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119. Ref. 84, p. 433.
120. Ref. 84, p. 439.
121. Ref. 84, p. 438.

OLAF MICKELSEN
Consultant

WHEAT GERM OIL. See Fats and fatty oils.

WHEY. See Pet and livestock feeds.

WHISKEY. See Beverage spirits, distilled.

WHITE LEAD. See Pigments, inorganic.

WHITENING AGENTS. See Brighteners, optical.

WHITING, $CaCO_3$. See Pigments, inorganic.

WINE

The word wine was possibly first applied to the fermentation product of the sugars in the juice of grapes; this is its primary meaning. However, the fermented juices of many fruits are now called wine, and the term is also sometimes incorrectly applied to the alcoholic fermented juice of various plant materials containing sugars, eg, rice wine. It is thus used in contrast to fermented liquids made from starch-containing materials, such as beer (qv) and related beverages. The unmodified term wine applies only to the product obtained from fermented grapes. Orange, peach, cherry, blackberry, loganberry, currant, apple, strawberry, and other fruit wines are produced commercially in limited quantities in the United States, but in larger quantities in France, the UK, Poland, and Sweden. There is also a small but widespread home industry that produces wines from herbs and vegetables (dandelion, beans, rhubarb, or roses) by treating them with a sugar solution or from fermented honey (see also Beverage spirits, distilled).

An important aspect of wine is its intimate and long association with artistic, cultural, and religious activities. Thus, at the beginning of recorded history, wines were described or their production portrayed and their properties critically evaluated and praised. By 2500 BC, the Egyptians had evolved hieroglyphics that described various types of wines. Noah's reputed experience in planting a vineyard and making wine also indicates the early development of wine making. The Old Testament contains many references to wines and their properties, as does Greek literature. Greek wines

frequently contained herbs, perfumes, and flavors, a practice that survives today (see also Flavors and spices). The reason for adding herbs and spices is not known, but it may have been an attempt to mask spoilage or prevent its development. Honey was probably added for the same reason and may have resulted in a secondary fermentation which produced enough alcohol (≥15%) to prevent spoilage. Some herbs were probably added because of supposed medicinal or aphrodisiac values.

The religious and allegorical significance of wine was developed by the Greeks and has been utilized by many other religions including Christianity. It is unlikely that unfermented grape juice was more than a vintage-season beverage before the 19th century because of the lack of sterilization procedures and techniques.

In ancient Rome, wine production became increasingly organized and specialized, and the cultivation of grapes was highly developed. Various varieties of grapes and different methods of wine production were described by Columella and Pliny. Clay amphora of Greek origin and later wooden casks were used for aging. Although many Roman wines must have been very poor by modern standards, it is clear that the Romans had cultivated a taste for the beverage, lavished much care on its production, and gave it literary and artistic praise. The writings of Horace and Virgil on wines are well known.

During the Middle Ages, wines were produced in the Mediterranean countries and in northern France and Germany. The spread of Islam nearly destroyed the wine industry around the Mediterranean between 800 and 1400 AD. In the Moslem countries, only Christians and Jews produced small amounts for personal and sacramental purposes. The need for wine for religious ceremonies and the large number of monastic communities led to the production of wine by monasteries. Many important European vineyards from France to Yugoslavia and Cyprus owe their origins to Cistercian and other monastic orders which made wine for their own use as well as for sale. In the 17th century, the cooper's art improved, bottles were less expensive, and after corks became available, wines could be stored safely and for longer periods. Already in the pre-Christian era, wines were stored in caves under relatively constant and cool conditions; both are essential for minimizing secondary fermentation and for proper aging.

In the 19th century, the work of Pasteur and others not only demonstrated the role of yeasts in grape-juice fermentation, but also identified the various microorganisms responsible for spoilage; methods for their control were developed, and wine production changed from an uncertain art to a scientific industry. Wine making is still something of an art, as far as quality is concerned, but today most of the world's wine is produced by modern technology.

Definitions

Wine is the fermented juice of the fruit of one of several species of *Vitis*, most often of cultivars of *Vitis vinifera*, with or without the addition of sugar, grape concentrate, or reduced must (boiled-down grape juice), herbs, flavors, or alcohols. In the eastern United States, varieties of *V. labrusca* and hybrids of *V. vinifera* and *V. labrusca* are used. In the southeastern United States, varieties of *V. rotundifolia* are employed. Over 95% of the world's wine is made from varieties of *V. vinifera*, possibly because of the more subtle flavors of most *V. vinifera* wines. Grape breeders generally try to remove the strong labrusca flavor by complicated interspecific hybridization.

The present legal definition of wine in the United States (1) is:

United States Internal Revenue Code. Sec. 5381. Natural Wine. Natural wine is the product of the juice or must of sound, ripe grapes or other sound, ripe fruit, made with such cellar treatment as may be authorized under section 5382 and containing not more than 21 percent by weight of total solids. Any wine conforming to such definition except for having become substandard by reason of its condition shall be deemed not to be natural wine, unless the condition is corrected. . .

Sec. 5382. Cellar Treatment of Natural Wine. (a) General. Proper cellar treatment of natural wine constitutes those practices and procedures in the United States and elsewhere, whether historical or newly developed, of using various methods and materials to correct or stabilize the wine, or the fruit juice from which it is made, so as to produce a finished product acceptable in good commercial practice. Where a particular treatment has been used in a customary commercial practice, it shall continue to be recognized as a proper cellar treatment in the absence of regulations prescribed by the Secretary finding such treatment not to be a proper cellar treatment within the meaning of this subsection.

(b) Specifically Authorized Treatments. The practices and procedures specifically enumerated in this subsection shall be deemed proper cellar treatment for natural wine:

(*1*) The preparation and use of pure concentrated or unconcentrated juice or must. Concentrated juice or must reduced with water to its original density or to not less than 22 degrees Brix or unconcentrated juice or must reduced with water to not less than 22 degrees Brix shall be deemed to be juice or must, and shall include such amounts of water to clear crushing equipment as regulations prescribed by the Secretary may provide.

(*2*) The addition to natural wine, or to concentrated or unconcentrated juice or must, from one kind of fruit, of wine spirits (whether or not taxpaid) distilled in the United States from the same kind of fruit; except that (A) the wine, juice or concentrate shall not have an alcoholic content in excess of 24 percent by volume after the addition of the wine spirits, and (B) in the case of still wines, wine spirits may be added in any State only to natural wines produced by fermentation in bonded wine cellars located within the same State.

(*3*) Amelioration and sweetening of natural grape wines in accordance with section 5383.

(*4*) Amelioration and sweetening of natural wines from fruits other than grapes in accordance with section 5384.

(*5*) In the case of effervescent wines, such preparations for refermentation and for dosage as may be acceptable in good commercial practice, but only if the alcoholic content of the finished product does not exceed 14 percent by volume.

(*6*) The natural darkening of the sugars or other elements in juice, must, or wine due to storage, concentration, heating processes, or natural oxidation.

(*7*) The blending of natural wines with each other or with heavy-bodied blending wine or with concentrated or unconcentrated juice, whether or not such juice contains wine spirits, if the wines, juice, or wine spirits are from the same kind of fruit.

(*8*) Such use of acids to correct natural deficiencies and stabilize the wines as may be acceptable in good commercial practice. . .

Sec. 5383. Amelioration and Sweetening Limitations for Natural Grape Wines. (a) Sweetening of Grape Wines. Any natural grape wine may be sweetened after fermentation and before taxpayment with pure dry sugar or liquid sugar if the total solids content of the finished wine does not exceed 12 percent of the weight of the wine and the alcoholic content of the finished wine after sweetening is not more than 14 percent by volume; except that the use under this subsection of liquid sugar shall be limited so that the resultant volume will not exceed the volume which could result from the maximum authorized use of pure dry sugar only. . .

Sec. 5384. Amelioration and Sweetening Limitations for Natural Fruit and Berry Wines. (a) In General. To natural wine made from berries or fruit other than grapes, pure dry sugar or liquid sugar may be added to the juice in the fermenter, or to the wine after fermentation; but only if such wine has not more than 14 percent alcohol by volume after complete fermentation, or after complete fermentation and sweetening, and a total solids content not in excess of 21 percent by weight; and except that the use under this subsection of liquid sugar shall be limited so that the resultant volume will not exceed the volume which could result from the maximum authorized use of pure dry sugar only. . .

Sec. 5385. Specially Sweetened Natural Wines. (a) Definition. Specially sweetened natural wine is the product made by adding to natural wine of the winemaker's own production a sufficient quantity of pure dry sugar, or juice, or concentrated juice from the same kind of fruit, separately or in combination, to produce a finished product having a total solids content in excess of 17 percent by weight and an alcoholic content of not more than 14 percent by volume, and shall include extra sweet kosher wine and similarly heavily sweetened wines.

(b) Cellar Treatment. Specifically sweetened natural wines may be blended with each other, or with natural wine or heavy bodied blending wine in the further production of specially sweetened natural wine only, if the wines so blended are made from the same kind of fruit. Wines produced under this section may be cellar treated under the provisions of section 5382(a) and (c). Wine spirits may not be added to specially sweetened natural wine.

Sec. 5386. Special Natural Wines. (a) In General. Special natural wines are the products made, pursuant to a formula approved under this section, from a base of natural wine (including heavy-bodied blending wine) exclusively, with the addition, before, during or after fermentation, of natural herbs, spices, fruit juices, aromatics, essences, and other natural flavorings in such quantities or proportions as to enable such products to be distinguished from any natural wine not so treated, and with or without carbon dioxide naturally or artificially added, and with or without the addition, separately or in combination, of pure dry sugar or a solution of pure dry sugar and water, or caramel. No added wine spirits or alcohol or other spirits shall be used in any wine under this section except as may be contained in the natural wine (including heavy-bodied blending wine) used as a base or except as may be necessary in the production of approved essences or similar approved flavorings. The Brix degree of any solution of pure dry sugar and water used may be limited by regulations prescribed by the Secretary in accordance with good commercial practice.

(b) Cellar Treatment. Special natural wines may be cellar treated under the provisions of section 5382(a) and (c). . .

Sec. 5387. Agricultural Wines. (a) In General. Wines made from agricultural products other than the juice of fruit shall be made in accordance with good commercial practice as may be prescribed by the Secretary by regulations. Wines made in accordance with such regulations shall be classed as "standard agricultural wines." Wines made under this section may be cellar treated under the provisions of section 5382(a) and (c). . .

The standards of identity and quality in the California regulations generally conform to those of the Federal government.

Various states and foreign countries have slightly different definitions based on local needs (see Table 1). The regulations of the European Economic Community (EEC) provide for uniform regulations for trade in wines between its members and for imports from nonmember countries. Generally, the regulations have been written to allow legitimate local practices, eg, addition of sugar to low-sugar musts in the FRG and parts of France.

