9.12.2 Wines And Brandy

9.12.2.1 General

Wine is an alcoholic beverage produced by the fermentation of sugars in fruit juices, primarily grape juice. In general, wines are classified into two types based on alcohol content: table wines (7 percent to 14 percent, by volume) and dessert wines (14 percent to 24 percent, by volume). Table wines are further subdivided into still and sparkling categories, depending upon the carbon dioxide (CO_2) content retained in the bottled wine. Still table wines are divided into three groups: red, rosé (blush), and white, based on the color of the wine.

9.12.2.2 Process Description[1-4]

The production of still table wines is discussed in the following paragraphs, followed by more concise discussions of the production of sweet table wines, sparkling wines, dessert wines, and brandy.

Still Table Wines -

The basic steps in vinification (wine production) include harvesting, crushing, pressing, fermentation, clarification, aging, finishing, and bottling. A simplified process diagram outlining the basic steps in the production of still table wines is shown in Figure 9.12.2-1.

Harvesting of grapes is usually conducted during the cooler periods of the day to prevent or retard heat buildup and flavor deterioration in the grape. Most wineries transport the whole grapes but some crush the grapes in the vineyard and transport the crushed fruit to the winery. Stemming and crushing are commonly conducted as soon as possible after harvest. These two steps are currently done separately using a crusher-stemmer, which contains an outer perforated cylinder to allow the grapes to pass through but prevents the passage of stems, leaves, and stalks. Crushing the grapes after stemming is accomplished by any one of many procedures. The three processes generally favored are: (1) pressing grapes against a perforated wall; (2) passing grapes through a set of rollers; or (3) using centrifugal force. Generally, 25 to 100 milligrams (mg) of liquified sulfur dioxide (SO_2) are added per liter of the crushed grape mass to control oxidation, wild yeast contamination, and spoilage bacteria.

Maceration is the breakdown of grape solids following crushing of the grapes. The major share of the breakdown results from the mechanical crushing but a small share results from enzymatic breakdown. In red and rosé wine production, the slurry of juice, skins, seeds, and pulp is termed the "must". In white wine production, the skins, seeds, and pulp are separated from the juice before inoculation with yeast and only the juice is fermented. A fermenting batch of juice is also called "must". Thus, the term "must" can refer to either the mixture of juice, seeds, skins, and pulp for red or rosé wines or only the juice for white wines. Maceration is always involved in the initial phase of red wine fermentation. The juice from the grapes may be extracted from the "must" in a press. Additionally, gravity flow juicers may be used initially to separate the majority of the juice from the crushed grapes and the press used to extract the juice remaining in the mass of pulp, skins, and seeds (pomace). There are many designs of dejuicers but, generally, they consist of a tank fitted with a perforated basket at the exit end. After gravity dejuicing has occurred, the pomace is placed in a press and the remaining juice extracted. There are three major types of presses. The horizonal press is used for either crushed or uncrushed grapes. A pneumatic press can be used for either crushed or uncrushed grapes as well as for fermented "must". In the continuous screw press, the "must" is pumped into the press and forced in the pressing chamber where perforated walls allow the juice to

