemakers from Mesopotamia and Egypt would store their wine in amphorae, clay flasks. These vessels played an important role in regard to the Ancient Greece and Roman's trading success, in that amphorae served in a similar manner to our modern-day shipping containers. Amphorae were used for far more than just storing wine but were used to store and transport oil, processed food items of the day, and household supplies. The markings on the outside of the container would indicate to the buyer what type of product was found within, which led them to be given the nickname "silent salesmen" [10]. Amphoras were also designed with temper evidence closures to prove to the consumer "truth in packaging" [11].

The first glass vessel was not produced until 1600 B.C.E. in Mesopotamia; however, these vessels were so delicate and too expensive for mass production. In 250 B.C.E. during the Babylonia Empire, glass became easier to produce but was still outside the realm for wine storage. It was not until the rise of the Roman Empire that glass products became more widely accessible to the common people [12][13]. It did not take long before people began to realize that glass is a great way to store wine, easily allowing long term storage in the bottle, and because of the inert properties of glass, there are no negative effects on the flavor of the wine. Glass bottle production remained relatively the same from the time of the Roman Empire until the 19th century when glass bottles were being produced by glass blowers [14]. These bottles were hand blown and would range in size, shape, and quality based upon the glass maker. Bottles could range anywhere from 700 to 800 mL. Due to the inconsistency in the size of the bottles, consumers were never truly aware of how much they

were purchasing. It was not until the mid-19th century that glass blowing technology began to keep up to demand and provide a consistent size and shape as mass-produced product. The split mold process, developed in 1821, is what ultimately took glass manufacturing to the next level and quickly resulted in the decline of glass blowing. The split mold process allows for a number of different shapes to be mass produced utilizing a mold. For the production of consistent shapes and sizes, paper labels could be added to bottles. Semi-automation started taking place in 1887 by the Ashley Glass Company in Castleford, Yorkshire, in the United Kingdom. The semi-automated split mold process allowed the Ashely Glass Company to increase their production to over 200 bottles an hour, which was revolutionary at the time. It would take another 16 or so years, before glass manufacturing became fully automated in a process developed by American engineer named Michael Owens [8]. This highly efficient manufacturing has allowed a number of wine bottle styles to be developed and are named after the region or wine style for which they are primarily manufactured, such as Bordeaux, Burgundy, and the German Riesling [15][16].

2. Sensory and Flavor

Wine like other fermented beverages is a complex product. Wine is primarily composed of water (80–85%), alcohols (ethanol being the major one 9–15%), and a variety of other minor components (3%) [17]. Minor components include organic acids, sugars, phenols, nitrogenous compounds, enzymes, vitamins, lipids, inorganic anions and cations, and other volatile compounds (esters, ketones, fusel alcohols, etc.) [18]. Wine flavor is a complex mixture of volatile compounds (alcohols–lower and fusel, esters, organic acids, aldehydes, phenols, lactones, sulfur containing compounds, methoxypyrazines, norisoprenoids, ketones, and terpenes) and a delicate balance of sweet (sugars), sour (organic acids), and bitterness/astringent (polyphenols) [7][18][19]. The flavor and aroma of the wine depends on the grape varietal(s) used, growing conditions (soil type, climate), and wine making practices (processing techniques, yeast strain, fermentation conditions) [20] wine aging, storage conditions among others [20]. Therefore, the consumer experience can be greatly affected by the packaging, transport, and storage conditions.

Wine aging can be divided into two phases: maturation (between fermentation and bottling) and bottling (aging within the bottle). During the aging process, the wine's composition is altered through a number of complex chemical reactions, and some chemical classes such as phenolics (anthocyanins, flavan-3-ols, flavonols, hydroxycinnamic acid) and volatile organic compounds (esters, fusel alcohols, aldehydes, ketones, acids, etc.) can result in noticeable changes to the sensory and physical characteristics of final product [21].

