Organic winemaking and its subsets

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The wine industry has evolved over time, and more so recently, to encompass many different subsets, one of which is the organic wine market. The organic wine industry has grown in recent years, especially in California. This rapid gain in interest has resulted in the evolution of several subsets, including biodynamic, natural, and clean wine. While biody-namic and natural wine, function more as a fulfillment of niche markets, clean wine may provide benefits for consumers that otherwise suffer from side effects of wine consumption. Low sulfite levels and lack of histamines in clean wine plausibly decrease headaches and adverse effects some consumers experience when drinking wine.

Keywords: oenos ; organic wine ; clean wine ; biodynamic wine

1. Introduction

Organic winemaking as a concept has existed since the inception of organic farming, but unlike organic fruit and vegetable farming, it has struggled to gain market popularity and raise consumer awareness. Interestingly, it has not been until recently (2010s) that there has even been an organic wine market in the US. There are a variety of reasons for such delay, including a gradually increasing demand for artisan-made wines and a consumer base who wanted transparency in winemaking, with few to no added chemicals and maximum authenticity in the process [1]. In fact, in 2019, US sales of organic wine reached $80 million, a 28% increase since 2004 (https://www.organicconsumers.org/news/organic-wine-booming-across-us). While the market is still relatively small in terms of clientele and sales, it is growing as new types and branches of the organic wine industry develop [2].

Consumer perception of organic wine continues to shift, as the market continues to change, and it becomes important to evaluate these ever-shifting views. In a 2019 study investigating the willingness to pay (WTP) more for organic wine, 500 Italian wine consumers were randomly surveyed. Characteristics regarding general wine consumption, organic wine consumption patterns, intrinsic and extrinsic characteristics of organic wine purchase, WTP, and sociodemographic characteristics were all collected. In total, 57% of participants were male, while 20% of participants were 18–35 years old, 41% 36–50, 33% were between 51–65, and the remanding 5% were over 66. Overall, 73.2% of consumers reported an unwillingness to pay more, but this was determined to be due to a lack of means to do so, not because of a lack of interest or persuasion. Of participants who did have the means to pay a higher price, 13.2% reported being willing to pay 20% more. Therefore, if an organic winemaker wanted to market their wine as “premium”, the most ideal pricing would be 20% more than a standard, nonorganic bottle of wine. Participants also reported the increased WTP due to environmental concerns and the distinctness of organic wine, illustrating increased interest in sustainability that consumers now hold [3]. This constitutes an example of the shifting market—at its inception, while organic farming was heavily focused on generating a “better-for-you” product, over time, interest has seemed to be shifting to also include more sustainable practices and environmental concerns, generating new subsets of organic wine (Figure 1). However, the sector can be clouded by lack of definition and standardized regulation.

Figure 1. Illustration of the classification and flow of organic wine. Note: Natural wine is frequently implicated with biodynamic wine, but the two can be exclusive. This relationship is illustrated by the dashed line.

2. Food Safety and Winemaking

The Food Safety Modernization Act (FSMA) was created in 2011 out of a drive to increase precautions and ensure food safety in the United States, and it was the first significant piece of legislation to address food safety since 1938 [4]. It has become the standard for all food processing across the United States, aiming to ensure quality and safety in food products, including wine. Wine has been long regarded for its history of safety and lack of bacteria due to fermentation, but is still included in FSMA [5]. FSMA states that every winery will be visited at least once within the first seven years of its enactment, and then regularly thereafter [6]. Wineries that generate <$500,000/year with at least 51% of income from food sale direct to consumers or local retailers, or wineries that qualify as a “very small business” are required to maintain systematic records to ensure proper practices and notify the Food and Drug Administration (FDA) of compliance with regulations. All other wineries must comply with a formalized education and training program for employees; proper recording of current good manufacturing practices, sanitary facilities, and controls; and must record each ingredient used in each wine [7][8]. No nutrition or ingredient labeling is currently required, although that cannot be excluded in the future.

There has been some concern regarding safety in organic wine, especially considering the ban on pesticides and the potential introduction of foodborne illness caused by animal exposure in outdoor conditions [9]. However, it has been supported that safety is, in fact, greater in organic foods as related to metabolic and long-term health parameters, due to lower nitrogen applications, the ban on pesticides, and the ban on prophylactics, all of which may decrease cancer risk in consumers [9]. While there is still potential for exposure to foodborne pathogens, risks can be mitigated through increased safety measures during processing to ensure high quality, thus minimizing actual food safety risk [9].

