CHAPTER 8

Vermouth: Technology of Production and Quality Characteristics

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Abstract

The aperitif wine, known as vermouth, is primarily prepared by adding a mixture of herbs and spices or their extract to a base wine. As such, it could also be called aromatized liquor, or a fortified wine. Various plant parts, such as seeds, wood, leaves, bark, or roots in dry form can be used in flavoring. These additives may be infused, macerated, or distilled in a base white wine, or added at various stages of preparation. The final liquid is filtered, pasteurized, and fortified (by the addition of alcohol). Some vermouths are sweetened, whereas other are left unsweetened (dry vermouth). These tend to have a bitterish finish. The two versions differ in alcohol content as well.

Vermouths are most commonly prepared from grape-based wines, but fruit-based wines made from mango, apple, plum, sand pear, and wild apricot may also be used. These possess distinct physicochemical and sensory qualities from standard vermouths.

The review gives comprehensive information on the historical developments and technology of vermouth production, the various spices and herbs used in its production, and its quality characteristics. In addition, the chapter also discusses the commercial potential of nongrape fruits in vermouth production.

I. INTRODUCTION

Vermouth is officially classified as an ''aromatized fortified wine,'' referring to its derivation from a white base wine fortified and infused with a proprietary set of different plant parts: barks, seeds, and fruit peels. These are collectively termed botanicals. Vermouths are particularly popular in Europe and in the United States (Amerine *et al.*, 1980; Griebel, 1955; Panesar *et al.*, 2009). The term ''vermouth'' is derived from the German word for wormwood *Wermut*. It is supposedly derived from *Wer* (man) and *Mut* (courage, spirit, manhood; Pilone, 1954). When vermouth was introduced into Bavaria in the first half of the seventeenth century, by the Piedmont producer Alessio, *Artemisia absinthium* was probably translated literally as *Wermutwein*. When it reached France, it was changed to vermouth (Liddle and Boero, 2003).

Vermouth is fortified up to 15–21% alcohol. The proprietary mixture of herbs and spices impart an aromatic flavor as well as its bitter taste

(Amerine *et al.*, 1980). Vermouths are typically classified as sweet (Italian) or dry (French). In the Italian version, the alcohol content can vary from 15% to 17%, with 12–15% sugar. French versions have 18% alcohol with 4% reducing sugar. Dry vermouth contains less herb and spice extract than the sweeter vermouth—about 3.74–5.62 mL/L for dry, and 5.62–7.49 mL/L for sweet (Amerine *et al.*, 1980; Panesar *et al.*, 2010).

Traditionally, vermouth and aperitif wines are prepared from grape-based wine, with the addition of an herb and spice mixture or their extracts. In Europe, these beverages are served straight (without the addition of water), whereas in America, they are mostly used in preparing cocktails. The herbal infusion gives vermouth its unique flavor and aroma.

The herbal infusions donate antioxidant characteristics to vermouths, primary from the addition of phenolic compounds. This may provide some protection against the oxidative stress.

II. HISTORY OF VERMOUTH

The term *vermouth*, as discussed earlier, is derived from *Wermut*, the German word for wormwood—a frequent ingredient in vermouth. This is probably based on the alleged beneficial properties derived from wormwood. Wormwood has powerful medicinal and psychoactive qualities and was historically used to cure stomach problems, including intestinal worms. Wormwood is also very bitter. Wormwood is no longer added, but vermouth is still characterized by a bitter undertone contributed by the botanicals.

The addition of wormwood to wine appears to date from early Roman, and probably early Greek, times. It was classically used in the treatment of intestinal worms and added to wine and ale since the time of the Greek mathematician, Pythagoras. Wine infused with herbs, including wormwood, was utilized as a tonic and medical treatment by Hippocrates.

Commercial production of vermouth did not begin until the eighteenth century. The wine was first produced in Italy by infusing it with wormwood (Pilone, 1954), presumably to enhance the taste of sour or uncompromising wine with the flavors of a variety of sweeteners, spices, herbs, roots, seeds, flowers, and peels.

Vermouth's commercial origin dates to 1786, when Antonio Benedetto Carpano began marketing the aromatized wine he produced in Turin, Italy. However, the consumption of vermouth-like products, and its precursors, stretches back centuries (Clarke, 2008; Panesar *et al.*, 2009; Pilone, 1954).

Vermouth is typically made from neutral-flavored, dry, white wines, flavored with herbs, roots, and barks. These typically include cardamom, cinnamon, marjoram, and chamomile. The wine is finally fortified with a neutral grape spirits.