Table 1. EEC, Federal, and California Standards for Wines

Type	Alcohol, % max	Max volatile acidity[a], as % acetic acid	Min fixed acidity, as % tartaric acid	Max sulfur dioxide, mg/L	Min extract[b], g/100 mL
EEC					
red table		0.120		175[c]	
white and rosé		0.108		225[c]	
Federal					
red table	14	0.140	[d]	350[e]	none
white table	14	0.120	[d]	350[e]	none
dessert	17–21	0.120	[d]	350[e]	none
California					
red table		0.120	0.40	350	1.8
white table		0.110	0.30	350	1.7
dessert		0.110	0.25	350	none[f]

[a] Exclusive of sulfur dioxide.
[b] Minimum soluble solids content.
[c] For table wines with residual sugar the maximums are higher—up to 400 mg/L.
[d] No specification given.
[e] Not more than 70 of which may be free.
[f] Either minimum degree Balling or minimum percent reducing sugar is required, varying with the type.

Wines have been sold under regional names for many centuries. The Madrid and Lisbon agreements gave protection to regional names for many products including wine. However, the United States and some other countries did not participate in these conventions.

Codification for national protection to regional names began in France in 1935 under what is called *appelation d'origine contrôlée* (AOC or sometimes just AC) (2–3). In general, these regulations delimit the region protected, limit the varieties of grapes that can be used and the production per hectare, and restrict the enological practices. Larger geographical definitions may also contain smaller areas or even specific vineyards. Thus, Bordeaux includes all of the wines produced in the delimited Bordeaux district. Bordeaux supérior has higher standards. Médoc is a smaller regional appellation, and Pauillac is the smallest (a commune or roughly a township). Individual châteaux do not have an appellation of origin. In Burgundy, the subdivisions are Bourgogne or the area around a town, eg, Beaune or Meursault, and finally subdivisions such as Beaune Bressandes or Meursault Genevries. These smaller areas may belong to one or many growers. There are also some lesser appellations in France, *vins de consummation courant* (VCC) and subdivisions, and *vins delimitee qualité supérior* (VDQS).

Similar regulations have been developed for the FRG: Besitz, local area, and vineyards. Examples are Rheingau, Geisenheim (town), and Geisenheimer Mäuerchen (vineyard area). Again, a vineyard may have one or many owners. Furthermore, the sugar content of the fruit at harvest may permit quality designations, eg, Kabinet, Spätlese, Auslese, Beerenauslese, and Trockenbeerenauslese (for increasing sugar content and prices).

The Italian regulations provide for a *denominazione di origin controllata* (DOC) and *denominazione di origin controllata guarantie* (DOCG) (4). Several hundred DOCs have been defined but, so far, only a few DOCGs. The requirements for a DOCG are more restrictive than for a DOC, and presumably the quality and prices are higher.

In 1978, U.S. regulations were changed to give protection to regional names. These may be for large or small areas. So far, Augusta, Mo., Fennville, Mich., Finger Lakes, New York (and 8 other non-California regions), and Arrago Seco, Caramel Valley, Cienega Valley, Guenoc Valley, McDowell Valley, Napa Valley, Santa Cruz Mountains, San Pasqual, Santa Maria Valley, and Sonoma Valley (and 11 others), all in California, have been approved. Many others await approval. These are strictly geographical appellations with no indication of the types of wines that may be produced within the delimited area.

Proprietary wines are those with a name that is owned by a producer. All names of wines are in lower case except varietal types, proprietary types, and those with special regional significance. Thus, California burgundy is not capitalized since there is no regional significance to the name as used here. On the other hand, Burgundy designates a wine from the region of that name in France.

Standards

There are two types of standards for wines in the United States and most other countries. First, there are those based on taxes. In the United States, the tax is levied

according to the alcohol content:

alcohol, %	≤14	>14–≤20	>21–24
tax, ¢/L	4.5	17.7	63.4

Very few wines have an alcohol content of 21% or more. The Federal government and some states have set up standards for spoiled wines to protect the consumer. These standards primarily limit the content of volatile acids, mainly acetic acid.

The international, Federal, and state public health authorities also set standards for wines on the basis of chlorides, sulfates, lead, arsenic, and other constituents. In the United States, it is seldom necessary to determine these constituents, since they are not known to be present in U.S. wines in excessive amounts.

Salicylic, benzoic, and monochloracetic acids may not be added to American wines, whereas clarification agents and sulfur dioxide, sorbic acid (qv), or sorbates are permitted. It can be presumed that additives not listed in the standard are prohibited. The maximum amounts permitted are specified. Other countries likewise generally prohibit certain practices and permit others, and those not specifically listed generally may not be employed without permission. Analytical procedures are discussed in refs. 5–8.

Classification

Wines may be classified in many ways: by alcohol (ethanol) content, place of production, color, method of production, or variety of grape or fruit. Wines with ≤14% alcohol are defined as table wines since they are normally consumed with meals. Wines with >14% are called dessert or aperitif wines since they are usually consumed after or before meals.

I. Wines without added herbs or plant materials.
  A. Wines with excess carbon dioxide.
    1. From fermentation of added sugar. Usual pressure, 200–600 kPa (ca 2–6 atm).
      a. Containing anthocyanin and related (red) pigments.
        (*1*) Pink—pink or rosé sparkling types.
        (2) Red—sparkling burgundy or champagne rouge.
      b. Not containing red pigments.
        (*1*) With muscat flavor—sparkling muscat and muscato spumante
        (2) Without muscat flavor—Champagne, California (etc) champagne, or bulk-process champagne, Sekt, spumante, espumante, shampanski, etc.
          (a) Below 1% sugar—brut type.
          (b) Above 1.5% sugar, sec (dry), demi-sec, and doux types with increasing sugar.
    2. Wines with excess carbon dioxide, not from added sugar. Usual pressure, 20–200 kPa (ca 0.2–2 atm).
      a. Gassiness from fermentation of residual grape sugar. Includes occasional wines in Switzerland, France (some Vouvray), Italy, and the muscato amabile type of California.
      b. Gassiness from malo–lactic fermentation—vinhos verdes wines (white and red from northern Portugal) and some Italian wines.

3. Wines with added carbon dioxide.
   a. Containing anthocyanin and related (red) pigments—carbonated burgundy, and several proprietary red wines.
   b. Not containing red pigments—some Swiss and French types but increasingly rare.

B. Wines without obvious excess carbon dioxide.
1. Wines 8–14% alcohol.
   a. Wines with anthocyanin and related (red) pigments.
      (*1*) Pink wines.
         (a) Dry—pink or rosé types and varietal types, such as Gamay, Grenache, Grignolino, and Tavel.
         (b) Sweet—Aleatico (see, however, 3a(*1*) below).
      (2) Full red color.
         (a) Dry (below 0.5% sugar).
            -1- With distinguishable (usually) varietal aromas.
               -a- With high acidity—Barbera.
               -b- With moderate acidity—Barolo, Beaujolais, Bordeaux (Médoc, St.-Émilion, etc), Burgundy, Cabernet Sauvignon or C. franc, Châteauneuf-du-Pape, Chianti, Fresia, Gamay, Hermitage, Petite Syrah, Pinot noir, P. St. George, Pinotage, Rioja, Ruby Cabernet, Syrah (Schiraz), Zinfandel, etc.
            -2- Without (normally) distinguishable varietal aromas—California (etc) burgundy, Carignane (Carignan), California (etc) claret, California (etc) dry red table, California (etc) chianti, Charbono, Cinsaut, Malvoisie, Mourestel, Nebbiolo (usually), Valdepenas.
         (b) Sweet. Proprietary types with or without Concord aroma (see also 2a below), California (etc) red table, and California sweet red table.
   b. Wines without anthocyanin and related (red) pigments.
      (*1*) Wines usually with distinguishable varietal aromas.
         (a) Containing sugar—German Auslese and California "Late Harvest" types, and many non-Auslese German wines from the Moselle, Rhine, etc, regions, Hungarian Tokay, light muscat, light sweet muscat, Late Harvest California Sauvignon blanc, White Riesling, etc, some Loire wines, Sauternes, sweet Catawba, sweet Sauvignon blanc, sweet Sémillon, and various proprietary wines.
         (b) Not containing sugar—Catawba, Chablis, Chardonnay, Chenin blanc (Steen), Delaware, Folle Blanche, Flora, some French Colombard (Colombard), Gewürztraminer, Graves, some Gray Riesling, some Loire wines, Moselle, Müller-Thurgau, Pinot blanc, Rhine (Rheingau, etc), Sauvignon blanc, Sémillon, Sylvaner, and White Riesling, etc.
      (2) Wines usually without distinguishable varietal aromas.
         (a) Containing sugar—California (etc) "château" types, California (etc) sweet white table, sauterne, sweet sauterne, and various proprietary labeled types. (See 2b below).

(b) Not containing sugar—California (etc) dry sauterne, California (etc) rhine, California (etc) white table, Burger, some French Colombard, some Gray Riesling, Green Hungarian, Ugni blanc (Trebbiano).

2. Wines with 14–17% alcohol.
   a. Containing anthocyanin or related (red) pigments—miscellaneous sweet red types—mainly with proprietary names.
   b. Not containing red pigments—miscellaneous sweet white types—mainly with proprietary names.
   c. Special types.
      (*1*) Blending—to increase the alcohol or to impart a special flavor to other wines or even other products, eg, whiskey.
      (*2*) Ecclesiastical, usually sweet (eg, *vino santo*) and various wines with dessert-type names but specially produced for special markets.
      (*3*) Fino and manzanilla types in Spain.
3. Wines with 17–21% alcohol.
   a. Containing anthocyanin and related (red) pigments.
      (*1*) With a muscat flavor
         (a) Pink—Aleatico (see also B1a(*1*) above).
         (b) Red—red or black muscatel.
      (2) Without a muscat flavor.
         (a) With a baked odor—California tokay.
         (b) Without a baked odor.
            -1- Brownish red—tawny port.
            -2- Red—port (including ruby, tawny, and vintage port).
   b. Not containing red pigments.
      (1) With a muscat aroma—Muscat blanc (ie, Muscat Frontignan and Muscato Canelli), Samos, Setúbal (Portugal), Sitges (Spain), and Australian and California muscatel.
      (2) Without a muscat aroma.
         (a) With a special odor due to treatment or aging.
            -1- With a raisin, cooked, reduced-must, or rancio odor.
               -a- Raisin odor—Malaga.
               -b- Baked odor—California (etc) sherry (dry, medium, or sweet), Madeira (usually sweet).
               -c- Reduced-must or burnt odor—Marsala.
               -d- Rancio (aged, slightly oxidized) odor—Banyuls (may have tawny color), Tarragona (such as Priorato), etc.
            -2- With a film yeast odor.
               -a- Dry (<1% sugar)—Spanish sherry (flor or fino, amontillado, etc), Australia, California, Cyprus, South Africa, and Soviet Union (various dry or cocktail sherries), Château Chalon (France).
               -b- Sweet—California medium or sweet flor sherry, some sweet Spanish sherry types.
         (b) Without a special odor due to treatment or aging.
            -1- With amber color—Angelica (California) white port

(Portugal), and some oloroso types (Spanish and others).

-2- Without amber color—white port (California).

II. Wines with added herbs or plant materials containing alkaloids or other flavoring materials.
   A. With a red color.
      1. Proprietary types—includes certain wines containing quinine and similar additives (Byrrh, Dubonnet, Campari, etc).
      2. Medicinal or home-produced types, such as iron- or herb-containing.
   B. Without a red color.
      1. Nearly dry—dry or French-type vermouth.
      2. Sweet (usually with a muscat flavor)—sweet or Italian-type vermouth.
      3. Proprietary types of fruit-flavored dessert and table wines (Thunderbird, Silver Satin, etc).
      4. Medicinal or home-produced types, such as gentian, rhubarb, dandelion, etc (see also A, 2 above).