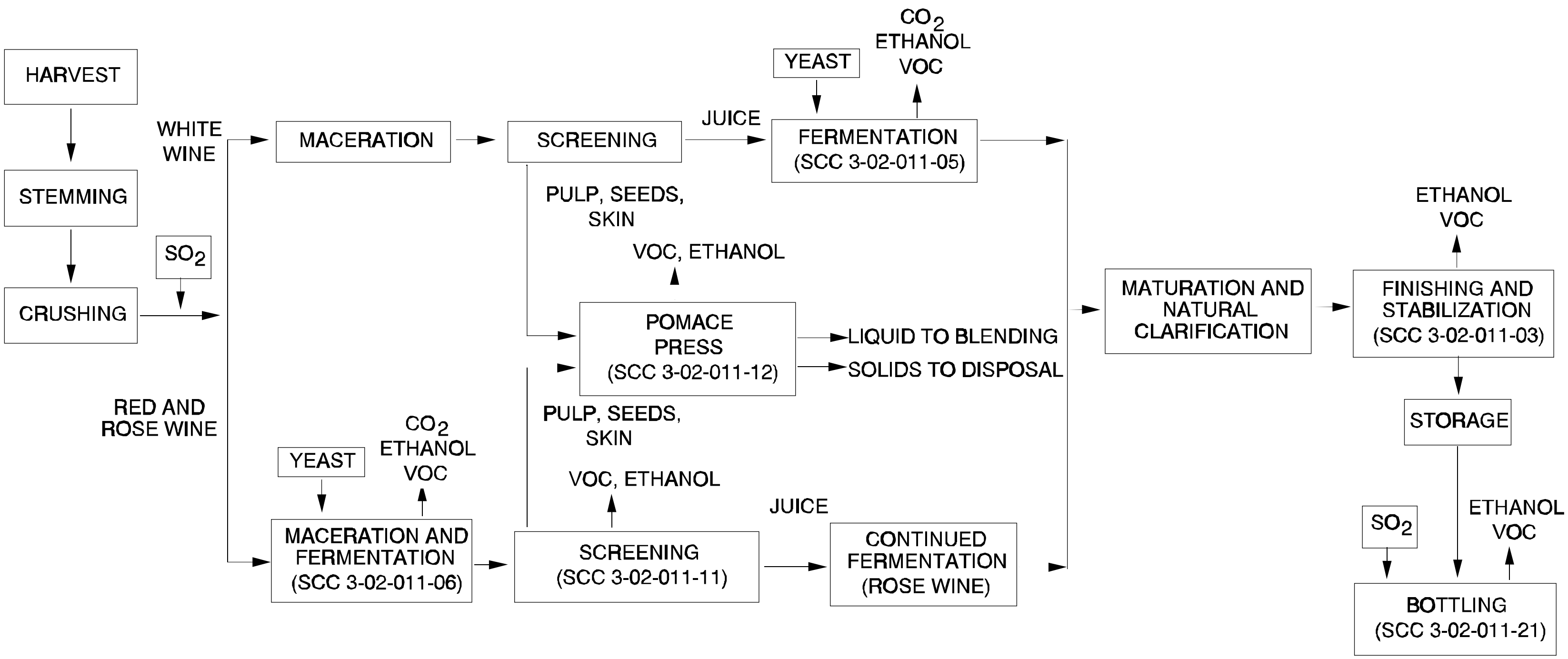

Figure 9.12.2.-1. Basic steps in still table wine production.
(Source Classification Codes in parentheses.)

escape. After pressing, white "must" is typically clarified and/or filtered prior to fermentation to retain the fruity character. The white juice is commonly allowed to settle for up to 12 hours but may be centrifuged to speed the clarification.

Fermentation is the process whereby the sugars (glucose and fructose) present in the "must" undergo reaction by yeast activity to form ethyl alcohol (ethanol) and CO_2 according to the equation:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

In the U. S., the sugar content of the juice is commonly measured with a hydrometer in units of degree Brix (°B), which is grams (g) of sugar per 100 grams of liquid. Fermentation may be initiated by the addition of yeast inoculation to the "must". The fermentation process takes place in tanks, barrels, and vats of a wide variety of shapes, sizes, and technical designs. Tanks are different from vats in that tanks are enclosed, whereas vats have open tops. In most of the larger wineries, tanks have almost completely replaced vats. Since the 1950s, the move has been away from the use of wooden tanks, primarily to stainless steel tanks. Lined concrete tanks are also used, and fiberglass tanks are becoming more popular because of their light weight and lower cost.