Ochratoxin A (OTA) poses a significant risk in winemaking due to its nephrotoxic, mutagenic, and teratogenic effects at high concentrations [10]. Gentile et al. investigated OTA presence in organic wine, a toxin that, when present in high concentrations, can produce nephrotoxic, mutagenic, and teratogenic effects. Fifty-five different wine samples (n = 40 red, n = 15 white) during two vintages were assessed, and toxin detection was done using ultra performance liquid chromatography (UPLC). OTA presence is allowed in wine at a maximum concentration of 2 ng/mL. It was found that the red wine samples had a higher presence of OTA than white, but all samples had an OTA level below 1.0 ng/mL. In total, 53.3% of the white wine samples contained OTA levels below the limit of quantification, and all samples demonstrated OTA levels below 0.1 ng/mL [10]. When compared to commercial wines, it was observed that organic winemaking does not increase OTA incidence [10].

It constitutes standard practice for wineries to select pure yeast strains in order to control fermentation more effectively and ensure quality [11]. Prior to fermentation, bacteria are present, but as fermentation enters its final stages, most bacteria are killed-off due to the alcohol content rising levels and the low pH value. Therefore, regardless of wine production type (organic versus nonorganic), it is the fermentation step that is vital to ensuring safety in the final product, thus rendering both organic and nonorganic wines similar in terms of food safety for the consumer[11].

3. Wine Microbiology and Chemistry

Wine microbiology and wine chemistry are crucial components to winemaking, and extra attention to these characteristics is typically placed in organic winemaking, making them vital to ensure high quality and a unique product. While organic wine is relatively similar biologically to conventional wine, there are some key differences distinguishing the two, such as yeast presence and chemical composition, thus somewhat differentiating the microbiology and chemistry of organic wines compared to conventional ones.

Perhaps the biggest difference between organic and conventional wines are the yeast strains typically present in each. This difference in the demography of yeast can then affect sensory attributes after fermentation, potentially creating a distinct difference between organic and conventional wine. Xu et al. investigated yeast succession during spontaneous fermentation of grapes from both conventional and organic vineyards. Wine was fermented using standard fermentation practices and yeast was identified using high-throughput sequencing. A group of 18 total yeast genera and 36 species of yeast were identified, with *Saccharomyces*, *Hanseniaspora*, and *Ascomycota* being the most abundant. Overall, organic grapes exhibited higher occurrence of *Saccharomyces*, which dominated during fermentation. The overall diversity of organic wine decreased more dramatically during fermentation than conventional wine as well. Sensory analysis was also conducted, with conventional wines presenting more acidity and sweetness, whereas organic wines scored better in terms of clarity, alcohol, and fruitiness, as assessed by the panel. The organic wine was also determined to have a mellower mouthfeel. The differences in flavor and the aroma are attributed to the yeast strain and understanding the diversity of yeast in organic wine may constitute a predictor for quality and overall flavor, while also informing the aroma and the bouquet of the wine [12].

Spontaneous fermentation typically utilizes non-*Saccharomyces* yeasts for ethanol production, which results in higher yeast diversity, increased aroma, and significant and clearly noticeable differences in flavor profile compared to conventional wine [13]. Some non-*Saccharomyces* yeasts are described often as “killer” yeasts, with the ability to inhibit spoilage yeasts. Combined use of these (“killer”) yeasts can result in optimal flavor profiles with decreased risk for spoilage. Benito et al. investigated the concept while they fermented Tempranillo grapes with a culture of *Schizosaccharomyces pombe* and *Lachancea thermotolerans* to undergo malolactic fermentation. Typical malolactic fermentation can result in off-flavors and other quality issues. However, through the approach the researchers employed, *Schizosaccharomyces pombe* stabilized the wine, as it evidently consumed all malic acid initially present. *Lachancea* *thermotolerans* then produced lactic acid, finalizing the process. As a result, risk of quality issues related to type of yeast was diminished, and the wines produced demonstrated lower levels of acetic acid and biogenic amines. While this set of experiments addressed merely one use of "killer" yeasts, it does hint towards opportunity in the wine industry to improve wine quality through yeast strain selection [14]. Both organic and conventional winemaking can utilize spontaneous fermentation, but as illustrated in the previous study , organic wine made through this process can also result in higher yeast diversity. This can effectively create an opportunity in the organic wine market to utilize these yeasts, as the wine may be significantly better equipped to handle these yeasts during fermentation.

In a separate set of experiments, Setati et al. utilized the theory of sampling to sample grapes from three adjacent vineyards in South Africa for a better understanding of the vineyard microbiome. The three vineyards differed regarding their agricultural practices, while they were also under different management. Out of the three vineyards used, one was conventional, the second biodynamic, and the third integrated in terms of production practices. Integrated production can be defined as an agricultural approach that is more environmentally friendly, but is not regulated by a particular system or certification body. The authors reported that the total yeast population was higher in both the biodynamic and conventional vineyard than the integrated, and total population ranged between 4–8 × 104 CFU/g for all vineyards. The biodynamic vineyard displayed the most unique biodiversity, with the identification of several yeasts identified as responsible for biocontrol. All three vineyards exhibited high levels of oxidative yeasts; however, these yeasts cannot survive in winemaking, and therefore do not affect quality ultimately. While the biodynamic vineyard did demonstrate the most species richness, vineyards are subject to fluctuation, which may be responsible for the differences in intra-vineyard wine quality. However, vineyard mapping is still of importance, especially when considering biodynamic wine, in order to gain a better and a more inclusive understanding of the vineyard footprint, while also to better comprehend how growing conditions may impact wine flavors [15].