In the early seventeenth century, vermouth production was brought by a Piedmontese Italian, Signor Alessio, to Bavaria. He called his preparation *Vinum Hippocraticum*, the name used for it by ancient Romans. Hippocrates is reported to have macerated the flowers of dittany and wormwood in strong, sweet Greek wine. The satisfying and digestive beverage was called ''Hippocratic wine'' or *Vinum absinthianum*. Later, the Romans elaborated on the production of such wines by introducing other herbs, such as thyme, rosemary, myrtle, and celery. The beverage was used throughout ancient times as well as during the Middle Ages (Liddle and Boero, 2003). Alessio's *Vermutwein* was possibly a rediscovery or refinement of this very old, well-known drink (Doxat, 1976).

From here, it is believed to have been brought to the French royal court, where its name was gallicized to *vermout* (Doxat, 1976). Nonetheless, Alessio's maceration of wormwood flowers, an improvement on earlier vermifuges, failed to appeal to the Parisian public. Thus, France lost the opportunity of becoming the original home of vermouth production.

By the late seventeenth century, homemade vermouths were commonly being made in Piedmont (Italy). In the decades following Carpano's commercial debut, other vermouth makers began production in Turin. Nonetheless, the founding of the modern vermouth industry dates from 1840. At that time, King Carlo Alberto of Sardinia-Piedmont (1798–1849) enforced the first rigorous quality control relative to its production in Turin, the world's vermouth capital. The firm now known as Martini & Rossi, the largest manufacturer of vermouth, received its first license and started production in 1863 (Clarke, 2008; Kauffman, 2001).

Vermouth was initially made from red wine, produced to be slightly sweet, and possess a mildly sharp after taste. However, around 1800, dry vermouth made its appearance in the Marseilles, France. In 1813, Joseph Noilly created the style that came to be known as dry or French vermouth. By 1855, Noilly's son, Louis, and his brother-in-law, Claudius Prat, were producing Noilly Prat dry vermouth in southern France. This white, wine-based, fortified drink, is now flavored with as many as 40 aromatic herbs and flavorings, such as juniper, cloves, quinine, orange peel, nutmeg, and coriander (The New Encyclopaedia Britannica, 1995).

Both sweet and dry versions are used as aperitifs, with French vermouth used in martinis, while Italian vermouths are used in manhattans (Edmunds, 1998; Kauffman, 2001). In the middle of nineteenth century, the north of Italy, mainly around Turin, and the Chambery district of France become established centers of herb production for vermouth.

In parts of the world where vermouth is popular, additional versions are available, beyond the two mainstream styles (Clarke, 2008). In the 1960s, Cinzano launched a rosé vermouth. Martini & Rossi also produce a rosé vermouth, sold primarily in France. The French producer Dolin produces a strawberry-flavored vermouth, called Chamberyzette, for the European market. Noilly Prat makes limited quantities of Noilly Ambre. It is a rich-tasting vermouth, flavored with botanicals, including cinnamon and orange peel. It is sold almost exclusively from its production facility in Marseillan.

III. MEDICINAL AND AROMATIC VALUE OF VERMOUTH

The infusion of spices and herbs not only gives vermouth its unique flavor and aroma but also imparts medicinal properties. Some of the benefits ascribed to vermouth are given in Table 8.1. Feher and Lugasi (2004) compared the antioxidant characteristics of young vermouth with three red, three white, and one rosé wine. Consumption of one unit (100 mL) of vermouth provided 220 mg polyphenolics, whereas wine in the same quantity was reported to have 35 mg. Polyphenolic compounds are reported to play a substantial role in protection against oxidative stress.

TABLE 8.1 Medicinal properties of vermouth

• The plants dittany and wormwood possess tonic and digestive properties
• Wormwood has been added to wine and ale since the time of Greek mathematician Pythagoras was utilized as a tonic and medical treatment by Hippocrates
• Hippocrates macerated the flowers of wormwood plants in strong, sweet Greek wine to produce a satisfying and digestive beverage
• It is used as a treatment against intestinal worms
• This maceration of wormwood flowers improved on earlier vermifuges
• Various Indian spices are added in vermouth such as cinnamon, black pepper, coriander, cumin, clove, large cardamom, saffron, nutmeg, and ginger possess various therapeutic values
• Plant extracts are also added like rosemary, adhatoda, withania, asparagus, and woodfordia have various medicinal properties

Source: Robertson *et al.* (1989), Rimm *et al.* (1993), Stampfer *et al.* (1993), Klatsky (1994), Kiechl *et al.* (1994), and Feher and Lugasi (2004).

IV. CLASSIFICATION OF VERMOUTH

As noted, vermouth is typically classified into two categories: sweet and dry—the main difference being the number and types of botanicals used in the recipe. Quality differences arise from the nature of the base wine and the kind, quality, and amounts of herbs used (Pilone, 1954).

A. Sweet (Italian) vermouth

Sweet vermouths are produced in Italy, Spain, and Argentina, as well as other countries, such as the United States. Typically, Italian vermouth is dark amber in color, with a light Muscat sweet nutty flavor. It also possesses a well-developed and pleasing fragrance, with a generous and warming taste, and a slightly bitter but agreeable aftertaste. In Italy, vermouth must contain at least 15.5% alcohol and 13% or more reducing sugar (Rizzo, 1957; Walter, 1956). American vermouths are generally higher in alcohol and somewhat lower in sugar.

