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Chemical Change and Quality Control in Winemaking

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Abstract: Wine is an alcoholic beverage made from grapes that are greatly consumed in the modern society. Winemaking also known as vinification, is a process of converting fruit juice, in particular those from grapes into wine through the process called fermentation. The winemaking process involved many chemical changes, such as alcoholic fermentation, and malolactic fermentation (MLF). Microbiota which is used in the winemaking has great impact on the quality of wine, additionally, may cause negative attributes to some type of wines. Therefore, the modern wine industry tries its best to pay more attention to some critical quality control points to avoid off-flavors, and aim to produce wines with pleasant tastes with healthy substances, such as wine with antioxidant properties.

Keywords: Chemical change; Fermentation; Sulfur dioxide; Maturation of wine; Antioxidants

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1. Introduction

Winemaking is a process involving the transformation of a raw plant material into wine, where it is an intriguing and complicated process. It begins with the harvest or raw plant material arrival to the cellar, followed by the most effective fermentation processes, subsequently some wines undergo a long maturing process, to improve the flavor and fragrance [1].

This review mainly discusses the process of wine making in the fermentation and aging stage, in contrast other processes which are involved in winemaking, such as wine filtration, packaging, and bottling are not discussed in this paper.

2. Chemical changes

The sugar in the grapes is consumed by the yeast, where the sugar is broken down into ethanol and carbon dioxide, simultaneously produces heat. Wines are classified into different types, based on the yeast strains, and grape varieties, which are used in the winemaking process. These variations are the result of intricate interactions between the biological growth of the grape, the grape growing environment, and the yeast strain [2].

Chemical interactions also take place between the molecules which are present in the must, those gradually extracted from the grape solids during fermentation, those obtained from metabolism, and those released by the wood, in addition the biochemical reactions catalyzed by enzymes produced by yeast or bacteria. In the large number winemaking process, the temperature and dissolved oxygen factors which are associated with the technological operations of the winery, may have a dramatic effect on the wine, additionally the type and intensity of reactions which that took place, may determine the quality of the finished wine.

2.1. Yeast

Yeasts that are frequently discovered on grapes and in wine are commonly from the following genera; *Saccharomyces, Kloeckera, Hanseniaspora, Candida, Hansenula, Pichia,* and *Brettanomyces.* Many non-*Saccharomyces* yeasts, including *Kloeckera, Hansenula, Candida*, and others, are thought to thrive and take part in the initial stages of natural or spontaneous fermentation [3]. In order to produce Fino wines (biological aging), Amontillado wines (biological aging followed by oxidative age) or Oloroso wines, the fermented wine musts go through two selection processes (oxidative aging only) [4].

The ethanol concentration rises with the fermentation procedure, additionally high level of ethanol prevents native non-*Saccharomyces* yeasts from proliferating and becoming active, promoting the development and dominance of *Saccharomyces cerevisiae* yeast, followed by the fermentation process. Natural fermentation proponents assert of wine with a mixed culture fermentation has more nuanced aromas [3].

2.2. Alcohol fermentation

Alcohol fermentation is a biological process that turns glucose into ethyl alcohol and carbon dioxide using yeast, some types of bacteria, or a few other microorganisms. Aqueous monosaccharide solutions are utilized as the culture media and yeast is often used as the bio-culture agent in this fermentation process to produce wine. Yeast typically performs the aerobic fermentation step in the production of alcohol; however, it is also capable of performing anaerobic fermentation of the basic ingredients. Alcohol fermentation takes place in the yeast cytoplasm in the absence of oxygen. Glycolysis, is a process which yeasts break down carbohydrates to produce pyruvate molecules, a precursor for alcohol fermentation. Two molecules of pyruvic acid are created during the glycolysis of a glucose molecule, subsequently the molecules of pyruvic acid are broken down into ethanol and carbon dioxide (CO_2) as shown in **Figure 1** [3].

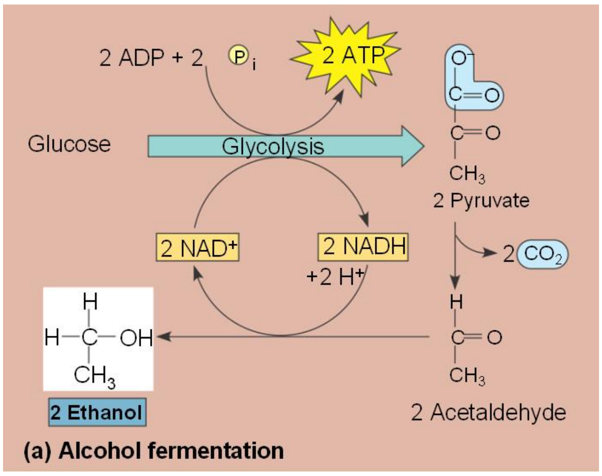

Figure 1. Alcohol fermentation releases CO_2 as a byproduct in addition to producing alcohol