Note. Only the more important types have been included in this classification with particular emphasis on the wines produced in, or imported into, the United States. Proprietary wines are those having a name that is owned by a producer. All wine types are in lower case except varietal types, proprietary types, and those having a specific legal regional significance. Thus, California burgundy is not capitalized as there is no geographical significance to the name as employed here. On the other hand, Burgundy means a wine from the region of that name in France. The "etc" following California usually represents other U.S. wines, such as New York or Ohio wines.

Legal Restrictions

Not only is the composition of the wines offered for sale subject to legal restrictions, but every producer of U.S. wines, except those produced in limited quantities for home consumption, must secure a Federal permit and take out a bond before beginning operations. Since this basic permit may be canceled for willful violation of Federal laws or regulations, the government possesses a powerful tool to deter violations. The regulations are frequently changed, and the regional office of the Bureau of Alcohol, Tobacco and Firearms of the Department of the Treasury should be consulted by anyone considering the wine business as to the necessary forms, bonds, and other papers which must be submitted. The bonded premises must be properly posted and protected by locks, and possess certain equipment (such as scales, ebulliometer) to facilitate inspection by government agents (commonly called gaugers). The capacity of all tanks must be recorded, and accurate records of production and movement of the wines and permissible additives must be maintained. The addition of sugar is strictly regulated and is forbidden in the production of most California wines. State laws are not as strict as Federal laws. In many countries, the regulations of production and labeling of wines are very detailed and require expert interpretation.

In most countries, the sale of wines is subject to permits, regulations, and taxes. The tax varies from state to state (or country to country) and is usually a function of the alcoholic content or type of wine. Most countries levy an import tax. In some cases,

special tax stamps are purchased and affixed on the bottle or container. Special state taxes for state-sponsored advertising and research may also be assessed.

The addition of alcohol or herbs (fortification) to dessert wines and the production of vermouth and sparkling wines are subject to regulations. In some countries, the regulations are less stringent. Sweetening agents used for sparkling wines must be declared to the appropriate government agency.

A recent court decision in the United States requires the manufacturers of alcoholic beverages to disclose the ingredients of their products (9) but the case is on appeal.

Production

The special character of the fermentation of the various types of wines depends to a considerable extent on the composition of the fruit juice fermented (see also Fermentation).

Composition of Grapes. Grapes contain ca 15–25% sugar; partially dried grapes contain 30–40%. The percentage of sugar in the grapes, the extent of the fermentation, and the losses or additions of alcohol during treatment and storage determine the percentage of alcohol in the finished product. Since at least 9 vol % alcohol is usually necessary to prevent rapid acetification or spoilage, sugar must sometimes be added (chaptalization) to permit fermentation to reach the required alcohol content. The approximate amount of sugar necessary is calculated from the fermentation equation; ca 1% sugar fermented yields 0.55 vol % alcohol.

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

A minimum sugar content of ca 16.4% is therefore necessary to produce a wine of 9% alcohol. The soluble solids content of mature grape juice is >90% sugar. Usually, the sugar content of grape juice is determined with a hydrometer. The Brix or Balling hydrometer, used in the United States, reads in grams of sugar per 100 grams of liquid. In Europe, the specific gravity hydrometer (Oechsle) or other special hydrometers are employed; in Australia, the Baumé hydrometer is used. Sugar content can also be determined with a refractometer. For fruits, the hydrometer or refractometer is usually employed (see also Sugar, sugar analysis).

In the United States, it is permitted to add sugar to the must in all states except California. In Europe, sugar is added most frequently in Germany and occasionally in Switzerland and parts of France. Elsewhere, the sugar content of grapes is usually high enough to produce a wine with at least 9% alcohol. Although addition of sugar is prohibited in California, in the cool year of 1948 some grape concentrate (ca 70 wt % sugar) was added to musts (grape juice) from the cooler regions to ensure wines of >10% alcohol. Other fruits and vegetables contain smaller amounts of sugar, and supplementation is usually essential. Sucrose or invert sugar is commonly used. More sugar is added to fruit than to grapes, since the finished wine is usually not fermented dry, ie, without sugar, but is allowed to remain sweet. The chemical composition of wine and must is given in Table 2.

The organic acids are the second most important constituents. Grapes contain mostly tartaric and malic acids. The content varies with the state of maturity (decreasing as the grapes ripen), the variety, and the climatic conditions of the season or region (lower in warmer regions). It is always higher under cool conditions and may

Table 2. Composition of Grape Must[a] and Wines

Component	Must, mg/L	Wine, mg/L
Water	70–85[b]	60–85[b]
Carbohydrates	15–25[b]	0–20[b]
glucose [*50-99-7*]	8–13[b]	0.1–10[b]
fructose [*30237-26-4*]	7–12[b]	0.1–10[b]
pentoses	10–200[b]	100–500[b]
arabinose [*5328-37-0*]	40–130[b]	trace
rhamnose [*10485-94-6*]	2–40[b]	trace
xylose [*58-86-6*]	trace	trace
pectin [*9000-69-5*]	40–900[b]	30–500[b]
inositol [*87-89-8*]	2–8[b]	trace
Alcohols and related compounds		
methanol [*67-56-1*]	trace	70–140
ethanol [*64-17-5*]	trace	5.6–17[b]
1-propanol [*71-23-8*]	trace	15–50
2-propanol [*67-63-0*]	?	trace
1-methylthio-1-propanol [*3877-15-4*]	?	0.5–2
2-methyl-1-propanol [*78-83-1*]	trace	33–150
1-butanol [*71-36-3*]	trace	trace–5
2-butanol [*78-92-2*]	trace	trace–40
2-methyl-1-butanol [*137-32-6*]	trace	13–50
3-methyl-1-butanol [*123-51-3*]	trace	50–160
2,3-butanediol (*threo*) [*513-85-9*]	?	340–680
1-pentanol [*71-41-0*]	trace	trace–0.4
2,3-pentanediol [*42027-23-6*]	?	7–18
1-hexanol [*111-27-3*]	trace	0.5–3
1-heptanol [*111-70-6*]	trace	trace
1-octanol [*111-87-5*]	trace	0.2–1.5
benzyl alcohol [*100-51-6*]	?	0.1–0.3
2-phenethanol [*60-12-8*]	trace	15–105
linalool [*78-70-6*]	trace	trace–0.4
nerol [*106-25-2*]	trace	trace
geraniol [*106-24-1*]	trace	trace
3,7-dimethyl-1,5,7-octatrien-3-ol [*29957-43-5*]	trace	trace–0.25
α-terpineol [*98-55-5*]	trace	trace–0.4
sorbitol [*50-70-4*]	trace	trace[b]
glycerol[c] [*56-81-5*]	trace	0.4–2.5[b]
Ketones and aldehydes[d]		
acetone [*67-64-1*]	trace	trace–0.04
4,5-dimethyl-3-hydroxy-2(5*H*) furanone [*28664-35-9*]	?	trace
3-hydroxy-2-butanone [*513-86-0*]	?	0.8–3.6
3-methyl-2-butanone [*563-80-4*]	trace	?
2,3-butanedione [*431-03-8*]	?	0.1–3
2,3-pentanedione [*123-54-6*]	?	0.02–0.3
3-hydroxy-2-pentanone [*3142-66-3*]	?	0.4–2.8
β-ionone [*14901-07-6*]	trace	trace
acetaldehyde [*75-07-0*]	trace	1–>300[e]
propanal [*123-38-6*]	trace	?
1-pentanal [*110-62-3*]	trace	?
butanal [*123-72-8*]	trace	?
hexanal [*66-25-1*]	trace	trace
benzaldehyde [*100-52-7*]	trace	?
trans-2-hexenal [*6728-26-3*]	trace	?
Acids	0.3–1.5[b]	0.3–1.2[b]
formic [*64-18-6*]	?	1.5–6.3
acetic [*64-19-7*]	trace–0.02[b]	0.03–0.15[b,f]
2-methylpropanoic [*554-12-1*]	?	trace
butanoic [*107-92-6*]	?	<0.5
2-methylbutanoic [*116-53-0*]	?	>0.5
3-methylbutanoic [*2835-39-47*]	?	<0.5
pentanoic [*109-52-4*]	?	trace
hexanoic [*142-62-1*]	?	1–>3
2-ethylhexanoic [*149-57-5*]	?	trace
cis-3-hexenoic [*4219-24-3*]	?	trace
heptanoic [*111-14-8*]	?	trace
octanoic [*124-07-2*]	?	2–>4
nonanoic [*112-05-0*]	?	trace
decanoic [*334-48-5*]	?	0.5–1
9-decenoic [*14436-32-9*]	?	0.1–0.5
undecenoic [*1333-28-4*]	?	trace
dodecanoic [*143-07-7*]	?	trace
lactic [*50-21-5*]	?	0.01–0.3[b]
oxalic [*144-62-7*]	?	11–90
mesoxalic [*473-90-5*]	?	trace
malonic [*141-82-2*]	?	trace
succinic [*110-15-6*]	?	0.01–0.20[b]
2,3-dimethyl succinic [*13545-04-5*]	?	trace
3,3-dimethyl succinic [*597-43-3*]	?	trace
ethyl acid succinate [*636-48-6*]	?	0.1–>0.5
glutaric [*110-94-1*]	?	1–10
adipic [*124-04-9*]	?	trace–30
pimelic [*111-16-0*]	?	trace–20
azelaic [*123-99-9*]	?	trace–30
sebacic [*111-20-6*]	?	trace–10
fumaric [*119-17-8*]	?	21–52
furan 3,4-carboxylic [*3387-26-6*]	?	trace–10
benzoic [*65-85-0*]	?	trace
2-phenylacetic [*103-82-2*]	?	trace
2-phenylpropanoic [*501-52-0*]	?	trace
glycolic [*79-14-1*]	?	trace–40
3-phenylpropenoic [*621-82-9*]	?	trace
cis-aconitic [*499-12-7*]	?	trace–50
tricarballylic [*99-14-9*]	?	trace–10
2-methyl-2,3-dihydroxy-butanoic		
(*threo*) [*14868-24-7*]	?	40–200
(*erythro*) [*19774-31-3*]	?	trace–95
trans-geranoic [*4698-08-2, 4613-38-1*]	?	<0.1
ascorbic [*50-81-7*]	10–180	?
malic [*6915-15-7*]	0.03–0.6[b,e]	0.001–0.5[b,e]
2-methylmalic [*2306-22-3*]	?	1.9–15
tartaric [*87-69-4*]	0.5–1.0	0.4–0.8[b,e]
citric [*77-92-9*]	10–50	130–400[e]

Table 2 (*continued*)