Previously, wine made from Muscat Blanc was the preferred base wine in Piedmont. It donated a pronounced muscat flavor. Currently, white wines with a more neutral flavor are used. These generally come from southern Italy. Vermouth made from these wines age more quickly and can be clarified easily. In Turin, the base wine is usually flavored with an alcohol extract from various herbs and spices. Coriander, bitter orange peel, cinchona, European centaury, calamus, elder flowers, angelica, orris gentian, cinnamon, nutmeg, and cardamom are commonly used (Joslyn and Amerine, 1964). Liquid invert sugar or sucrose may be used for sweetening. Caramel may be added to give a dark color to sweet vermouths.

In France, the base wine is normally flavored by direct maceration with whole herbs and spices. The mixture is allowed to macerate with the wine for 1 or 2 weeks, with periodic stirring (Joslyn and Amerine, 1964). The wine is tasted periodically during extraction, being drawn off and filtered when there signs of excessive bitterness or herbaceousness becomes apparent. After flavoring, the vermouth is aged for about 4.5 years or longer, in both Italy and France. The time between infusion and final bottling is normally 3–5 years (Rizzo, 1957).

In California, fortified sweet wines of light color, such as angelica and white port, may be used as a base wine for making sweet vermouth. The desired sugar content is obtained, as necessary, by the addition of grape concentrate or sucrose. The amount of water added as a result may not exceed 10% by volume of the vermouth. Citric acid may be added to adjust total acidity. The alcohol content must be sufficiently high to adjust for dilution when extracts low in alcohol are employed for flavoring.

The final alcohol content is usually 17%, total soluble solids (TSS) about 13–14%, total acidity about 0.45%, and tannic acid about 0.04%. Caramel syrup may be used if darkening is desired. However, Goswell and Kunkee (1977) recommend that grape concentrate, darkened by heating, is preferable to caramel. Pasteurization, refrigeration, and filtration are usually sufficient to stabilize the vermouth (Joslyn and Amerine, 1964). However, cloudiness may develop during refrigeration (Luckow, 1937). When this occurs, it must be removed. Prolonged aging is not desired as volatilization and oxidation can cause aroma loss (Joslyn and Amerine, 1964).

Pilone (1954) recommended that the pH be adjusted sufficiently low to prevent spoilage and that sulfur dioxide be added. Spoilage by *Lactobacillus trichodes* can be controlled by maintaining the total sulfur dioxide content at above 75 ppm (Amerine *et al.*, 1967).

B. Dry (French) vermouth

Dry vermouths usually have a higher alcohol content, lower sugar content, and are lighter color than sweet vermouths. In addition, they are usually more bitter in flavor. In a typical French dry vermouth, the alcohol content is 18% by volume, reducing sugar 4%, total acidity (as tartaric acid) 0.65%, and volatile acidity (as acetic acid) 0.053% (Joslyn and Amerine, 1964).

In Europe, the formulae for dry vermouth contain much higher amounts of bitter orange peel than sweet vermouths (Amerine *et al.*, 1967). Aloe, a bitter herb, has also been recommended as an additional ingredient. White wine from the Herault region is preferred, and may be blended with white wine made from Grenache grapes grown elsewhere (Sichel, 1945). However, the wine must be sound, light colored, and have moderate acidity. It is fortified with good quality, high-proof brandy to about 18% alcohol. Fewer herbs and spices are used than in Italian vermouth (Rizzo, 1957). The quantity of these flavoring materials per unit wine is customarily about 3.74 mL/L.

Neutral wine is mostly preferred as a base for dry vermouth in California (Joslyn and Amerine, 1964). For this, Pilone (1954) recommended grapes should be balanced in acid and sugar content, whereas higher natural acidity was recommended by Joslyn and Amerine (1964). The wine is first fortified to 24% alcohol, then combined with additional wine to reach a final ethanol content of 18–18.5%. The fortifying alcohol should be a neutral, high-proof brandy. Sherry as a fortifying agent is inappropriate as it can also mask the flavor of vermouth. American dry vermouths are generally pale colored and lightly flavored. Activated carbon is discouraged as a decolorizing agent because it absorbs flavoring and aromatic compounds. In contrast, decoloration with the fining agent casein can be used without appreciably removing flavorants. Gelatin may be added to remove excess tannins. In California, an extract or essence of spices and herbs may be used to flavor the base wine, instead of direct maceration.

The base wine is fermented to dryness. Sweetening, if desired, is added later (Pilone, 1954). The color of the wine is usually sufficiently deep as to obviate the addition caramel. Dry vermouths are given only short aging, finished, and bottled young. However, in France, dry vermouth may be aged for up to 3 years before bottling.