The fermentation process is an exothermic reaction and requires temperature control of the fermenting "must". Red wines are typically fermented at 25° to 28°C (70° to 82°F) and white wines at 8° to 15°C (46° to 59°F). Almost all of the fermentation is conducted by the batch process and continuous fermentors are rarely used in the U. S. Size of the fermentors is based primarily on the volume of "must" to be fermented. During fermentation of red wines, the CO_2 released by the yeast metabolism becomes entrapped in the pomace (layer of skins and seeds) and causes it to rise to the top of the tank where it forms a cap. The pomace cap is periodically covered with the "must" to increase color removal, aerate the fermenting "must", limit growth of spoilage organisms in the cap, and help equalize the temperature in the fermenting "must". For white wines, the main technical requirement is efficient temperature control. Temperature is one of the most influential factors affecting the fermentation process. During fermentation of both white and red "must", the CO_2, water vapor, and ethanol are released through a vent in the top of the tank. Malolactic fermentation sometimes follows the primary fermentation and results in a reduction in acidity and increased pH. There are very diverse opinions about this step because the fermentation, to varying degrees, can improve or reduce wine quality.

After fermentation, all wines undergo a period of adjustment (maturation) and clarification prior to bottling. The process of maturation involves the precipitation of particulate and colloidal material from the wine as well as a complex range of physical, chemical, and biological changes that tend to maintain and/or improve the sensory characteristics of the wine. The major adjustments are acidity modification, sweetening, dealcoholization, color adjustment, and blending. Following the fermentation process, a preliminary clarification step is commonly accomplished by decanting the wine from one vessel to another, called racking, in order to separate the sediment (lees) from the wine. Current racking practices range from manually decanting wine from barrel to barrel to highly sophisticated, automated, tank-to-tank transfers. In all cases, separation occurs with minimal agitation to avoid resuspending the particulate matter. The residue from racking may be filtered to recover wine otherwise lost with the lees or may be used "as is" for brandy production.

Stabilization and further clarification steps follow maturation and initial clarification to produce a permanently clear wine with no flavor faults. The steps entail various stabilization procedures, additional clarification (fining), and a final filtration prior to bottling. The most common stabilization technique used for many red wines and some white wines is aging the wine for a period of months or years. Vessels used to store and age wine, termed cooperage, are produced in a wide range of sizes, depending on their intended use. White oak has traditionally been used for the barrels to age wine, but currently its usage is reserved primarily for the production of premium white and red wines and some fortified wines. Water and ethanol are lost through the barrel surfaces and a partial vacuum develops in the space created by this loss. Each barrel is periodically opened and topped off with wine to fill the void created by the ethanol and water loss. Cooperage constructed from materials other than wood has many advantages and is less expensive to maintain. Stainless steel is often preferred, but fiberglass and concrete are also used. In addition to aging, other stabilization procedures are used to prevent formation of potassium bitartrate or calcium tartrate crystals, haziness (casse) resulting from protein coalescence, casse resulting from oxidation of tannins present in the wine, and haziness due to metal ions such as iron and copper. Enzyme mixtures are used to remove polysaccharides which can cause filtration problems and haze formation. Most wines contain viable but dormant microorganisms. Racking is used as an initial step in microbial stabilization but long-term stability frequently requires use of sulfur dioxide as the antimicrobial agent. Other methods include pasteurization and filter sterilization. Sulfur dioxide may be added at various stages in wine production to prevent microbial growth and oxidation. Finishing (fining) agents are commonly added to accelerate the precipitation of suspended material in wine. Prior to bottling, a final clarification step is used to remove any remaining suspended material and microbes in the wine. This step involves only physical methods of clarification, generally a filtration procedure.

Glass bottles are the container of choice for premium quality wines and for sparkling wines. Because of disadvantages such as weight and breakage, glass bottles are sometimes being replaced by new containers, such as bag-in-box, for many standard quality, high volume wines. To protect the wine against microbial spoilage, and to limit oxidation, the SO_2 content in the wine is adjusted to a final level of 50 mg/L before filling. Precaution is taken to minimize contact with air during filling and thereby to reduce oxidation. This is done by either flushing the bottle with inert gas before filling or flushing the headspace with inert gas after filling.