Component	Must, mg/L	Wine, mg/L
isocitric [*320-77-4*]	?	trace–60
salicyclic [*69-72-7*]	?	<0.1
glyoxylic [*298-12-4*]	?	trace–6
pyruvic [*127-17-3*]	?	8–50
oxalacetic [*328-42-7*]	?	trace–30
2-ketoglutaric [*328-50-7*]	trace	30–60
levulinic [*123-76-2*]	?	trace–40
gluconic [*133-42-6*]	?	trace–3090[c]
glucuronic [*576-37-4*]	trace	1–140[c]
galacturonic [*14982-50-4*]	?	10–>2000[c]
tetrahydroxyadipic [*526-99-8*]	?	trace–>650
2-furoic [*88-14-2*]	?	trace–30
4-hydroxybenzoic [*99-96-7*]	?	<0.1
3,4-dihydroxybenzoic [*99-50-3*]	?	1–5
4-hydroxy-3-methoxybenzoic [*121-34-6*]	?	1–5
2,6-dihydroxybenzoic [*303-07-1*]	?	1–5
2,5-dihydroxybenzoic [*490-79-9*]	?	1–5
3,5-dimethoxy-4-hydroxy-benzoic [*530-57-4*]	?	1–5
3,4,5-trihydroxybenzoic [*145-91-7*]	?	1–5
3,4,5-trihydroxycyclohexen-(1)-carboxylic [*138-59-0*]	?	1–5
1,3,4,5-tetrahydroxycyclo-hexen(1)-carboxylic [*77-95-2*]	?	1–5
eleagic [*476-66-4*]	?	1–5
2-hydroxycinnamic [*583-17-5*]	?	>0.1
4-hydroxycinnamic [*7400-08-0*]	?	0.5–2.0
3,4-dihydroxycinnamic [*331-39-5*]	?	0.5–2.0
3-methoxy-4-cinnamic [*1135-24-6*]	?	0.1–0.5
3,4-dimethoxy-4-cinnamic [*530-59-6*]	?	0.1–0.5
chlorogenic [*327-97-9*]	?	0.5–2.0
isochlorogenic [*14534-67-3*]	?	<1
neochlorogenic [*906-33-2*]		
nicotinic [*59-67-6*]	0.16–0.42	trace–10
2-carboxy-5-methoxy-indol [*4382-54-1*]	?	1–10
3-indolylacetic [*87-51-4*]	?	1–10
3-indolylacrylic [*1204-06-4*]	?	1–10
pantothenic [*79-83-4*]	0.5–1.4	0.5–1.9
glyceric	?	trace
sulfuric	0	0–350
carbonic [*463-79-6*]	trace	<392
Esters		
ethyl formate [*109-94-4*]	trace	trace–8
benzyl acetate [*140-11-4*]	?	trace–0.26
butyl acetate [*105-46-4*]	trace	?
ethyl acetate [*141-75-6*]	trace	35–285
geranyl acetate [*16409-44-2*]	trace	trace
isobutyl acetate [*123-86-4*]	?	trace–0.2
isopentyl acetate [*123-92-2*]	trace	trace–8
methyl acetate [*79-20-9*]	trace	trace
propyl acetate [*109-60-4*]	trace	?
pentyl acetate [*628-63-7*]	trace	?
2-phenethyl acetate [*103-45-7*]	?	trace–2.6
phenyl acetate [*122-79-9*]	trace	?
nonyl acetate [*143-13-5*]	trace	?
octyl acetate [*112-14-1*]	trace	?
hexyl acetate [*142-92-7*]	trace	0.2–2
ethyl propanoate [*105-37-3*]	trace	trace–1.2
pentyl propanoate [*624-54-4*]	trace	?
propyl propanoate [*106-37-3*]	trace	?
ethyl butanoate [*105-54-4*]	trace	trace
hexyl butanoate [*1117-59-5*]	trace	?
isobutyl butanoate [*539-90-2*]	trace	?
isobutyl isobutanoate [*97-85-8*]	trace	?
hexyl isobutanoate [*2349-07-7*]	trace	?
isopentyl butanoate [*106-27-4*]	trace	?
ethyl pentanoate [*539-82-2*]	trace	trace
hexyl pentanoate [*1117-59-5*]	trace	?
isobutyl pentanoate	trace	?
ethyl hexanoate [*123-66-0*]	trace	0.1–2
methyl hexanoate [*106-70-7*]	trace	?
ethyl octanoate [*106-32-1*]	trace	0.2–1.5
ethyl nonanoate [*123-29-5*]	trace	?
ethyl decanoate [*110-38-3*]	trace	trace–0.3
methyl anthranilate [*134-20-3*]	trace	trace–3
ethyl stearate [*111-61-5*]		
ethyl 2-hydroxypropanoate [*97-64-3*]	?	1–40
isopentyl 2-hydroxypropanoate [*19329-89-6*]	?	trace–0.06
ethyl 2-methylbutanoate [*7452-79-1*]	?	trace
ethyl 3-methylbutanoate [*108-64-5*]	?	trace
ethyl laurate [*106-33-2*]	trace	trace–0.4
diethyl malonate [*105-53-3*]	trace	trace
diethyl succinate [*121-75-5*]	trace	0.8–2.0
diethyl glutarate [*818-38-2*]	trace	trace
ethyl phenylacetate [*101-97-3*]	trace	trace
isopentyl octanoate [*2035-99-6*]	?	trace
ethyl linoleate [*544-35-4*]	?	0.8
hexyl hexanoate [*6378-65-0*]	trace	?
isobutyl hexanoate [*105-79-3*]	trace	?
isobutyl laurate [*37811-72-6*]	trace	?
hexyl laurate [*34316-64-8*]	trace	?
ethyl myristate [*124-06-1*]	trace	?
dimethyl phthalate [*131-11-3*]	?	?
pentyl octanoate [*638-25-5*]	?	?

Table 2 (*continued*)

Component	Must, mg/L	Wine, mg/L
3-(methylthio)-propyl acetate [*13327-56-5*]	?	trace
ethyl lactate [*97-64-3*]	?	6.8–10
Polyphenol and related compounds		
anthocyans[e]	trace	trace
chlorophylls [*479-61-8*, *519-62-0*]	trace	trace
xanthophyl [*127-40-2*]	trace	trace
carotene [various]	trace	trace
quercitin [*117-39-5*]	trace	trace
quercitrin [*522-12-3*]	trace	trace
kaempferol [*520-18-3*]	trace	trace
rutin [*153-18-4*]	?	4–10
catechin [*154-23-4*]	0.1–10	10–300
gallocatechin [*970-73-0*]	<1	
gallocatechin gallate [*27289-24-3*]	trace	
epicatechin gallate	trace–<0.5	
gallic acid [*149-91-7*]	trace	
Nitrogenous compounds		
total	300–1700	100–900
protein	10–1000	10–30
humin	10–20	10–20
amide	10–40	10–80
ammonia	10–12	0–200
residual	10–20	50–200
amino	170–1100	100–2000
4,5-dimethyl-1,3-di-oxolane-2-propanamine [*85236-72-2*]	?	trace
1-pyrroline [*5724-81-2*]	?	trace
Mineral compounds	0.3–0.5	0.15–0.40
potassium	0.15–0.25	0.045–0.175
magnesium	100–250	100–200
calcium	40–250	10–210
sodium	trace–200	trace–440
iron	trace–30	trace–50
aluminum	trace–30	trace–70
manganese	trace–51	trace–50
copper	trace–3	trace–5
boron	trace–70	trace–40
rubidium	trace–1	trace–4
phosphate	200–500	30–900
sulfate	30–3500	30–2200
silicic acid	2–50	2–50
chloride	10–100	10–600
fluoride	trace	1–10
iodide	trace	trace–10
Miscellaneous		
styrene [*100-42-5*]	?	0–0.1
nerol oxide [*1756-08-9*]	trace	trace–0.1
cis-rose oxide [*16409-43-1*]	trace	trace
trans-rose oxide [*35598-65-3*]	trace	trace
cis-linalool oxide [*5989-33-3*]	trace	trace–0.26
trans-linalool oxide [*34995-77-2*]	?	trace–0.15
ethanethiol [*75-08-1*]	?	trace
dimethyl sulfide [*75-18-3*]	?	trace–0.4
ethyl methyl sulfide [*624-89-5*]	?	trace
diethyl sulfide [*352-93-2*]	?	trace
diisopropyl sulfide [*625-80-9*]	?	trace
ethyl-*n*-propyl sulfide [*4110-50-3*]	?	trace
tert-butyl sulfide [*592-65-4*]	?	trace
isobutyl sulfide [*592-65-4*]	?	trace

[a] Refs. 5–8.
[b] g/100 mL.
[c] Except more for botrytised grapes.
[d] Numerous acetals, lactones, secondary acetamides, and phenols have been identified in wines but quantitative data are lacking.
[e] Depends on variety and climatic conditions and cellar treatment.
[f] More in spoiled wines.

sometimes impart an unpleasantly tart taste. This occurs in the eastern U.S., Canada, Switzerland, and the FRG in some years. Regulations, different in each country, permit the use of water, calcium, or potassium carbonate or ion exchange to reduce the acidity. The pH of normal grape juice in moderate climatic zones is 3.0–3.6, and the titratable acidity is 0.5–1% (calculated as tartaric acid). In this range, most deleterious organisms grow slowly or not at all, thus allowing rapid growth of the desirable yeast. The relatively high titratable acidity and low pH of musts aid in the extraction of color from the skins and in wine clarification. In other fruits, the acidity is due to malic, citric, oxalic, and isocitric acids in varying proportions. This acidity is usually high enough to permit a disease-free fermentation and a stable product, unless diluted with too much water. Moreover, some fruit and berry wines must be sweetened to mask excessive acidity.

Only a small amount of nitrogenous material (0.3–1.0%) is found in grapes. However, this material is of considerable significance for yeast nutrition, bacterial stability, and flavor development, presumably because of the many amino acids present (see also Amino acids). During fermentation, the total amino acid content decreases, although the content of some acids may be higher in the finished wine than in the must because of their release by autolysis of yeast cells. The most important amino acids reported in grape juices or wines are alanine [*56-41-7*], arginine [*74-79-3*], aspartic acid [*56-84-8*], cystine [*56-89-3*], glutamic acid [*56-86-0*], glycine [*56-40-6*], histidine [*71-00-1*], isoleucine [*73-32-5*], leucine [*56-87-13*], lysine [*56-87-1*], methionine [*63-68-3*], phenylalanine [*63-91-2*], proline [*147-85-3*], serine [*56-45-1*], threonine [*72-19-5*], tryptophan [*73-22-3*], tyrosine [*60-18-4*], and 1-valine [*72-18-4*]. In other fruits, yeast propagation is limited by low nitrogen, and a nitrogen-containing compound is added to stimulate yeast growth (see also Yeasts). Apple and pear juices, for example, ferment slowly for this reason.

The pigments of grapes and fruits are usually located in the epidermal cells. A few varieties have red juice as well. During alcoholic fermentation, the cells are killed and these pigments are released. By separating the skin of red grapes from the juice before fermentation, it is possible to produce a white or nearly white wine. Anthocyanin and related red pigments are responsible for the color and probably also aid in clarification. Red wine (from red grapes) also contains considerable tannins, which affect taste, color, oxidation–reduction potential, and rate of aging.

The pectins of some fruits and grapes are a source of difficulty in juice clarification. They are rather insoluble in alcohol and precipitate during alcoholic fermentation.

The inorganic constituents are not of critical importance as they are usually present in sufficient amounts to catalyze yeast or enzyme functioning; excess iron or copper may cause turbidity. The high potassium–sodium ratio is believed to be of interest to persons with hypertension. The small amounts of copper and zinc may have some nutritional value.