Martini and Rossi (Italy) and Noilly Prat (France) are the major vermouth producers in Europe and are universally recognized for their production of unique vermouths. Both are leaders in their respective countries but produce very different products (Boyd, 2007). Martini and Rossi, part of the Bacardi Empire, is the world's largest vermouth firm. It produces a range of aromatized wines, respecting tradition, but merged with modern, large-scale winemaking. The most popular Martini and Rossi vermouth in the United States is Rosso, followed by Extra Dry and Bianco. Other European vermouth houses widely recognized for their unique styles are Cinzano and Stock (Italy), and Boisserre and Dolin Vermouth de Chambery (France).

V. TECHNOLOGY OF PREPARATION

Vermouth is prepared from a base wine, extracting flavorants from herbs and spices in wine or a brandy mixture, blending the extract with the base wine, fortifying the mixture to the desired level, and finally maturing the prepared vermouth (Amerine *et al.*, 1980). The basic steps involved in a typical vermouth production process are illustrated in Fig. 8.1.

A. Preparation of the base wine

The base wine is prepared from grape juice or concentrate as for normal dry table wines (Amerine *et al.*, 1980; Jackson, 2008). The essential requirements of the base wine are that the wine be sound, neutral-flavored, and inexpensive (Joshi *et al.*, 2011a,b). For example, wine prepared largely from Ugni Blanc in Emilia is popular for Italian vermouths. The wine is fairly neutral in flavor with 10–11% (v/v) alcohol and low acidity (0.5–0.6%).

Many Italian producers use refined beet sugar for sweetening, whereas in France *mistelas* (fortified grape must) is preferred. Caramel is an important constituent where color intensification is desired and is prepared carefully for that purpose (Goswell and Kunkee, 1977). In American vermouth, wine of higher natural acidity is used.

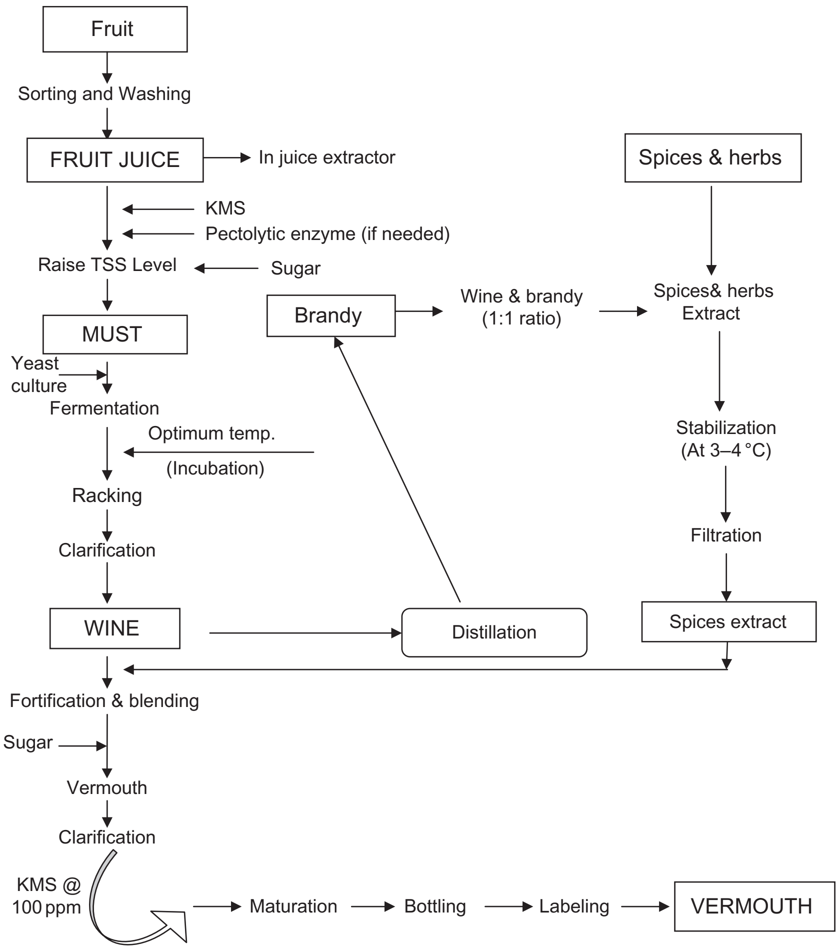

FIGURE 8.1 Basic processes involved in the preparation of vermouth.

B. Brandy distillation

Fermentation of the base white wine, used in producing the fortifying brandy, follows standard procedures. In Cognac, nonaromatic varieties, such as Trebbiano and Baco 22A, are used, where in Armagnac, Trebbiano is preferred. These cultivars have little varietal aroma, retain high acidity, and have limited alcohol production potential. In California, French Colombard, Thompson Seedless, and Tokay are the cultivars without distinctive flavor used to produce a brandy base wine.