2.3. Malolactic fermentation

Malolactic fermentation (MLF), also known as secondary fermentation or malolactic de-acidification, is a process in which the malic acid is transformed into mild-tasting lactic acid. Because no alcohol is created during the malolactic fermentation process, it should be noted that this process is essential for the decarboxylation of L-malic acid to produce L-lactic acid and CO_2 [5]. A rise in pH and a decrease in perceived acidity are the main outcomes of the malolactic fermentation process. A Typical a wine's acidity can be decreased by 0.1% to 0.3%. The malolactic fermentation process can occur naturally, or winemakers will initiate it intentionally by inoculating the specific bacteria into the wine. The bacteria which are commonly used to conduct the malolactic fermentation are from the genera *Lactobacillus* and *Pediococcus,* however, *Oenococcus oeni* is the preferred bacteria species for the malolactic fermentation process of all type's wines [3].

2.4. Sulfur dioxide

Sulfur dioxide is the most commonly used additive in winemaking, due to its numerous functions, including its ability to fight undesirable microbes, prevent oxidation, stop enzymatic and non-enzymatic browning reactions, and improve wine quality [3]. Therefore, the biggest efforts in winemaking are to reduce the amount of chemicals which can permanently bind the sulfur dioxide, increase the molecular sulfur dioxide by pH management or investigating new naturally occurring preservation substances [6].

Only sulfur dioxide in free form has the antioxidant and antimicrobial properties. The sulfur dioxide in free form has three states; molecular sulfur dioxide (SO_2), bisulfite (HSO_3^-), and sulfite (SO_3^{2-}). They are in dynamic equilibrium as shown in **Figure 2**. The quantities of these different forms of free sulfur dioxide depend on the pH, and each form has different properties. The antibacterial properties of sulfur dioxide, mostly attributed to the molecular form, which is typically only present in trace amounts. In contrast to the sulfite form, which is present in very tiny amounts and has little enological significance, the bisulfite form plays a significant role in the antioxidant capabilities of sulfur dioxide [7].

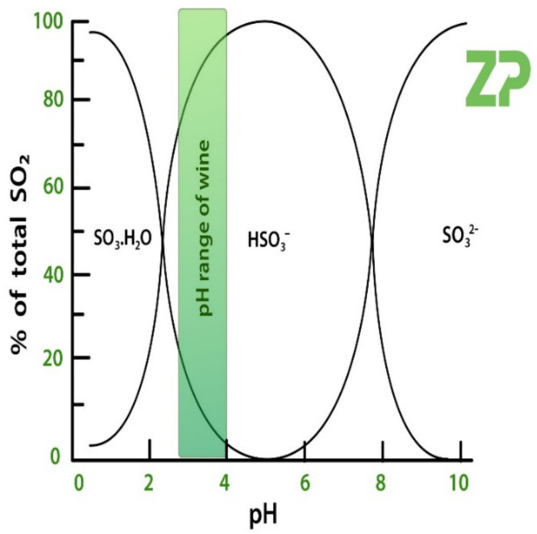

Figure 2. Three states; molecular sulfur dioxide (SO_2), bisulfite (HSO_3^-), and sulfite (SO_3^{2-}) of sulfur dioxide in wine

2.5. Maturation of wine

Maturation is a period during which the wine evolves at the winery, either in tanks or oak barrels, towards a degree of stability before undergoing fining and tartrate stabilization. Maturation is defined as the bulk storage period, whereas aging describes the changes in wine composition after bottling, and often these two terms are used interchangeably. Maturation whether in tanks or barrels, is essentially for oxidative reactions, meanwhile aging is more reductive in the bottle. The maturation of wine is a process of refining the wine by removing most of the residual CO_2, removing sediments, and other insoluble materials, and eliminating any raw or harsh odors and tastes [3].

3. Quality control points, sensory, and nutritional attributes

For a formation process to be completed, ten days to a month or more may be needed. Due to the must's overall sugar concentration, the alcohol content of a wine may be differ depending on the region. In a region with cold temperatures, an alcohol level of 10% in wine is considered usual, compared to a maximum of 15% of alcohol content in a warmer region. When the fermentation process is interrupted before all the sugar has been metabolized into alcohol, sweet wine would be produced. Typically, the winemaker makes this decision with awareness and intention [8].

3.1. Fermentation temperature

Most of the red wines should have their fermentation temperatures maintained between 70 to 85°F to obtain the greatest color and tannin extraction. It is crucial to remember that the finished product could have an unfavorable cooked flavor when temperatures start to get close to 90°F. In addition, wine may be controlled at its ideal temperature within a small 15°F range.

Next, high-quality white wine can be made at a fermentation temperature that is comparably lower than red wine, where white wines typically undergo a gradual fermentation process over a few months at 45 to 60°F.