Micro-oxygenation of red wines during the aging process is acceptable at least to some extent to help improve the quality of the wine by removing unwanted aromas, color stabilization, and improvement in the mouth feel [22]. Oxidation is one parameter that can affect the shelf-life of a table wine. Oxidation of the wine depends on several factors: the wine's ability to resist oxidation and the level of exposure to oxygen. Oxidation can produce significant organoleptic changes in the color, aroma (less of freshness), and degradation of anthocyanins and can cause the wine to appear brown due to precipitates of condensed phenolic material [23][24][25][26], which is why it is important to monitor and manage the amount of oxygen that comes into contact with the wine during manufacturing, storage, and packaging [27][28].

One of the primary parameters that affect wine through the aging process is the transfer of gases through the packaging materials [28], hence why the type of packaging will have a considerable impact on the extent of wine oxidation and the loss of other sensory properties [26].

2.1. Sensory and Flavor of Wine from Glass

The packaging of wine is a material intensive process with bag-in-box, glass, and PET bottles [29]. Glass containers are traditionally utilized as the control when it comes to accelerated shelf-life studies for wine. Glass has a high impermeability to gases and vapors and stability over time. It is also preferred over other materials due to its historical use and transparency and to being easily recyclable [28]. Ghidossi et al. 2012 analyzed the impact different packaging (glass, monolayer PET (0.3 mm thickness), Multi-layer PET (0.4 thickness), and BIB) types have on the physical and chemical properties of white and red wine over an eighteen-month period [30]. Although there were clear differences at 6 and 18 months regarding the chemical and physical analysis of the white wine, it was apparent that the glass bottles were superior in terms of limiting gas transfer (O_2, CO_2), maintaining SO_2 content, and protecting color intensity and sauvignon character for white wine in comparison to the other packaging types. Glass was found to be superior to the other packaging designs in that it had the lowest concentration of oxidative flavor markers phenylacetaldehyde [31], methional [32], and sotolon [26][31] all of which were below their perception threshold levels [30].

Moreria et al. 2018 analyzed the sensory and volatile composition of white wines under different packaging conditions for a twelve-month period. Wines packaged in glass had significantly higher concentrations of 2-phenylethanol, 2-phenylethyl acetate, isoamyl acetate, ethyl butanoate, and ethyl hexanoate than BIB [33]. Similar results were observed by Mentana et al. when comparing glass to traditional PET bottles. Flavor compounds were better protected from oxidation and flavor deterioration in the glass bottle vs. PET. This was particularly evident for white wine [28].

2.2. Bag-in-Box

A major downside of this packaging type is that the polyolefinic (polyethylene, polypropylene) film comes in contact with the wine. Polyolefinic films have a strong capacity to absorb the volatile and semi-volatile compounds from the wine resulting in flavor deterioration. The film used for this type of packaging has a sorption rate for non-polar compounds due to the hydrophobic nature of the polyolefins [34]. Revi et al. 2014, conducted a study comparing the impact wines packaged in bag-in-box (low density polyethylene–LDPE and ethylene vinyl acetate–EVA) vs. traditional glass had on the enological parameters as well as the volatile and semi-volatile compounds over a six-month period. It was concluded that the packaging design did have an impact on the wine at the end of the six-month time period. Wine deterioration was most pronounced when stored in the bag-in-box pouches due to the sorption of flavor compounds into the polymeric packaging material. However, between the different types of pouches used the LDPE lined pouched had the highest potential for flavor sorption. It should be noted that when comparing sensory acceptability, consumers felt that after 90 days, the wine was unacceptable [7]. Moreira et al. 2016 found similar results as well with their study looking at the influence wine packaging and aging had on the volatile and sensory attributes of red wine [7][26]. Due to the higher permeability of the bag-in-box design, wine should be consumed rather quickly and not aged.