Inoculation of the juice with active dry yeast is preferred to minimize the production of undesirable odors. Generally, *Saccharomyces bayanus* is employed to conduct the fermentation (Jackson, 2000). According to the United States Pharmacopeia, brandy for medicinal purpose is ''*spiritus vini vitis*, an alcoholic liquid obtained by the distillation of fermented juice of sound, ripe grapes and containing, at 15.56 °C, not less than 48% and not more than 54% by volume of ethyl alcohol. It must have been stored in wood containers for a period of not less than four years.''

Brandy can also be prepared from fruits other than grapes, notably apple, peach, plum, apricot, cherry, prunes, and various berries (Crowell and Guymon, 1973; Jaarsveld *et al.*, 2005; Joshi, 1997; Valaer, 1939). Further details on brandy distillation, including base wine preparation, distillation, and oak wood maturation is available in Amerine *et al.* (1980) and Jaarsveld *et al.* (2009).

In distillation, three fractions, termed the ''head,'' ''heart,'' and ''tails,'' are separated. The middle fraction (heart) is retained, whereas the head and tails are discarded (Amerine *et al.*, 1980; Jackson, 2008; Joshi, 1997). Double distillation of the hearts fraction increases the brandy's alcoholic strength.

C. Base wine flavoring

Brandy or alcohol extracts of spices and herbs may be used for flavoring vermouth (Rizzo, 1957). Spices like anola, and ginger are known to possess medicinal properties, as well as antimicrobial activities (Joshi and John, 2002). The precise details of extraction differ among manufactures. The more important botanical constituents include coriander, cloves, chamomile, dittany of Crete, orris, and quassia. Additional flavorant may include allspice, angelica, anise, bitter almond, cinchona, coriander, juniper, nutmeg, orange peel, and rhubarb.

1. Herbs and spices

Flavorants used in vermouth production have often been classified into bitter, aromatic, or bitter-aromatic categories (Pilone, 1954). These have been summarized by Brevans (1920), Pilone (1954), and Joslyn and Amerine (1964) (see Table 8.2).

The quality of these ingredients can be affected by harvesting and storage conditions. Climatic conditions may also considerably modify their characteristics. Extended dry storage often reduces quality as volatiles are lost during storage. Therefore, any dried herbs and spices should be as fresh as possible. Further, as volatilization of flavor and aroma is more rapid from ground material, the storage life of powdered and granular products is shorter than their native form (Amerine *et al.*, 1980).

2. Methods of flavoring base wines

Different herbs and spices may require different extraction methods. Therefore, various procedures are employed for extraction and addition.

TABLE 8.2 List of herbs and their plant part used in the production of vermouth

Common/ commercial name	Scientific name	Portion of plant commonly used
Allspice	*Pimenta dioica or P. officinalis*	Berry
Aloe (socotrine)	*Aloe perryi*	Plant
Angelica	*Angelica archangelica*	Root (occasionally seed)
Angostura	*Cuspar febrifuga or galipea*	Bark
Anise	*Pimpinella anisum*	Seed
Benzoin, gum benzoin tree	*Styrax benzoin*	Gum
Bitter almond	*Prunus amygdalus*	Seed
Bitter orange	*Citrus aurantium var. amara*	Peel of fruit
Blessed thistle	*Cnicus benedictus*	Aerial portion + seeds
Calamus, sweet flag	*Acorus calamus*	Root
Calumba	*Jateorhiza columbo*	Root
Cascarilla	*Croton eleuteria*	Bark
Cinchona	*Cinchona calisaya*	Bark
Cinnamon	*Cinnamomum zeylanicum*	Bark
Clammy sage, common clary	*Salvia sclarea*	Flowers and leaves
Clove	*Syzygium aromaticum*	Flower
Coca	*Erythroxylon coca*	Leaves
Common horehound	*Marrubium vulgare*	Aerial portion
Common hyssop	*Hyssopus officinalis*	Flowering plant
Coriander	*Coriandrum sativum*	Seed
Dittany of Crete	*Amaracus dictamnus*	Aerial portion + flowers
Elder	*Sambucus nigra*	Flower (also leaves)
Elecampane, common inula	*Inula helenium*	Root
European centaury	*Erythraea centaurium*	Plant
European meadowsweet	*Filipendula ulmaria*	Root
Fennel	*Foeniculum vulgare*	Seed
Fenugreek	*Trigonella foenum-graecum*	Seed
Fraxinella, gasplant	*Dictamnus albus*	Root
Galangal, galingale	*Alpinia officinarum*	Root
Gentian	*Gentiana lutea*	Root
Germander	*Teucrium chamaedrys*	Plant

(*continued*)

TABLE 8.2 (*continued*)