Sweet Table Wines -

The most famous of the sweet wines are those made from noble-rotted, *Botrytis*-infected grapes. These wines are produced to a limited extent in the United States. The *Botrytis* mold acts to loosen the grape's skin so moisture loss occurs rapidly and the sugar concentration increases in the grape. The grapes are then selectively picked, followed by pressing, and fermentation. Fermentation is a slow process, however, because of the high sugar content and the use of SO_2 to retard the growth of undesirable molds and microorganisms. Nonbotrytized sweet wines are also produced by drying the grapes. Drying involves allowing the grapes to dehydrate on mats or trays in the shade for weeks or months and then crushing the grapes and fermenting the concentrated juice. Heating, boiling, or freezing is also used to concentrate juice for semisweet wines.

Sparkling Wines -

Most sparkling wines obtain CO_2 supersaturation using a second alcoholic fermentation, typically induced by adding yeast and sugar to dry white wine. There are three principal methods of sparkling wine production: the *methode champagnoise*, the transfer method, and the bulk method. In the *methode champagnoise*, both red and white grapes may be used, but most sparkling wines are white. The grapes are harvested earlier than those used for still table wines and pressed whole without prior stemming or crushing to extract the juice with a minimum of pigment and tannin extraction. This is important for producing white sparkling wines from red-skinned grapes. Primary fermentation is carried out at approximately 15°C (59°F) and bentonite and/or casein may be added to aid the process and improve clarity. The blending of wines produced from different sites, varieties, and vintages distinguishes the traditional method. Before preparing the blend (*cuvée*), the individual base wines are clarified and stabilized. Aging typically takes place in stainless steel tanks but occasionally takes place in oak cooperage. The secondary fermentation requires inoculation of the *cuvée* wine with a special yeast strain. A concentrated sucrose solution is added to the *cuvée* just prior to the yeast inoculation. The wine is then bottled, capped, and stacked horizontally at a stable temperature, preferably between 10° to 15°C (50° to 59°F), for the second fermentation. After fermentation, the bottles are transferred to a new site for maturation and stored at about 10°C (50°F).

Riddling is the technique used to remove the yeast sediment (lees). The process involves loosening and suspending the cells by manual or mechanical shaking and turning, and positioning the bottle to move the lees toward the neck. Disgorging takes place about 1 or 2 years after bottling. The bottles are cooled and the necks immersed in an ice/$CaCl_2$ or ice/glycol solution to freeze the sediment. The disgorging machine rapidly removes the cap on the bottle, allowing for ejection of the frozen yeast plug. The mouth of the bottle is quickly covered and the fluid level is adjusted. Small quantities of SO_2 or ascorbic acid may be added to prevent subsequent in-bottle fermentation and limit oxidation. Once the volume adjustment and other additions are complete, the bottles are sealed with special corks, the wire hoods added, and the bottles agitated to disperse the additions. The bottles are then decorated with their capsule and labels and stored for about 3 months to allow the corks to set in the necks. The transfer method is identical to the *methode champagnoise* up to the riddling stage. During aging, the bottles are stored neck down. When the aging process is complete, the bottles are chilled below 0°C (32°F) before discharge into a transfer machine and passage to pressurized receiving tanks. The wine is usually sweetened, sulfited, clarified by filtration, and sterile filtered just before bottling.

In the bulk method, fermentation of the juice for the base wine may proceed until all the sugar is consumed or it may be prematurely terminated to retain sugars for the second fermentation. The yeast is removed by centrifugation and/or filtration. Once the *cuvée* is formulated, the wines are combined with yeast additives and, if necessary, sugar. The second fermentation takes place in stainless steel tanks similar to those used in the transfer process. Removal of the lees takes place at the end of the second fermentation by centrifugation and/or filtration. The sugar and SO_2 contents are adjusted just before sterile filtration and bottling.

Other methods of production of sparkling wine include the "rural" method and carbonation. The rural method involves prematurely terminating the primary fermentation prior to a second in-bottle fermentation. The injection of CO_2 (carbonation) under pressure at low temperatures is the least expensive and the least prestigious method of producing sparkling wines.