Microorganisms. Wines are normally produced by fermentation with the yeast *Saccharomyces cerevisiae*, sometimes with *S. bayanus* or *S. oviformis* (10). Taxonomists are still reclassifying the genus *Saccharomyces*. These and other yeasts, found in grapes or fruit, multiply rapidly in the sweet juice, eventually causing fermentation. Although this process is adequate for grapes under most conditions, it may be inadequate for fruit. Under unfavorable climatic conditions, it may also be inadequate for poor quality grapes. For this reason, it is customary to add a pure culture of fermenting yeast. Numerous strains of *S. cerevisiae* are available, which, however, all produce very similar results. Pure yeast cultures are usually added at a rate of ca 1–3%. The actively fermenting culture is grown in sterilized must. Pressed wine yeasts grown in nongrape media have also been used.

To prevent growth and competition of undesirable organisms, 50–200 mg sulfur dioxide are usually added per liter ca 2 h before the pure yeast culture is added. The sulfur dioxide acts as a selective antiseptic and permits more or less unrestricted growth of the added yeasts. Originally, a piece of sulfur in the form of a wick was introduced into the cask and burned. When the must was introduced, as much as ≥25 mg of sulfur dioxide per liter might be absorbed from the air on the moist wooden walls of the cask. However, the amount of sulfur dioxide introduced is not easily controlled, because elemental sulfur sublimes onto the walls of the cask or pieces of the sulfur wick drop onto the bottom of the cask. During fermentation, this sulfur is reduced to hydrogen

sulfide, imparting a very unpleasant odor. For this reason, salts that yield sulfur dioxide, such as potassium metabisulfite (pyrosulfite), aqueous solutions of sulfur dioxide, or the liquefied gas, are commonly used. The warmer the must and the poorer its quality, the more sulfur dioxide is needed (usually >150 mg/L). The sulfur dioxide kills or inhibits the growth and activity of undesirable bacteria and yeasts, increases the extraction of color and soluble material from the skins, and acts as an antioxidant. The resulting wines are thus of higher alcohol, extract, and total acid content, lower in volatile acidity, lighter in color in the case of white wines, and somewhat darker in the case of red wines, than those produced without sulfur dioxide. Other components, such as sugar, water, acid, or nitrogenous materials, eg, urea or ammonium phosphate, are added at the same time.

Equipment. Wine production can be very simple, but for large-scale operation, specialized equipment has been developed.

The grapes are crushed in combined stemmers and crushers. These remove the stems first by centrifugal force and then crush the berries. The actual crushing may be done by centrifugation or by passing the fruit through rollers or by both. Must pumps transfer the crushed grapes (must) to the fermentors or presses.

Fermentation tanks may be of wood, concrete, stainless steel, or iron lined with epoxy resins or a thin layer of stainless steel; they may be open or closed. Open wooden or concrete tanks were formerly used for red musts and closed containers for white musts. Today, stainless-steel or lined iron tanks are used for both red and white fermentation, for the storage of wines during clarification, for early maturing white table and dessert wines, and for blending and storage before bottling. Large open tanks may have coils, preferably of stainless steel, for cooling or heating, but most are now partially or wholly jacketed. In some wineries, the temperature is computer controlled.

After fermentation, the residue, ie, stems and skins, often called pomace or marc, must be transferred from the fermentor to the press. In some wineries, electric elevators are lowered into the tank and the pomace is raised to the top. From there, it is either dumped directly into the press or into a trough with a continuous belt or chain to carry it to the press. In other wineries, the fermentation tanks are raised above the floor and the tank's floor steeply slanted. The pomace is flushed with wine from the bottom into the conveyor and to the press. This wine can be used for distillation; water can also be used for the flushing, but the diluted wine can only be used for distillation.

The oldest type of press still in use is the screw-type basket press, usually operated vertically, either from above or below. It has been largely replaced by the horizontally operated hydraulic press. This press is more expensive to operate but produces a relatively clear juice from both red pomaces or white musts.

Another type has an inflatable rubber bag inside a cylinder with perforated holes. The cylinder is filled with crushed grapes. When the bag is inflated, the must in the cylinder is pressed. It is reported that computer-programmed operation extracts more juice with less pressure. Belt presses that crush and press are also available.

The continuous press, the most popular type, does not operate as well on fresh must, but is the cheapest to operate with fermented pomace and gives a high yield of liquid, albeit cloudy. When the press wine is distilled, the cloudiness is of no importance.

For some fruits, and occasionally for high pectin grape musts, the rack-and-cloth press was formerly used. This operation is now seldom seen, except possibly for apples and other fruits. The must is contained in cloth sacks which are placed between wooden racks. A pile of these is then pressed in a hydraulic press. The yield of clear juice is

better than that obtained with the other types, but the operation is more expensive and the press cloths are difficult to clean.

White Table Wines. White wines of <14% alcohol are designated as white table wines. They are usually made from white grapes. Occasionally, a white wine is made from red grapes (as in the Champagne district of France) by separating the skins from the juice immediately after crushing.

Dry. A good dry white wine retains a light color and a fresh, unoxidized flavor. The key to its production is rapid transportation of the grapes from the vineyard to the winery. Crushing, stemming, and pressing should follow immediately after picking. The press juice is dark in color and high in tannins and may be settled before fermentation; that is, the juice is placed in a tank, and 50–150 mg of sulfur dioxide per liter are added and allowed to settle for 24–36 h. During this time, pieces of skin and other solid material settle at the bottom. The clear supernatant liquid is drawn off and used for the fermentation. Settling is carried out more satisfactorily in smaller containers (<7.5 m^3). It is most useful with varieties that yields a pulpy must and where a new wine is desired that clarifies rapidly. Musts, especially those from moldy fruit, are also clarified by centrifugation. Clear musts ferment slowly but more cleanly.

Some wine makers favor a skin maceration period of 6–24 h to increase flavor extraction. This procedure may result in darker-colored wines.

The juice is inoculated with a pure yeast culture. Fermentation is conducted in closed containers at ≤15.6°C. Many white wines are fermented at 6–10°C, but more time is required for fermentation at these temperatures. When fermentation is conducted in tanks of >100-hL capacity, the carbon dioxide given off by fermentation prevents the oxygen from reaching the wine. For smaller containers, fermentation traps permitting outflow of gas but preventing inflow are often employed.

The temperature and percentage of sugar (degree Brix with the hydrometer) should be determined daily during the fermentation. If the temperature rises much above 16°C, it may be necessary to cool the must by pumping a cooling liquid into the jacketed tanks or by pumping the must through a tubular heat exchanger or into a sump with cooled pipes. If the fermentation stops, refermentation may be necessary.

As the fermentation nears its end (the degree Brix is close to 0°), the tank should be filled with another wine of the same type, closed with a trap, or covered with a thick cloth to prevent air reaching the wine. When the Brix value reaches ca −1°, the wine is racked (drawn off or pumped) into another container. This container should be filled completely and the bung tapped in gently. Each day thereafter until fermentation ceases the bung can be loosened to release gas pressure. If the wine is stored at ca 10°C, it normally settles in ca 6 wk, ie, yeast cells, mucilaginous material, and cream of tartar (potassium acid tartrate) precipitate (see Tartaric acid). The settling is slower at higher temperature and with large containers. Whether the settling is complete or not, the wine must be racked from the sediment after ca 6 wk. This is particularly important if the wine is stored at somewhat higher temperatures since autolysis of the yeast cells may occur and hydrogen sulfide and other undesirable compounds are produced. New white table wines are often centrifuged for rapid clarification.

In transferring white wines from one tank to the other (racking), contact with oxygen must be avoided unless the wine has a yeasty or hydrogen sulfide odor, in which case some aeration is helpful. The second tank may be filled with carbon dioxide gas, or the wine may be pumped from the first tank to the bottom of the second, or, in small-scale operations, a sulfur wick may be burned in the second tank.

Dry white table wines are commonly bottled during the first year. The wine thus receives only one or two rackings before it is bottled. Stabilization procedures are necessary to ensure that the wines remain clear.

In general, the wine is passed through a filter press at the beginning of the year. Later in the spring, it is chilled to −4°C and held at this temperature for several days to precipitate the excess tartrates. Alternatively, the wine may be passed through a cation exchanger to exchange the potassium for sodium or hydrogen. This increases the sodium content, however, and is not favored. In some countries, eg, the FRG, the sodium content cannot exceed 60 mg/L. The wine is then racked and clarified (fined) with a slurry of bentonite or kieselguhr and is filtered, under exclusion of air, directly into the bottle. Modern and careful wineries usually make a test bottling which they subject to heat, cold, and sunlight to determine whether the wine remains brilliant. Wines with residual sugar are usually filtered through membrane filters. Just before bottling, the sulfur dioxide content should be adjusted. In the United States, enough sulfur dioxide is added to bring it to ca 150 mg/L.

Sweet. This class of wines is more difficult to produce and even more difficult to stabilize because the wines may contain less than 12% alcohol but 0.5–20 wt % sugar.

The production problem is twofold: First, the must has to be sufficiently high in sugar to produce ca 9–11% ethanol and yet have residual sugar. Second, the fermentation must be stopped before the ethanol exceeds 14%, and this is sometimes difficult. In Europe, some wines of this type contain slightly more than 14% alcohol, which should be avoided because of American tax regulations and the high alcohol.

In the United States, a high sugar content in the grapes is secured by delaying the harvest of suitable varieties as much as possible. A long delay, however, may cause sunburn or raisining on the vines, which is undesirable in white table wines. It is sometimes necessary to add grape juice, dessert wine, or grape concentrate to the finished wine in order to secure the necessary sugar content.

In Europe and in some parts of California, high humidity permits the growth of the fungus *Botrytis cinerea* on the ripe grapes. This fungus loosens the skins and allows loss of water; the grapes shrivel and increase in sugar content sometimes to as much as 40 wt %. The Sauternes of France, the sweeter Tokays of Hungary, the sweetest German (Auslese) wines, and many late harvest wines in California, are all produced from this type of grape. In another method, the grapes are dried between straw, suspended from strings, or put in shallow boxes. After two or three months, the grapes are crushed and pressed. The first procedure is used to a limited extent in France, whereas the other two are often employed in central and northern Italy, especially for sacramental wines.

The grapes are crushed, stemmed, and pressed as for dry white wines. The pressing may be more forceful in order to obtain the maximum yield. Settling or centrifuging is definitely advantageous with this type of must. The fermentation is conducted at 4.4–7.2°C. Various methods of stopping the fermentation are employed. Frequent rackings during fermentation keep the yeast population low, the successive propagation of the yeast cells reduces the nitrogen content, and the increasing alcohol content in the presence of sugar restricts further yeast growth. Some operators rack off the yeast and add a large amount of sulfur dioxide. Cooling at the same time is helpful, and this is the usual procedure in California. The wine may even be filtered or centrifuged to remove as much of the yeast as possible.

The sweet new wine must be watched constantly for signs of refermentation, which may be prevented by cooling, racking, filtration, and addition of sulfur dioxide or sorbates. As the wine ages, the tendency to referment is reduced. Sweet table wines are frequently held in the cask for one or two years for stabilization.