Common/ commercial name	Scientific name	Portion of plant commonly used
Ginger	*Zingiber officinale*	Root
Hart's tongue	*Phyllitis scolopendrium*	Plant
Hop	*Humulus lupulus*	Aerial portion + flower
Lemon balm, common balm	*Melissa officinalis*	Flowering plant
Lesser cardamom	*Elettaria cardamomum*	Dried fruit
Lung wort, sage of Bethlehem	*Pulmonaria officinalis* or *P. saccharata*	Aerial portion + flower
Lungwort lichen, lung moss	*Styeta polmonacea*	Plant (a lichen)
Marjoram	*Origanum vulgare*	Aerial portion + flower
Masterwort, hog's fennel	*Peucedanum ostruthium*	Root
Nutmeg and mace	*Myristica fragrans*	Seed
Orris, Florentine iris	*Iris germanica var florentina*	Root
Pomegranate	*Punica granatum*	Bark of root
Quassia	*Quassia amara*	Wood
Quinine fungus	*Fomes officinalis*	Plant
Rhubarb	*Rheum rhapanticum*	Root
Roman camomile	*Anthemis nobilis*	Flowers
Roman wormwood	*Artemisia pontica*	Plant
Rosemary, old man	*Rosmarinus officinalis*	Flowering plant
Saffron, crocus	*Crocus sativus*	Portion of flower
Sage	*Salvia officinalis*	Aerial portion + flowers
Savory (summer)	*Satureja hortensis*	Aerial portion of plant
Speedwell	*Veronica officinalis*	Plant
Star anise	*Illicium verum*	Seed
Sweet marjoram	*Majorana hortensis*	Aerial portion + flower
Thyme, garden thyme	*Thymus vulgaris*	Leaf
Valerian	*Valeriana officinalis*	Root
Vanilla	*Vanilla fragrans*	Bean
Wormwood	*Artemisia absinthium*	Plant
Yarrow	*Achillea millefolium*	Plant
Zedoary, setwell, curcum	*Curcuma zedoaria*	Root

Source: Joslyn and Amerine (1964) and Panesar *et al*. (2010).

a. Direct extraction This is the simplest method of flavoring a base wine. Weighed amounts of the ingredients are placed in the wine and left until the wine has absorbed the desired amounts of flavor and aroma (Amerine *et al.*, 1980). To hasten extraction, the flavorants may be finely ground. However, this can facilitate the release of undesirable flavoring agents. The wine is usually stirred at periodic intervals during extraction. This may occur either at room or an elevated temperature. The latter speeds extraction. The extraction period generally lasts 2 weeks, or longer if the wine is not heated. To minimize excessive volatile loss, the extraction tank is sealed (Pilone, 1954).

The herbs and spices may be placed in cloth bags and suspended in the wine. After the first extraction, fresh base wine may be added for a second, and even a third extraction. Partial extractions are preferred, as complete extraction may result in the incorporation of undesirable flavors or aromas. This also avoids pressing the spent materials that is associated with the release of objectionable bitter flavors.

b. Preparation of concentrates Concentrated extracts are prepared by placing the material in a special vessel, through which base wine is circulated until the flavorants have been extracted. The extract is used to flavor the main volume of base wine (Pilone, 1954). The wine is usually heated during the extraction process. About 5.62–7.49 mL of the extract per liter is sufficient for sweet (Italian-style) vermouths. In contrast, dry (French-style) vermouth uses 3.74 mL/L.

Occasionally, hot water is substituted for the base wine in preparing concentrated extracts. However, because of the absence of ethanol, the water extract possesses a different composition of flavorants. Nevertheless, initially softening the plant material with hot water facilitates subsequent extraction (Joslyn and Amerine, 1964).

c. Other extraction methods Commercially available brandy or alcohol extracts can be used to flavor the base wine. These extracts may also be used in small amounts to balance the flavor of wine previously flavored by direct extraction or with a concentrated wine extracts. In Turin, Italy, an alcoholic infusion of herbs and alcohol is preferred. The herbs are infused with alcohol, mixed with alcohol and white wine, and distilled (Joslyn and Amerine, 1964).

Another method consists of macerating a mixture of herbs in sherry at 60 °C, cooling and allowing it to stand for 3–6 weeks (Valaer, 1950). The wine is then decanted and the herbs covered with hot wine and allowed to stand for 10 days. This blend was used to flavor the base vermouth wine. However, the procedure is reported to produce vermouth of lower quality (Amerine *et al.*, 1967).The herbs may also be first extracted with a wine and brandy mixture (50% alcohol) for 10 days, then with wine for 5 days (Kasakova, 1958), employing moderate heating.

D. Fortification and blending

Brandy is added to raise the alcohol content of vermouth to a specified limit. The base wine, brandy, spice extract, and sugar syrup are combined according to a proprietary formula appropriate for each type of vermouth. For Italian vermouths, extracts are prepared by soaking the herbs and spices (7–11 g/L) in highly rectified alcohol (~85%). For a darker color, after flavoring, caramel may be added. In French vermouth, fewer herbs and spices are used. The spice mixture of (4–8 g/L) is typically infused for flavor development, to avoid the uptake of undesirable herbaceous flavors.