Moreria et al. 2018 repeated their original packaging experiment using white wine in lieu of red [33]. Moreria et al. (2018) found similar results to their original experiment in which wine packaging design does have a major impact on the chemical and sensory properties of wine. Bag-in-box in comparison to glass for white wines had the highest levels of oxidized aromas and a significant decrease in aromatic (2-phenylethanol, 2-phenylethyl acetate, isoamyl acetate, ethyl butanoate, ethyl hexanoate) compounds [33].

2.3. Sensory and Flavor of Wine from Aluminum Cans

Within canned beverages, there is a greater concern for sensory/flavor deterioration caused by degradation, scalping, or tainting than microbial spoilage [33].

Degradation is a chemical process that happens throughout the life span of the product ultimately resulting in the products loss of quality. Oxidative deterioration is one of the biggest causes of flavor degradation in wine. To slow down oxidative deterioration, wine makers add between 20–40 mg/L of free sulfur dioxide (SO_2) to their packaged wine. Oxidative aromas, colors, and other signs of deterioration start to become apparent when free SO_2 levels are below 10 mg/L [35].

Scalping occurs when VOCs migrate from the food product or beverage into the packaging material. Non-polar flavor and aroma compounds are affected the most because they have the capacity to be absorbed into the non-polar polymer packaging materials. Scalping has not been studied in canned wine products and leaves an area for future research. Scalping has been thoroughly studied in beer, strictly focusing on the aroma active non-polar hop compounds like limonene. Although, limonene is found in wine below detectable threshold levels, 1,1,6-trimethyldihydronaphthalene (TDN), rotundone, and 2,4,6-trichloroanisole (TCA aka “cork taint”) are potential compounds that could be scalped by the can’s lining during storage [35].

Tainting refers to introduction of off-flavors into the food or beverage products from packaging material. The most well-known example of tainting pertaining to wines is cork taint; however, it does not affect canned wines. Taint that is more likely to happen within canned products is the interaction between the impurities found on the can lining and the food product, resulting in off-flavor in the product [22]. These types of reactions are called “secondary taint”, which can be much more difficult to predict and might be overlooked during simple model testing [35].

One issue associated with canned wine is the development of hydrogen sulfide (H_2S: rotten egg smell) after several months of storage. This issue has also been reported in canned hard ciders as well [35]. Hydrogen sulfide has a sensory threshold level of 1 ug/L (1 ppb) in wine, and oftentimes, this compound is a byproduct of yeast metabolism during the fermentation process [22]. Although the identification of hydrogen sulfide has not occurred in the literature pertaining to canned wines, it has occurred in multiple patents [36][37] as well as at conference proceedings. The issue is no one knows if their product will be affected. Some cans experience no detectable limits of hydrogen sulfide after a year of storage while others develop within a couple of months.

In recent blind tastings, more than a dozen canned wines scored between 85–90 points (Very good) on the Wine Spectator's 100-point scale [38].

2.4. Sensory and Flavor of Wine from Polyethylene Terephthalate (PET)

Mentana et al. 2009 conducted a study looking at the chemical and physical changes of Apulia table wine packaged in two different types of PET bottles (PET and Oxygen scavenging PET (OxSC-PET). The study looked at white and red wine over a six-month period. The flavor and aroma profile for red wines was analyzed following the completion of the storage period. The study concluded that there was a significant loss in a number of organic compounds including alcohols, acids, and esters for wines stored in PET bottles. Mentana et al. reported the loss of a number of these compounds to scalping by the PET bottle. However, OxSc-PET showed flavor scalping to a lesser extent than the regular PET bottle [28].

Ghidossi et al. 2012 analyzed the impact different packaging (glass, monolayer PET (0.3 mm thickness), Multi-layer PET (0.4 thickness), and BIB) types have on the physical and chemical properties of white and red wine over an eighteen-month period. Results from this study showed that PET bottles primarily the PET-monolayer had the highest degree of oxidation especially in the white wine [30]. Phenylacetaldehyde [31], methional [32], and sotolon [31][32] are three well known compounds associated with oxidation of white wine during storage. Ghidossi (2012) during their study showed that the PET monolayer (185 and 750 mL) bottles had increased concentrations of all three compounds due to increased oxygen levels found within the package over the eighteen-month period. All three compounds, phenylacetaldehyde, methional, and sotolon, had concentrations above their perception threshold levels 2 ug/L, 25 ug/L, and 2 ug/L. The presence of these compounds clearly impacts the overall flavor profile of white wine [30]. It is relatively common for the flavor compounds of white wines to age rapidly and develop sensory defects. Conversely, this study found no sensory differences within the red wine for the different packaging types over the eighteen-month study period.