The wine should be bottled only after a trial bottling and a stability test. Various methods for ensuring bottle stability are employed. Least desirable is a very high sulfur dioxide content, which affects the sensory quality of the wine. In pasteurization of standard-quality wines, the wine is first heat-stabilized to a temperature slightly higher than the final pasteurization temperature and then cooled and filtered to remove precipitated solids. Finally, it is pasteurized hot in the bottles, and sealed with screwcaps. More recently, centrifugation and sterile filtration through pad or membrane filters has been employed. A low filter pressure reduces the volume; careful control of the prefiltration sterilization is required. Enologists generally frown on pasteurization of high quality wines.

Although sweet table wines produced by fermentation are generally considered the best, a similar effect can be obtained by adding a sweetening agent to a dry table wine. In the eastern United States, sucrose is used for both white and red wines, usually a blend of California table wine and eastern Concord flavored wine. The sugar content is often 13–14 wt %. Pasteurization is usually required because germproof filtration is difficult with such sweet wines. Producers that require a low sugar content may blend in a sweet dessert wine such as Angelica or port. A number of white, red, and rosé table wines with ca 1.5–2.5 wt % sugar are produced in California by adding a dessert wine or a concentrate. In Europe, grape juice is occasionally preserved with sulfur dioxide (called muté), and this is added to obtain a white sweet table wine.

Recently, so-called light or soft wines, usually white, with a low alcohol content have appeared on the U.S. market. They are made from low sugar grapes by removing the alcohol from part or all of the wine and blending. They are sold as moderate wines, ie, moderate with respect to alcohol and caloric content.

Red Table Wines. Much of the world's wine is red table wine with <14% alcohol. In France and Italy, particularly, it is an important part of the daily caloric intake. Red wines are relatively easy to produce compared with white table wines, and they are less subject to spoilage or clouding during aging.

The grapes should be harvested when they are sufficiently ripe to produce 11–13% alcohol. A sugar content of ca 21.5–23.5% is best. The grapes should be transported from the vineyard to the crusher without delay to prevent development of spoilage bacteria. Prompt crushing and destemming are essential.

Fermentation. The primary problem in red-wine production is the management of the so-called cap, ie, the floating mass of skins that rises above the liquid during fermentation. If the cap is allowed to dry, it may acidify; however, this seldom occurs in closed stainless-steel tanks. Furthermore, if the cap is not periodically submerged into the liquid, too little color is extracted from the skins. With small fermentors, the cap can be submerged manually. With very large containers (>7.6 m^3 or >2000 gal), the cap is too heavy to be forced down with wooden paddles. The juice is then pumped from the bottom of the container and sprayed over the cap. Instead of allowing the cap to float freely, various submerging systems have been devised. The oldest was a wooden latticework that fitted into the tank. The must was introduced under the framework, and when fermentation started, the cap was retained under the lattice while the juice rose and covered it.

In older systems, a permanent tank cover was constructed with a narrow opening into a basin. Sufficient must was introduced into the tank in such a way that when the fermentation started, the cap pressed against the cover and the juice rose through the narrow opening into the basin. With both these systems, good color and flavor were extracted by intimate contact of the cap and the liquid. The disadvantage of the submerged-cap systems is the management of the wooden latticework, the possibility of too much oxidation because of the free-floating surface of the fermenting must, and an excessively rapid fermentation.

Methods of making red wines include fermentations under pressure and continuous and automatic systems. For pressure fermentation, a metal tank lined with an inert material is used; a pressure of ca 300 kPa (3 atm) is maintained. This does not prolong the fermentation unduly and increases the color extraction. The cap, under a carbon dioxide atmosphere, cannot acetify. However, equipment for pressure fermentation is expensive.

Continuous systems are used in Argentina, Italy, the USSR, France, and Algeria, among others. A tall tank is used, and the sulfited must is introduced about midway. The pomace is continuously taken off the top, and the partially fermented wine is removed from the bottom. The fermentation may be contaminated by poor quality musts. Furthermore, it is difficult to provide grapes of the same variety for a sufficiently long time to make the system truly continuous. Automatic procedures provide automatic circulation of the must. The carbon dioxide pressure raises a portion of the must which then flows back over the cap. Construction costs are high, and the quality of the wine is not the best. In Burgundy and elsewhere, heat is used to extract the color of red grapes, in so-called thermovinification. The grapes are heated to 70–80°C and then pressed and cooled to 20–25°C before fermentation. Opinions differ as to the quality.

There is continuing interest in Europe in producing red wines from uncrushed grapes via the *macération carbonique* process. The uncrushed grapes are placed in closed tanks. Respiration occurs in the fruit and a high carbon dioxide atmosphere results in the death of the skin cells, releasing color. A slow fermentation occurs. The wine is light in color and tannins and has a special flavor which some find unpleasant and others pleasant. The process has not found wide favor in California because extra fermentors are required.

Red wines are normally fermented in contact with the skins until 70–90% of the sugar is used. Since the color pigments are extracted more rapidly than the tannin, skins and juice are separated as soon as the color extraction has reached its maximum, usually when ca 50–70% of the sugar has fermented. Moreover, where the grapes contain many shriveled or raisined berries, extended contact of the skins and juice increases the extraction of sugar from the high sugar fruit and may result in wines that contain too much alcohol.

Hydraulic basket presses are used for red wines, and if the pressure is not too high, operate very satisfactorily. At high pressures too much tannin, bitter-tasting material, and solids are extracted. The same is true for continuous presses. However, if the press juice is used for distillation, the residual solid material is not important; continuous presses are less expensive to operate.

After pressing, fermentation of the residual sugar requires one to six weeks, if the location is not too cold. The fermentation should be completed and no residual sugar left in the wine. Unless special precautions are taken, a low alcohol sweet wine is subject to spoilage by a variety of microorganisms, particularly if the pH is >3.6.

Aging. As soon as the sugar has fermented, the wine should be separated from the yeast deposit. Red table wines clarify more easily than white wines, and often a simple racking is sufficient; a rough filtration may also be necessary. In warm climates, where the total acidity is low, an early racking is very desirable. In cold climates, where the total acidity is high, the sediment (called lees) is kept in longer contact with the wine, which often contains bacteria capable of decarboxylating malic to lactic acid. This reduces the titratable acidity, and since lactic is a weaker acid than malic acid, a higher pH is obtained and the wine is less sour. Longer contact of sediment and wine also results in yeast autolysis which releases amino acids essential for the growth of the malolactic bacteria.

Because of their high tannin content, many red wines must be stabilized before bottling. The best red wines are aged for two or three years in wooden casks. The excess tannins are gradually oxidized or combine with aldehydes and precipitate; tartrate stability results. When red wines are bottled young, a special chilling removes excess tartrates. In addition, clarification (fining) with gelatin to remove excess tannin may be required. Just before bottling, a close (pad) filtration brings the wine to a perfect state of clarity. Even so, red wines frequently have a slight deposit when aged in the bottle for several years. If red table wines contain residual fermentable sugar, germ-proof filtration or hot bottling may be required.

Aging of red wines not only reduces excess sourness and tannins but also produces wines of special bouquets (by complicated oxidation–reduction–esterification reactions).

White table wines lose their yeasty odor during early aging. Many are then bottled and hardly change upon further aging. However, wines with a higher alcohol content, eg, Chardonnay, white Burgundy, Sauternes, Auslese, may be develop complicated and desirable bouquets in the bottle.

Sparkling Wines. Wines containing a permanent visible excess of carbon dioxide are called sparkling wines. The nomenclature of the sparkling wines is somewhat complicated. The most famous name is champagne, originally produced only in the region of that name in France where this appellation may be used only for wines produced and fermented in that region. However, the name is used in other countries as well, although local names are used in some countries, eg, Sekt in Germany and spumante in Italy. In the United States, the term champagne is used for most sparkling wines produced by a secondary fermentation of sugar in closed containers. If fermented in tanks, it must be so stated on the label.

In Europe, many wines are bottled with a slight residual sugar content. During aging this sugar may ferment, and the wines become slightly gassy; wines of Alsace, the Loire region, and Switzerland are frequently of this type. A certain amount of yeast growth is necessary to produce this gassiness, but the yeast deposit is often surprisingly small. At slightly higher temperature, this type of wine loses the gassiness that is one of its chief attractions; furthermore, the residual sugar may ferment, thereby producing a large yeast deposit which affects the odor.

Gassiness also results when the malic acid of the wine ferments, giving lactic acid and carbon dioxide. However, a high malic acid content is necessary for such fermentation. The vinho verde wines of Portugal are of this type, as are some gassy northern Italian wines.

Red wines must be a medium red without brown or violet overtones and have minimal tannin content. White sparkling wines must have a fresh fruity taste, have a light color, and be free of undesirable odors. Other requirements are given in the following list.

alcohol, %	10–11
pH	3.0–3.4
volatile acids	<0.04

Fermentation. The production of sparkling wines requires careful control of the harvesting, crushing, pressing, and fermentation. The harvest must be timed to obtain a sugar content adequate for at least 10% ethanol. However, it must not be delayed too long or the acidity is too low and the alcohol content will be too high. The crushing should be rapid and complete, followed immediately by pressing and settling. Where red grapes are used to produce white musts, as in the Champagne region of France, crushing may be omitted and the grapes sent straight to the presses. This gives a clearer and lighter colored must.

The must is fermented below 16°C and no sugar should remain. Pure yeast cultures of some agglutinating strains are employed. The new wines are clarified as rapidly as possible. They are cooled at 4.4°C for several weeks or chilled at ca −7°C for several days; tartrate stability is tested. The wines are fined and filtered.

Since only a rare single wine has all of the desired qualities, blending is common with wines of higher and lower alcohol content and acidity. However, low volatile acidity is essential as is absence of off-odors or off-tastes. Small amounts of citric acid are added to correct the total acidity. The free sulfur dioxide content should not exceed ca 5–10 mg/L in order not to interfere with the secondary fermentation or contribute an undesirable odor. The blended wine should be filtered and analyzed for sugar, iron, copper, and protein. Recommended maximums are 200, 5, 0.3, and 25 mg/L, respectively.

The total sugar content is then increased to 24 g/L. This is sufficient to give a pressure of ca 600 kPa (6 atm) in equilibrium with the wine if the carbon dioxide is not allowed to escape. In general, commercial invert sugar solutions are used, and occasionally sucrose. Rock candy is sometimes dissolved in wine containing ca 0.5% citric acid and heated to give a 50 vol % solution of invert sugar. An actively fermenting culture of *Saccharomyces cerevisiae* is then added at ca 1%. The so-called champagne strain is usually employed since it is an agglutinating type. To aid in later clarification, some producers also add a small amount of clarifying agent, such as bentonite, to the wine.

At this stage, the wine may either be transferred to special bottles (700–750 mL) or to stainless-steel pressure tanks of 20–1500 hL (500–40,000 gal) capacity for fermentation. In the tank process, the blending tank is used for the second fermentation. Although both procedures are used in the United States, the tank method is cheaper and less hazardous than the bottle procedure. The temperature is easily controlled, excess pressure can escape, and the wine can be stabilized in the tank. However, air comes in contact with the wine during the transfer from tank to tank since no counterpressure of carbon dioxide may be used in the United States. Fermentation in bottles is considerably more expensive; manual operations require great skill, and much equipment and time is needed. However, these wines have a lower aldehyde content and greater bouquet, presumably because of greater yeast autolysis during the longer aging period in bottles.