E. Aging and finishing

The young vermouth is initially cold stabilized (by refrigeration), filtered, and matured. Sweet vermouths are subsequently aged for about 4.5 years (or longer). The duration between herbal/spice infusion and final bottling is normally 3–5 years (Valaer, 1950). Further aging can lower the quality (Amerine *et al.*, 1967). The pH of the wine may need to be adjusted to a more favorable value and the sulfur dioxide content (50–75 ppm) adjusted to prevent microbial spoilage (Pilone, 1954). With dry vermouths, the color of the wine is usually appropriate, obviating any need for caramel addition.

A fractional blending system similar to that in sherry maturation is used. For this oak puncheons or small tanks are employed. In the system, a fraction of the matured wine is taken and added to the lesser matured wine and so on. During the process no more than 50% of the wine is removed in a year which maintains the continuity of wine's character.

F. Bottling

Sweet vermouth is ultrafiltrated just prior to bottling. Spoilage by the bacterium *L. trichodes* can also be controlled by maintaining the sulfur dioxide content above 75 ppm (Amerine *et al.*, 1967).

VI. PREPARATION OF VERMOUTH FROM NONGRAPE FRUITS

Vermouth preparation from wine is well established. However, other fruits have also been successfully used for the vermouth preparation, as reviewed here.

A. Mango vermouth

An aromatized wine from mango, known as mango vermouth, has been described by Onkarayya (1985). The base wine was made from the cultivar Banganpalli, by raising the TSS to 22 °Brix, adding 100 ppm sulfur dioxide, and 0.5% pectinol enzyme. Fermentation was carried out at 22 ± 1 °C with *Saccharomyces cerevisiae* (Montrachet # 522). The composition of the vermouth, in respect to pH, total acidity, alcohol, aldehydes, and total phenols, was comparable to values reported for grape vermouths. The herbs and spices mixture used in this preparation is given in the Table 8.3.

B. Apple vermouth

In India, only a small proportion of its apple production is processed into low-alcoholic beverages such as cider, in comparison with other countries (Joshi and John, 2002; Sharma and Joshi, 2005). Due to differences in the composition, the production of apple vermouth has required some modification in the technique employed for grape vermouth production (see Fig. 8.2; Jarczyk and Wzorek, 1997; Joshi *et al.*, 2000).

TABLE 8.3 Herb mixture for dry and sweet mango vermouths

	Amount used (g/L of base wine)			
	Dry wine		Sweet wine	
Herbs	*A*	*B*	*C*	*D*
Black pepper	0.75	1.25	2.5	5.0
Coriander	0.70	1.25	2.5	5.0
Cumin	1.25	2.50	3.0	4.0
Bishop's weed	0.50	1.00	1.50	2.0
Clove	0.25	0.50	0.75	1.0
Large cardamom	0.50	1.00	1.50	1.0
Saffron	0.10	0.10	0.10	0.10
Fenugreek	0.50	1.50	2.0	2.50
Nutmeg	0.25	0.50	0.50	0.75
Cinnamon	0.50	1.00	1.50	2.00
Poppy seeds	1.00	1.50	2.0	2.50
Ginger	1.00	1.50	2.0	2.50
Flame of forest	0.25	0.50	0.75	0.75
Lichen	0.25	0.50	1.00	2.00

Source: Onkarayya (1985).