Dessert Wines -

Dessert wines are classified together because of their elevated alcohol content. The most common dessert wines are sherries and ports.

Baking is the most popular technique for producing sherries in the United States. Grapes are crushed and stemmed and SO_2 added as soon as possible to control bacteria and oxidation. The maximum amount of juice is separated from the skins and the juice is transferred to fermentors. The juice is inoculated with starter and fermented at temperatures of 25° to 30°C (77° to 86°F). The new wine is then pumped from the fermentor or settling tank to the fortification tank. High proof spirits are added to the sherry material, or shermat, to raise the alcohol content to 17 to 18 percent by volume and then the wine is thoroughly mixed, clarified, and filtered before baking. Slow baking occurs when the wine is stored in barrels exposed to the sun. More rapid baking is achieved through the use of artificially heated storage rooms or heating coils in barrels or tanks. After baking, the sherry is cooled, clarified, and filtered. Maturation is then required and is usually carried out in oak barrels. Aging can last from 6 months to 3 years or more.

Port wines are produced by the premature termination of fermentation by addition of brandy. When the fermenting must is separated from the pomace by gravity, it is fortified with wine spirits containing about 77 percent alcohol, by volume. Most white ports are fortified when half the original sugar content has been fermented, except for semidry and dry white ports which are fortified later. The type and duration of aging depend on the desired style of wine. Blending is used to achieve the desired properties of the wine. The final blend is left to mature in oak cooperage for several months prior to fining, filtration, stabilization, and bottling.

Brandy Production —

Brandy is an alcoholic distillate or mixture of distillates obtained from the fermented juice, mash, or wine from grapes or other fruit (e. g., apples, apricots, peaches, blackberries, or boysenberries). Brandy is produced at less than 190° proof and bottled at a minimum of 80° proof. (In the United States, "proof" denotes the ethyl alcohol content of a liquid at 15.6°C (60°F), stated as twice the percent ethyl alcohol by volume.) Two types of spirits are produced from wine or wine residue: beverage brandy and "wine spirits".

In brandy production, the grapes are pressed immediately after crushing. There are major differences in the fermentation process between wine and brandy production. Pure yeast cultures are not used in the fermentation process for brandy. Brandy can be made solely from the fermentation of fruit or can be distilled either from the lees leftover from the racking process in still wine production or from the pomace cap that is leftover from still red wine fermentations.

In the United States, distillation is commenced immediately after the fermentation step, generally using continuous column distillation, usually with an aldehyde section, instead of pot stills. For a detailed discussion of the distillation and aging of distilled spirits, which include brandy and brandy spirits, refer to AP-42 Section 9.12.3, "Distilled And Blended Liquors". After distillation, the brandy is aged in oak casks for 3 to 15 years or more. During aging, some of the ethanol and water seep through the oak and evaporate, so brandy is added periodically to compensate for this loss. Caramel coloring is added to give the brandy a characteristic dark brown color. After aging, the brandy may be blended and/or flavored, and then chilled, filtered, and bottled.

9.12.2.3 Emissions And Controls[5-11]

Ethanol and carbon dioxide are the primary compounds emitted during the fermentation step in the production of wines and brandy. Acetaldehyde, methyl alcohol (methanol), n-propyl alcohol, n-butyl alcohol, sec-butyl alcohol, isobutyl alcohol, isoamyl alcohol, and hydrogen sulfide also are emitted but in much smaller quantities compared to ethanol emissions. In addition, a large number of other compounds are formed during the fermentation and aging process. Selected examples of other types of compounds formed and potentially emitted during the fermentation process include a variety of acetates, monoterpenes, higher alcohols, higher acids, aldehydes and ketones, and organosulfides. During the fermentation step, large quantities of CO_2 are also formed and emitted.

Fugitive ethanol emissions also occur during the screening of the red wine, pressing of the pomace cap, aging in oak cooperage, and the bottling process. In addition, as a preservative, small amounts of liquified SO_2 are often added to the grapes after harvest, to the "must" prior to fermentation, or to the wine after the fermentation is completed; SO_2 emissions can occur during these steps. There is little potential for VOC emissions before the fermentation step in wine production.