In the bottle operation, the blended, sweetened wine plus yeast are continuously agitated during bottling. Special bottles capable of withstanding a pressure of ca 800 kPa (8 atm) are used. They are closed with crown caps, which are cheap and conve-

niently attached and removed. The bottles are stacked in a constant-temperature room or, more commonly, held in bins. In the United States, the fermentation temperature is 16°C to ensure rapid and complete fermentation. However, the quality is enhanced at a lower temperature of 10°C. The fermentation takes from three weeks to six months, depending on the temperature and the particular wine. Wines with an alcohol content above 11.5% and lower nitrogen content may ferment more slowly below 10°C. Aging in the bottles in contact with the yeast for one to three years improves the quality (bouquet).

During fermentation, a yeast deposit forms on the lower side of the bottle, which must be removed before the wine is marketed. The bottles are placed upside down in special A racks to permit shaking the yeast deposit gradually down onto the cork. This procedure is called riddling and takes ca 3–6 wk. It is a highly labor-intensive hand manipulation which is being replaced by mechanized riddling racks or by mechanical shaking of large bins containing ca 500 bottles.

Then the deposit on the cork must be removed. The wine is under a pressure of at least 600 kPa (6 atm). The bottles are chilled to ca 2°C, and the necks are frozen solid by submersion in an ice–salt mixture or in special freezers. At this temperature the pressure is reduced considerably, and when the cork is removed the solid ice plug from the neck of the bottle containing the yeast deposit is ejected, carrying with it the yeast deposit. This procedure is called disgorging. Immediately after the plug is ejected, the bottle is temporarily closed to prevent loss of pressure. A small measured amount of sweetening agent and enough wine of the same kind to fill the bottle are then added. The sweetening agent (*liqueur d'expédition*) is usually a mixture of brandy, wine, and sugar. The formula is different for each company; however, American producers use little or no brandy. The best aged sparkling wines receive only enough of this mixture to bring the total sugar content to ca 1%. This is sold as brut or nature. The so-called dry (or sec) wines are sweeter (2–3% sugar), and the demi-sec may have ≥5% sugar. Very little sweet or doux sparkling wine, containing ca 10% sugar, is prepared. The bottle is closed with a large cork which is kept in place with a wire netting. The bottle is then ready for labeling and shipment. Losses during aging and disgorging reduce the pressure within the bottle of the finished wine to 300–400 kPa (3–4 atm). In many wineries, disgorging, sweetening, and corking operations are mechanized.

Instead of individually disgorging bottle-fermented wines, they are sometimes disgorged into a tank, sweetened, and then filtered into a bottle. No riddling is necessary. This procedure is called the transfer system. To counteract oxygen pick-up, a small amount of sulfur dioxide is usually added and a counterpressure of nitrogen applied. This procedure is less expensive.

In the tank system, two or more tanks are required. The first tank is jacketed for temperature control during fermentation and clarification. The fermentation is carried out at ca 16°C, since the main advantage of the tank system is rapid turnover of wine. Lower temperatures, ca 10°C, are reported to give a better quality. Fermentation is complete in 1–4 wk. The wine is then chilled and filtered to a second tank, where the required amount of sugar is added. Then the wine is bottled under pressure; sometimes the sugar solution is placed in the bottle first. The entire process may be completed in 4–6 wk. Sulfur dioxide is employed as an antioxidant to prevent fermentation of the added sugar and inhibit yeast growth. It may, however, impart an unpleasant odor. Since there is little time in the tank process for the yeast cells to die, a few viable yeasts may pass through the filter and into the wine. In the bottle process, when properly conducted, most of the yeast cells are dead after two or three years' storage.

Sparkling burgundy and other red or pink sparkling wines are produced by the same procedures. Because of their higher tannin content, they are frequently sweetened to 5% sugar to mask the astringency.

Carbonation. Instead of using costly fermentation processes to secure an excess of carbon dioxide, the gas may be added to the wine; good mixing is essential. Direct carbonation is conducted at a low temperature and with small bubbles. Carbonated wines are traditionally cheaper than fermentation-produced wines. Wines of lower quality and price may be used in their production. They may be older, but they should still retain a fruity flavor, have a light unoxidized color, and be free of off-odors. For the best flavor, the wines should have a relatively low redox potential; small additions of sulfur dioxide and ascorbic acid may be desirable. Before carbonation, the wine is clarified and the requisite amount of sugar added, ca 1–4%. Carbonation pressure is usually ca 400–500 kPa (4–5 atm). The same closure, cork or plastic, is employed as for other sparkling wines. Very few fully carbonated wines are now produced.

Dessert Wines. Less than 20% of all the Californian wines are fortified as dessert wines with an alcohol content of 17–21%. Both red and white dessert wines are produced; the white may be either dry or sweet (11). Worldwide, probably less than 10% of the wines are dessert types.

White Dessert Wines. Muscatel, Angelica, white port, and sweet sherry are the sweet dessert wines produced in the United States; dry sherry is the only dry type and it is often at least slightly sweet. Famous European dessert wines include Malaga (Spain), Marsala (Sicily), and Madeira (Madeira Islands).

For muscatel and related types, a must of high sugar content ($\geq$24%) is required. However, the pH should not be too high, and the grapes not raisined. They are crushed as for dry white table wines, but pressing is frequently dispensed with in California. Only the free-run juice is drawn off and used for wine. The sweet pomace is mixed with water and fermented. The wine thus produced is used for distillation. This procedure is economical as a large amount of alcohol is required in the production of dessert wines. Since only alcohol produced from wines may be used, considerable distilling wine is required. In the production of muscatel, the must and skins usually remain in contact for a day or two in order to increase the extraction of muscat flavor from the skins.

Normally ca 100 mg of sulfur dioxide per liter are added after crushing, and except at the beginning of the season, pure yeast cultures are seldom employed because the fermentation period is only 2–3 d. For example, a must of 25° Brix is fermented to ca 15° in order to produce a finished fortified wine of 12% sugar. At 15°, there is <5% alcohol. Since dessert wines are sold with 17–20% alcohol, ca 12–15% must be added. In the United States, this procedure is called addition of wine spirits or fortification; it is carried on under the strict control of the Bureau of Alcohol, Tobacco and Firearms of the U.S. Treasury Department. The fortifying brandy is ca 95% alcohol or 190 proof. Fortifications of 1000–4000 hL (25,000–100,000 gal) are commonly made in California.

The fortified wine is stored in tanks where the yeast is allowed to settle. The first racking and rough filtration follow a few weeks later. Dessert wines can be brought to brilliancy earlier than table wines because they are not very sensitive to the undesirable oxidative changes that occur with the repeated manipulations of table wines. Chilling, pasteurization, heavy fining, and repeated filtrations secure a brilliant wine. Some dessert wines reach the market within six months of the vintage and are stored in lined metal tanks. Others may be aged in casks or barrels for months to years. Al-

though dessert wines profit by aging in wooden casks, this is done only where the original quality justifies it and when the demand for quality dessert wines is sufficient. Because of their high alcohol content, dessert wines are not as subject to acetification and thus can remain in the cask at higher temperatures for longer periods than table wines.

California white port is very young Angelica which has been partially decolorized with large amounts of charcoal or made from very light-colored free-run musts. It is seldom aged and production is small. Portuguese white port is not decolorized. California white port, Angelica, and muscatel are marketed with ca 12–14% sugar.

California sherry is a fortified wine of low sugar content that acquires its characteristic odor by being heated (baked) at ca 57°C for three or four months. It resembles the wines of Madeira much more than those of the Spanish sherry district, which are produced by different processes. This must is fermented as for sweet dessert wines, except that the fortification is postponed until only 1–7% sugar remains. The fortified wine is clarified and then placed in large redwood, lined metal, or stainless steel tanks. It is brought to the desired temperature by circulating hot water or steam in pipes placed in the tank or through the tank jacket. Not much additional heat is needed to maintain the temperature. Very little wine is baked in barrels exposed to the sun, since there is a large loss by evaporation. After the heating, the wine is clarified and marketed; it improves by aging in oak cooperage of 2–100 hL (50–2600 gal).

Sweet California sherry is usually a blend containing some slightly sweet sherry produced as described above plus some very sweet California Angelica. Baking a very sweet wine at 60°C results in a caramel flavor. If too pronounced, blending is necessary. A wine called California Tokay is produced by blending ca equal proportions of sherry, port, and Angelica. It has a brown-pink color and some of the slightly burnt flavor of sherry.

In the production of Spanish sherry, a surface film of yeast forms after the primary fermentation to ca 15% alcohol (12–13). The wine is kept in barrels that are only ca three-fourths full. Various oxidation–reduction changes occur during the formation of the film, including an increase in acetal and acetaldehyde and a decrease in acetic acid. This procedure gives the wine a characteristic and much appreciated bouquet. Variations of this process are now employed in Australia, California, Canada, Cyprus, South Africa, and the USSR.

Film-type yeasts have been successfully grown in submerged culture. A suitable dry white wine of 15.5% alcohol is pumped into a lined tank equipped with a stirrer. A rapidly fermenting culture of the film-type yeast is added and a small amount of air bubbled through the wine at a pressure of ca 101 kPa (1 atm). Periodically, the stirrer is operated to prevent the yeast from settling to the bottom of the tank. Under these conditions, the aldehyde content increases rapidly, often reaching 500–700 mg/L in 2–3 wk. For sale, the aldehyde content is reduced to 150–200 mg/L by blending. The process is being used commercially in Canada, the USSR, and California.

Red Dessert Wine. Port and port-type wines are the main red U.S. dessert wines, although a small amount of red muscatel is also produced. The prototype port is produced in a delimited district along the Douro river east of Oporto in Portugal. A number of red varieties are used, ie, the darker, stronger flavored wines are used for vintage or ruby port, whereas the lighter-colored wines are aged for tawny port.

The primary problem in the production of red dessert wines is to secure an adequate extraction of color during fermentation. This is made more difficult by the

limited period of fermentation and the normally low color of grapes grown under warm climatic conditions. Most of these wines are produced in warm regions in order to secure grapes of high sugar content. The grapes are harvested at a 24° Brix or more and crushed and stemmed as for red table wine. For the best color, they should be harvested before the pH is too high. A compromise has to be made between 24° Brix and a pH of <3.5 or 3.6. In order to secure a good extraction of color from the skins, the juice and skins are heated very rapidly to ca 82°C, held for one or two minutes at this temperature, and then cooled. Previously, the mass of grapes was gradually heated to ca 70°C and then cooled, usually by circulating water in pipes in the tank. This procedure takes longer and may impart a cooked taste and a color more purple than desired. The cooled must is then fermented to the proper degree Brix.

In the absence of heating, the cap must be pressed down frequently into the fermenting liquid. In Portugal, the treading of grapes in shallow tanks had the same objective, but this custom is now disappearing. Whatever the system, pressing or drawing-off takes place in 2–4 d.