3. Attitudes toward Purchasing Alternative Wine Packaging Designs

There has been a significant increase in the consumption of wine in the past several decades. Annual consumption for wine in the United States is roughly around 13.4 L (2.95 gals). The increase in consumption is a direct result of the number of wineries that have opened, wine brands, labels, bottle shapes and colors, style of closures, and regional designations [39]. Since 2009, there has been a 50% increase in the total number of wineries in the United States, with each state having at least one winery. The total number of wineries within the United States is approximately 11,053 [40]. The majority of legal drinking adults in the United States say they prefer beer (36%) over wine (30%) and distilled spirts (29%) based on a 2020 survey [41].

Purchasing a bottle of wine can oftentimes be a very difficult process for most consumers. Particularly since the quality of the product cannot be accessed until after consumption. The marketing of a wine package consists of several cues (bottles shapes, color, closure, and label design), which all interface with the consumers experience, knowledge about wine, and self-confidence, and the occasion and/or reason for purchasing wine will influence purchasing decisions [42]. Experienced wine consumers who know what they want will purchase wine based on past experiences and packaging cues, while inexperienced buyers will place more emphasis on the information obtained by reading the wine label [43]. Barber and Almanza (2007) conducted a study to look at how influential the wine packaging was on purchasing intent. It was determined that wine package had a greater influence on the purchasing intent for the consumer than other marketing cues [43].

As consumers become more aware of how their actions impact the environment around them, consumers are starting to make more environmental conscious decisions regarding their everyday lives [44]. As the wine industry becomes more and more competitive, global marketers are having to find ways to separate themselves from their competitors. Nevertheless, with the choices of wines numbering into the thousands, selecting a particular wine comes down to how the wine is perceived and brand success. Wine promoters who are more environmentally conscious are trying to provide more information to consumers to help increase their knowledge and change their attitudes in the hope of them purchasing more environment friendly wines [45][46][47]. A possible way of attracting environmentally conscious consumers who are interested in protecting the environment and reducing their ecological footprint would be to utilize selective marketing techniques geared toward these individuals [48][49].

Wineries large and small are trying to implement sustainable viticulture and winemaking practices to lessen their impact on the environment [50]. Barber (2012) found that environmentally conscious consumers were more willing to pay more for environmentally friendly wines [50]. Ferrara et al. 2020 conducted a study to look at people's willingness to purchase alternative packaging types for wine, and 91% of respondents were not willing to consider other packaging alternatives

mainly due to their view of them being inferior to glass [51]. Although Barber (2012) found consumers were willing to pay more for environmentally friendly wines, it does not necessarily translate into actual purchasing of those products [42].

4. Conclusions

The question comes down to whether bottles are outdated. Nowadays, with so many different types of packaging (BIB, PET, OxSC-PET, cans, TetraPak®, glass) and closure (screw cap, natural and synthetic corks) options available, winemakers and producers are able to select the type of packaging that will best fit their needs and allow them to stand out in a competitive market. Glass is still one of the most commonly used packaging types for wine worldwide and will likely never go away. Wine like other fermented beverages is a complex product, composed of a number of different chemical classes of volatile and semi-volatile compounds that are continuously changing throughout the maturation and storage life span of the product. However, a number of studies have looked at the impact wine packaging type has on the chemical and sensory attributes during the aging process of wine. It has been confirmed by numerous studies that glass is still superior to other packaging types despite its environmental impact.

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