Except for harvesting the grapes and possibly unloading the grapes at the winery, there is essentially no potential for particulate (PM) emissions from this industry.

Emission controls are not currently used during the production of wines or brandy. Five potential control systems have been considered and three have been the subject of pilot-scale emission test studies at wineries or universities in California. The five systems are (1) carbon adsorption, (2) water scrubbers, (3) catalytic incineration, (4) condensation, and (5) temperature control. All of the systems have disadvantages in either low control efficiency, cost effectiveness, or overall applicability to the wide variety of wineries.

Emission factors for VOC and hydrogen sulfide emissions from the fermentation step in wine production are shown in Table 9.12.2-1. The emission factors for controlled ethanol emissions and the uncontrolled emissions of hydrogen sulfide and other VOCs from the fermentation step should be used with caution because the factors are based on a small number of tests and fermentation conditions vary considerably from one winery to another.

The only emission factors for wine production processes other than fermentation, were obtained from a 1982 test.[7] These factors represent uncontrolled fugitive ethanol emissions during handling processes. The factor for fugitive emissions from the pomace screening for red wine (SCC 3-02-011-11) is 0.5 lb/1,000 gal of juice. An ethanol emission factor for the pomace press is applicable only to red wine because the juice for white wine goes through the pomace press before the fermentation step. The emission factor for red wine (SCC 3-02-011-12) is 0.02 lb/ton of pomace. Although fugitive emissions occur during the bottling of both red and white wines, an emission factor is available only for the bottling of white wine. The factor for white wine bottling (SCC 3-02-011-21) is 0.1 lb/1,000 gal of wine. All of these factors are rated E. These emission factors should be used with extreme caution because they are based on a limited number of tests conducted at one winery. There is no emission factor for fugitive emissions from the finishing and stabilization step (aging).

There are no available data that can be used to estimate emission factors for the production of sweet table wines, dessert wines, sparkling wines, or brandy.

Table 9.12.2-1. EMISSION FACTORS FOR WINE FERMENTATION[a]

EMISSION FACTOR RATING: E

Wine type	Type of control	Ethyl alcohol, lb/10^3 gal	Methyl alcohol, lb/10^3 gal	n-Propyl alcohol, lb/10^3 gal	n-Butyl alcohol, lb/10^3 gal	Sec-Butyl alcohol, lb/10^3 gal	Isobutyl alcohol, lb/10^3 gal	Isoamyl alcohol, lb/10^3 gal	Acet-aldehyde, lb/10^3 gal	Hydrogen sulfide, lb/10^3 gal
Red (SCC 3-02-011-06)	None[b]	4.6[c]	0.0025	0.0034	5.5E-5	4.5E-5	0.0036	0.014	0.0027	0.0017
	Carbon adsorption[d]	0.17[c]	ND	ND	ND	ND	ND	ND	ND	ND
	Catalytic incineration[e]	1.1	ND	ND	ND	ND	ND	ND	ND	ND
	Wet scrubber[e]	0.056	ND	ND	ND	ND	ND	ND	ND	ND
White (SCC 3-02-011-05)	None[b]	1.8[c]	6.4E-4	0.0023	ND	ND	6.9E-4	0.0051	7.2E-5	0.0014
	Carbon adsorption[d]	0.092[c]	ND	ND	ND	ND	ND	ND	ND	ND
	Catalytic incineration[e]	0.15	ND	ND	ND	ND	ND	ND	ND	ND
	Wet scrubber[e]	0.083	ND	ND	ND	ND	ND	ND	ND	ND

[a] Emission factor units are lb/1,000 gal of fermented juice produced. SCC = Source Classification Code. ND = no data.
[b] References 8-11.
[c] EMISSION FACTOR RATING: C
[d] References 8-10.
[e] Reference 8.

References For Section 9.12.2

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