Ports are relatively simple to clarify and age. Some wines made from heated musts contain too much pectin and remain cloudy, and a pectin-splitting enzyme may be used to aid clarification. Ports may have the normal red color or be of the tawny type; it may require 3–5 yr to develop the proper tint. Alternatively, early maturing tawny ports may be produced by using tawny-colored grapes. Tawny ports are sometimes produced by heating the wine for three or four weeks at 60°C, but this procedure is illegal in Portugal and may produce an undesirable caramel flavor. A very limited amount of the finest Portuguese and port-types of other countries, including California, are bottled after two years' aging. After 10 to 20 years, this wine develops a special bouquet which is much appreciated. This wine is called vintage port and is very expensive.

Fruit and Berry Wines. The production of fruit wines is similar to that of grape wines, except that the sugar must always be added because of the low sugar content of most berries and fruit (13). Most fruits are soft and easily crushed. The juice is separated from the pulp of apples and pears, but most other fruits, particularly berries, are fermented with the pulp. Sufficient sugar is added to make a wine of 11–13% alcohol. For European fruit wines, only enough sugar to produce 9–11% alcohol is used. If fermented with the pulp, the juice is separated when color extraction is complete. The new wine is clarified in the usual way; most U.S. fruit wines are sweetened to 10% sugar or more before sale, although apple and pear wines are occasionally sold without sweetening. A few wines, eg, from peaches or apricots, are fortified to 18% alcohol as well as sweetened.

Grape and berry wines may not be mixed unless sold and labeled as a mixture. All berry and fruit wines are best when consumed young. After aging, the color fades and the characteristic odor of the fruit often disappears or is greatly diminished. These wines are easily stabilized and can safely be marketed soon after production. They are almost always pasteurized in the bottle to prevent fermentation. In the United States, demand appears to be limited.

Naturally Flavored Wines. In the United States, these wines were legally recognized in 1958. Natural herbs, spices, fruit juices, aromatics, essences, and other natural flavorings may provide the base, and sugar and caramel may be added; apple wine may be blended in. These wines are made both as table (<14% alcohol) and dessert wines. All are sold with proprietary names, eg, Bali Hai, Silver Satin, and Thunderbird. These

wines are usually consumed with ice and soda. Some have a distinct citrus aroma. Sales have decreased since the 1960s.

Vermouth. Vermouths are nearly dry or sweet fortified wines to which herbs or herb extracts are added (10). The nearly dry or French type is used straight or for martini cocktails. The sweet or Italian type is used for Manhattan cocktails, but in Europe is more often consumed as a dessert wine or aperitif. The herbs in vermouth should be easily detectable, but the odor of no single herb should be allowed to predominate (see also Flavors and spices).

Dry. For dry vermouth, a light-colored wine of moderate total acidity is fortified to ca 17–18% alcohol. In the United States, dry table and dessert wines, such as low sugar sherry, are sometimes blended to yield a wine of the proper alcohol content and 1–4% sugar, to which a mixture of herbs is added, such as wormwood, gentian, orris, marjoram, centuary, bitter orange peel, pomegranate root, anise, nutmeg, vanilla, cinnamon, and others. The herbs and the proportions of each used are proprietary. Some typical formulas are given in refs. 11 and 14.

The herb mixture may be blended directly or placed in sacks that are submerged in the wine. The extraction may take from a few days to two weeks, depending on the flavor strength desired. If the extraction takes too long, tannins and other bitter substances are also extracted. Today, most wineries use herb extracts.

The wine is then filtered and stabilized. Some aging is desirable, but the color should be kept light. Much of the vermouth sold in the United States is partially decolorized with charcoal because bartenders prefer a very light-colored vermouth for martinis.

Sweet. The Italian sweet vermouth was originally produced in the 18th century with a muscatel wine as a base. At present, any sweet white dessert wine is used and grape concentrate or sucrose may be employed for sweetening. Furthermore, some caramel or dark-colored sherry is frequently added. Herb extracts rather than the herbs are generally employed. The appropriate mixture of herbs is extracted with alcohol, the extract filtered, and the proper amount added to the wine base. Sweet-vermouth herb mixtures often contain some vanilla. Clarification may be difficult if the herb extract was not clear or if the herbs were placed directly in the wine. Chilling, heating, and clarification with bentonite provide clarity.

Finishing. The aging, blending, clarification, and bottling practices in American wineries are carefully controlled by laboratory tests (14). Trained chemists taste and analyze the wines and prescribe the proper treatments to secure stability and the best quality.

Filtration. The wine is passed through a porous pad or layer of inert material with a fine pore size. For removing large particles, coarse pads are used; the filter plates can be ≥ 1 m in diameter. In order to extend the filtration, a filter aid of diatomaceous earth is mixed with the wine before filtration. Other filters consist of fine screens on which a precoat of porous inert material is placed. Smaller filters with pads of small pore size are employed for a polishing filtration or a prebottling filtration. For sweet table wines, sterile filtration may be required through pads with a pore size small enough to remove yeast cells. The entire bottling line must be sterile, and the filtration is conducted at a low, steady pressure. Membrane filters of small pore size are used for this purpose (see Membrane technology; Ultrafiltration).

Fining. Mechanical or chemical clarification is an old practice. A gelatin solution combines with the tannin in the wine, and the precipitate fines or clarifies the wine; a solution of egg white or isinglass may also be used. More recently, the organic fining agents have largely been supplanted by bentonite, a montmorillonite clay with excellent swelling properties and some adsorption capability. It may be used on hot or cold wines, and an excess does not result in cloudiness, as it may with organic clarifiers. It is especially effective in removing proteins. However, a large flocculant deposit is produced, and therefore the wine is tested to determine the minimum amount needed. A similar material, kieselguhr, is used in Europe.

Refrigeration. During the cold winters in Europe, wines lose their excess cream of tartar, especially when in small containers and after a long period of aging. In California, because of the mild winters, large containers, and relatively shorter aging period, artificial chilling is needed to remove tartrates. Of course, this is also practiced in Europe and elsewhere. Table wines are chilled to ca −4°C and dessert wines to <−5.5°C. Chilled rooms, insulated tanks with internal circulating systems, and jacketed tanks are used. The process requires ca two weeks, and the tartrates should be filtered cold to prevent resolution.

Ion-exchange resins are now used by a few wineries to reduce the danger of cream of tartar precipitation and partially replace potassium by sodium or hydrogen. These must be used with caution. At least 500 mg/L of potassium should remain in the finished wine, and the sodium content should be <200 mg/L.

Pasteurization. Pasteurization stops microbial growth and aids in clarification; in the United States, the latter is more important. Contrary to common belief, pasteurization does not prevent reinfection; in fact, pasteurized wines may be more sensitive to infection. Pasteurization, however, when properly used, kills undesirable bacteria and is a useful practice for wines of moderate quality. Sweet table wines are sometimes hot-bottled above 66°C as a safety measure. When heating to aid clarification, even higher temperatures (but shorter periods) are used. The wine is then rapidly cooled and filtered.

Packaging. Automatic bottling, corking or capping, labeling, and casing lines are employed in large wineries. These are less labor intensive and give better results than manual procedures. The bottles are packed in cardboard boxes for shipment. Most wines are sold in glass bottles or plastic containers. There are standards for filling, and only certain bottle sizes are permitted in the United States.

Corks are employed for wines aged in the bottle, that is, for the better quality red and white table wines. Plastic or metal screw caps with inert liners are used for other table wines and most dessert wines (see Cork).

Spoilage

Wines are relatively immune to spoilage because of their alcohol content and low pH (10,14–15). Contact with air may result in acetification, which can be avoided by keeping the containers full or by pasteurization. Low acid wines may be spoiled by lactic acid bacteria, which can be prevented by a low concentration of sulfur dioxide. Yeast infection may be a problem.

Iron and copper originating from equipment occasionally cause cloudiness in white table wines; this problem does not occur with stainless-steel equipment. Iron cloudiness is partially inhibited by small amounts of citric acid which forms an iron complex.

Copper–protein cloudiness is partially inhibited by fining the wine while hot with bentonite, which removes the proteins responsible.

Economic Aspects

U.S. production and consumption of wines constitute only a small fraction of the world total (see Table 3). In 1980, the estimated world production was 351×10^5 m^3 (927×10^7 gal). The U.S. wine industry has been engaged for a number of years in a public relations campaign to increase per capita consumption. World production consists predominantly of red and white table wines.

The California wine industry dominates U.S. production. Some California grape concentrate and wine spirits are shipped to the east and then appear as eastern production. California produces more sparkling wine and vermouth than the other states combined. Californian wine is also shipped east and is converted there into sparkling wine or vermouth. The U.S. wine trade and production are given in Tables 4 and 5, respectively.

The prices of California wines have fluctuated very widely over the years, as bulk prices, in cents per liter, demonstrate:

	1967	*1978*
dessert wines, ¢/L	15	42
table wines, ¢/L	9–12	34

Table 3. Wine Production and Consumption, 1980

Country	Production, 10^5 m^3	Annual per capita consumption, L
France	69.20	95.4
Italy	84.75	93.1
Spain	43.52	60.0
United States	18.40	8.0

Table 4. U.S. Wine Trade, 1980–1981 Calendar Year Average [a], m^3 [b]

Type	Domestic production	Imports	Total
table	10,595	3,552	14,146
table, sparkling	991	226	1,217
dessert	1,521	106	1,628
vermouth	206	109	314
other special natural wines	1,225	119	1,344
Grand total	*14,538*	*4,112*	*18,649*

[a] Prepared from Reports of U.S. Treasury Department, Bureau of Alcohol, Tobacco and Firearms, and U.S. Department of Commerce, Bureau of the Census.

[b] To convert m^3 to gal (U.S. liquid), multiply by 264.

Table 5. U.S. Wine Production, 1980–1981 Crop Year Average[a], m^3

Type	California	All other states	Total
gross[b]	15,596 (estd)	1,795 (estd)	17,391 (estd)
sparkling	922	155	1,078
vermouth	182	27	209
other special natural wines	1,155	107	1,262

[a] Prepared from reports of U.S. Treasury Department, Bureau of Alcohol, Tobacco and Firearms.

[b] Gross wine production is the quantity removed from fermentors plus the increase after fermentation by amelioration, sweeting, and addition of spirits, minus withdrawals for distillation. It includes wines subsequently used in producing sparkling wines, vermouth, or other special natural wines.

Sensory Evaluation

Consumers have definite preferences and tolerances for different types of wine. These originate largely from family and cultural traditions. In examining wines for their sensory differences or in serving wines with a meal, the drier (less sweet) wine with lower alcohol content precedes the sweeter, more alcoholic wines; white wines are generally served or tasted before red.

Anyone who so desires can become a wine connoisseur. Although some information is available (16–17), preference is highly subjective, and wines are judged on personal taste.

Professionals use score cards, ranking, paired, duo–trio, and triangular tests for identifying differences in wines. Statistical analysis of the data is recommended.

The results of local and regional judgings are often difficult to evaluate because of the varied ability of the participants and the usual lack of statistical evaluation of the results.

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M. A. AMERINE
University of California at Davis
Consultant, San Francisco Wine Institut

WINTERGREEN OIL. See Oils, essential.

WITHERITE, $BaCO_3$. See Barium compounds.

WOLFRAM AND WOLFRAM ALLOYS. See Tungsten and tungsten alloys.