Organic and conventional wines have also indicated differences in the chemical composition level. Polyphenol oxidase (PPO) contributes to browning and is present in grapes. The PPO levels in organic and conventional grapes were assessed, with grapes from three sections of each vineyard [15]. It was found that PPO activity in the organic grapes was twice that of conventional, which could be a result in changes in the phenolic metabolism when grown with or without synthetic chemical pesticides. The high PPO activity may also contribute to disease resistance, as PPO allows for the rapid oxidation of phenols to quinines, effectively inhibiting polygalacturonase, an enzyme responsible for the degradation of the cell wall [16]. A brief summary of the various characteristics is provided on Table 1.

Table 1. Summary of chemical and microbial characteristics in conventional vs. organic wine. Strength of differences is illustrated by +/-, i.e., one + demonstrates a probable difference, whereas 2 demonstrates a stronger difference.

Wine Type	**Biodiversity**	**Yeast Strains**	**PPO Presence**	**Sensory Attributes**	**Disease Resistance**	**References**
Conventional	− −	*Hanseniaspora*	− −	Acidic, sweeter	−	12–18
Organic	+ +	*Saccharomyces*	+ +	Mellow mouthfeel, increased clarity, increased fruitiness	+	12–18

Mulero et al. investigated antioxidant activity and phenolic compound presence in organic red wine using three different vinification processes. *Monastrell* grapes were used, all of which were grown organically. Grapes underwent either vinification after prolonged maceration (21 days), vinification with the addition of enological enzymes, or traditional vinification procedures (10-day maceration). Additionally, 70 mg/kg of SO2 was added. Total phenolic compounds and antioxidant activity were then measured. It was found there was no significant difference in antioxidant activity among the three vinification processes. The average total phenolic compounds in wines made with the addition of enzymes was not significantly different than those made with traditional methods. Total phenolic compounds were initially higher in wines with a prolonged maceration time but decreased after three months of storage. Overall, there was no significant difference between the three processes and phenolic compound concentration. While all three of these processes utilized the same organically grown grapes, the results are still of interest. It is likely that the grapes themselves contribute to phenolic compound concentration, not necessarily the growing practices [17].

Vilanova et al. studied aromatic compound presence in three red cultivars—Caiño Tinto, Caiño Longo, and Caiño Bravo. Two vintages were studied (2002 and 2003). Grapes were crushed by hand and allowed to undergo spontaneous fermentation for 14 days. It was not mentioned whether grapes were organically or conventionally grown. Alcohol, ester, and acetate presence was determined by gas chromatography. 3-methyl-butanol was the most common alcohol, though the concertation for the three cultivars varied significantly. In 2002, Caño Bravo produced the highest concentration of higher alcohols, whereas in 2003, Caño Tinto produced the highest. Ester and acetate contents were significantly different among the wines as well, with the majority of esters being found in the Caño Longo wines. Ethyl acetate was the most commonly seen ester. Overall, the 2002 vintage was more similar across the three cultivars than the 2003 vintage [18]. This again illustrates that it is more likely the grape, rather than the growing practice, that contributes to flavor and chemical makeup of the wine.

It is also worth noting that there is a knowledge gap in terms of chemical makeup of organic versus conventional wine, with research focusing on just one of the two. This may be due to the likelihood that the grape is the major contributor to differences, but may be worth further investigation

It becomes evident that organic wine significantly differs from conventional wine biologically. However, there is also variation within the subset. Parpinello et al. compared Sangiovese wines from organic and biodynamic vineyards, looking at both the differences in chemical composition and sensory differences. Grapes from two consecutive vintages (2011 and 2012) from both organic and biodynamic vineyards were harvested, and wine was made following European Union regulations (European Food Safety Authority, EFSA). Result sets of chemical analyses were then compared to one another, as well as to those obtained from a previous study that investigated the chemical analysis of Sangiovese wines in a vineyard that was converted from organic to biodynamic viticulture (2009 and 2010 vintages) [19]. Both the 2011 and 2012 vintages behaved similarly, with no significant difference in color intensity and total polyphenols. When compared to the previous vintages however, the 2011 and 2012 vintages showed significantly decreased differences in volatile components. In terms of sensory conditions, the 2011 biodynamic vintage was reported to be fruitier, whereas acid was higher in the organic wine. Consumers did not show a clear preference for one wine over the other. It was thus evident that transition from organic to biodynamic farming may cause changes in chemical and sensory attributes during transition, but these quickly return to pretransition attributes. It also became evident from the study of Parpinello et al. that no major chemical differences were observed when comparing biodynamic to organic wines. However, it is important to note that only one wine grape was studied, and results are not inclusive of every type of biodynamic winery [20].

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