The exquisite white wine's delicate fruit flavors and ephemeral scents are perfectly preserved by the cooler temperature. Taking the Sauvignon Blanc fermentation temperature as an example, Gene Spaziani claims that the best temperature range for fermentation is between 42 and 50°F (one of the lower ranges for white wines) [9].

3.2. Fermentation sensory attributes

The proportion of aromatic molecules varies depending on the used yeast strain, thereby deciding how the wine smells and tastes [10]. In addition, MLF process also has great influence on the wine taste. Malic acid is believed to taste like the green apple peel, and has a sour flavor, meanwhile lactic acid has a buttery or milky flavor. This issue can be resolved by the MLF process, which can transform the malic acid into lactic acid, to produce wine with smooth and distinctive unique taste [11].

In addition, milk and other dairy products contain lactic acid. In fact, milk acid is a common nickname for lactic acid [12]. If a Chardonnay is described as tasting buttery, it has probably experienced malolactic fermentation, which imparts a buttery or creamy flavor to wine. Besides, a mouthfeel impact might be perceived [13].

3.3. Sulfur-like off-odors

Sulfur contributes to several wines off-flavors, including the presence of hydrogen sulfide (H_2S), reductive aromas (developed by mercaptans/thiols or disulfides), and a high concentration of free sulfur dioxide. The word sulfur is often used incorrectly, to describe all of these aromas and flavors. However, each defect has a particular aroma/flavor that is somewhat unique; (1) H_2S has the aroma of rotten eggs or hard-boiled eggs; (2) Mercaptans or thiol-based compounds and disulfides have various aromas/flavors, and common descriptors including canned or cooked vegetables, canned asparagus, garlic, onion, cooked cabbage, garbage, putrefaction, burnt rubber, canned corn, and molasses; (3) High free SO_2 smells like recently burned matches, and often causes a burning or irritation in the nose.

Chemically, all of these compounds are very different despite the fact they all contain the element of sulfur. Further, remediating these defects in wine requires winemakers to properly identify the problem, and use appropriate techniques to treat the problem [14].

3.4. Brettanomyces or Dekkera off-flavor

Wine is frequently contaminated with the yeast *Brettanomyces*, which can be found in every wine-producing location of all the six continents. The biggest problem of this yeast is, it can create biofilms or coatings on tanks, hoses, and on other winery surfaces which are extremely hard to remove, and is a place where an organism can thrive and withstand the effects of disinfectants [15]. In addition, barrels are hard to clean and sterilize because of their porous nature, and its ability to produce wood sugar. They also frequently support colonies of Brettanomyces. The fact that Brettanomyces can persist in the condition known as a viable non-culturable (VNC) state is another factor contributing to this issue. The majority of sanitation procedures are evaluated, by examining the treated surface to determine if there are any living organisms present on the surface. Under these circumstances, organisms in a VNC state do not develop and give the impression that the sanitation program was ineffective, but they are really still alive and capable of growing in the future [16].

3.5. Maturation of wine

Young wines of excellent quality are distinguished by being full of floral to fruity tastes, distinct varietal scents (if distinctive of the grape cultivars used), possessing a balanced mouthfeel, and producing a flavorful enjoyment. A wine that benefits from a long aging, in contrast, has little scent when young (because it is too bonded to nonvolatile wine ingredients), and is frequently quite astringent [17].

The grape-derived smells diminish as the wine ages, while more nuanced and palatable aromas emerge, further the wine's flavor also varies. Astringent and harsh tastes are replaced by smoother and rounder tastes. Additionally, changes in color can also occur during the maturation process. Wineries frequently employ the process of maturing wine in oak barrels to improve the stability and richness of their products [3]. Further, different maturation temperature can also have an impact on wine color, volatiles, and sensory profile [18].

3.6. Antioxidants produced

Phenolic compounds and glutathione are the two primary categories of antioxidants found in grapes and wines. Phenolics are a broad range of substances that may be found in both white and red grapes. The amount of phenols in wine varies depending on the grape cultivar, how the grapes are handled and processed, how the grape juice are handled, and how alcohol the is fermented. An essential tripeptide with sulfur and glutathione, can also be used as an antioxidant in wine, and the variables which may influence its production are juice processing method, oxidation process, and yeast strain [19]. Typically, red wines often have stronger antioxidant activity than white or sherry wines [20].

4. Conclusion

In summary, winemaking is a complicated process. In order to change a wine's component formula, and make important decisions should be made depending on the quantities of acid, sugar, tannin, and other wine components, where a winemaker has to integrate scientific principles with practical expertise. Winemaking is often described as the blend between science and art, thereby a winemaker should be well grounded in chemistry and microbiology, as well have the creativity and artistic nature to create genuinely fine wine, consistently.

Disclosure statement

The author declares no conflict of interest.

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