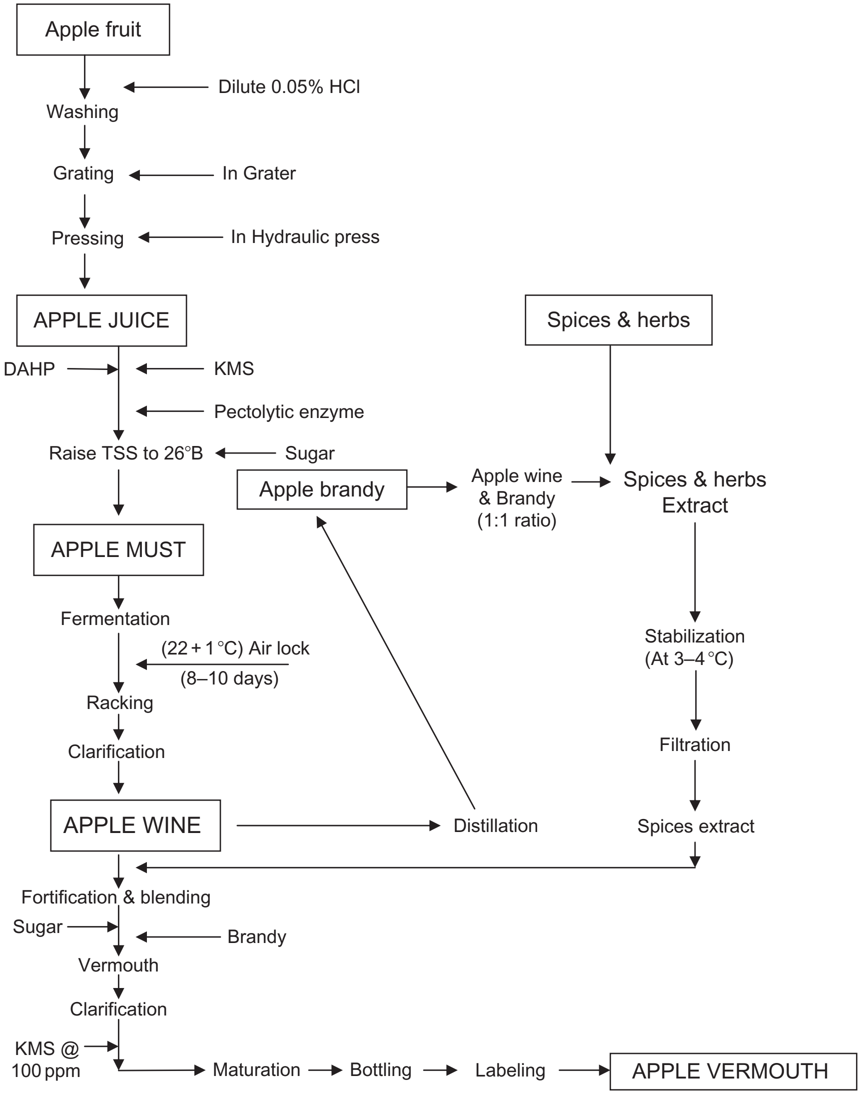

FIGURE 8.2 Flow sheet for the preparation of Apple Vermouth (source: Joshi *et al.*, 2000).

Joshi and Sandhu (2000) have described the production of an apple vermouth with different ethanol concentrations (12%, 15%, and 18%), sugar contents (4% and 8%), and spice extracts (2.5% and 5.0%). These variables significantly influence their respective sensory qualities. Spices extract levels did not, however, affect TSS (°Brix), titratable acidity, color, total sugar, total tannins, volatile acidity, mineral content, except for potassium, esters, or aldehyde contents. The product with 15% alcohol, 4% sugar, and 2.5% spices extract was preferred. By increasing acidity, acceptability of the product with 18% alcohol content was considerably enhanced. Descriptive analysis, along with principal component analysis (PCA), was used to characterize the product with respect to flavor and as a tool for further quality improvement (Joshi and Sandhu, 2009).

C. Plum vermouth

An attempt to prepare plum vermouth of commercial acceptability has also been made (Joshi *et al.*, 1991). The herbs, spices, and the parts used in vermouth preparation are shown in the Table 8.4.

Increased alcohol concentrations augment the aldehyde, ester, phenol contents, TSS but decrease acidity and Vitamin C content. Addition of the herb/spice extract increased total phenols, aldehyde, and ester content of the vermouth. Sensory evaluation showed the sweet products were

TABLE 8.4 Spices and herbs used in the preparation of plum vermouth

Common name	Botanical name	Parts used	Quantity (g/L)
Black pepper	*Piper nigrum* L.	Fruit	0.75
Coriander	*Coriander sativum* L.	Seeds	0.70
Cumin	*Cuminum cyaninum* L.	Seeds	0.50
Clove	*Syzygium aromaticum* L.	Fruit	0.25
Large cardamom	*Amomum subulatum Roxb.*	Seeds	0.50
Saffron	*Crocus sativus* L.	Flower	0.01
Nutmeg	*Myristica fragrans*	Seed	0.25
Cinnamon	*Cinnamomum zeylanicum Breyn*	Bark	0.25
Poppy seed	*Papaver somniferum* L.	Seed	1.00
Ginger	*Zingiber offocinale Rosc.*	Dried root	1.00
Woodfordia	*Woodfordia floribunda*	Flower	0.25
Asparagus	*Asparagus* sp.	Leaves	0.10
Withania	*Withania somnifera*	Roots	0.20
Adhatoda	*Adhatoda* sp.	Leaves	0.25
Rosemary	*Rosmarinus officinalis*	Flowering plant	0.10

Source: Joshi *et al.* (1991).

perceived as superior to the dry. The sweet vermouth with a 15% alcohol content was found to be superior.

D. Sand pear vermouth

Juice of the sand pear can also be converted into vermouth (Joshi *et al.*, 1999). The complete process is illustrated in Fig. 8.3. Dry and sweet versions, with various alcohol levels, have been prepared (Attri *et al.*, 1993). TSS, acidity, aldehyde, phenol, and ester contents increase as a

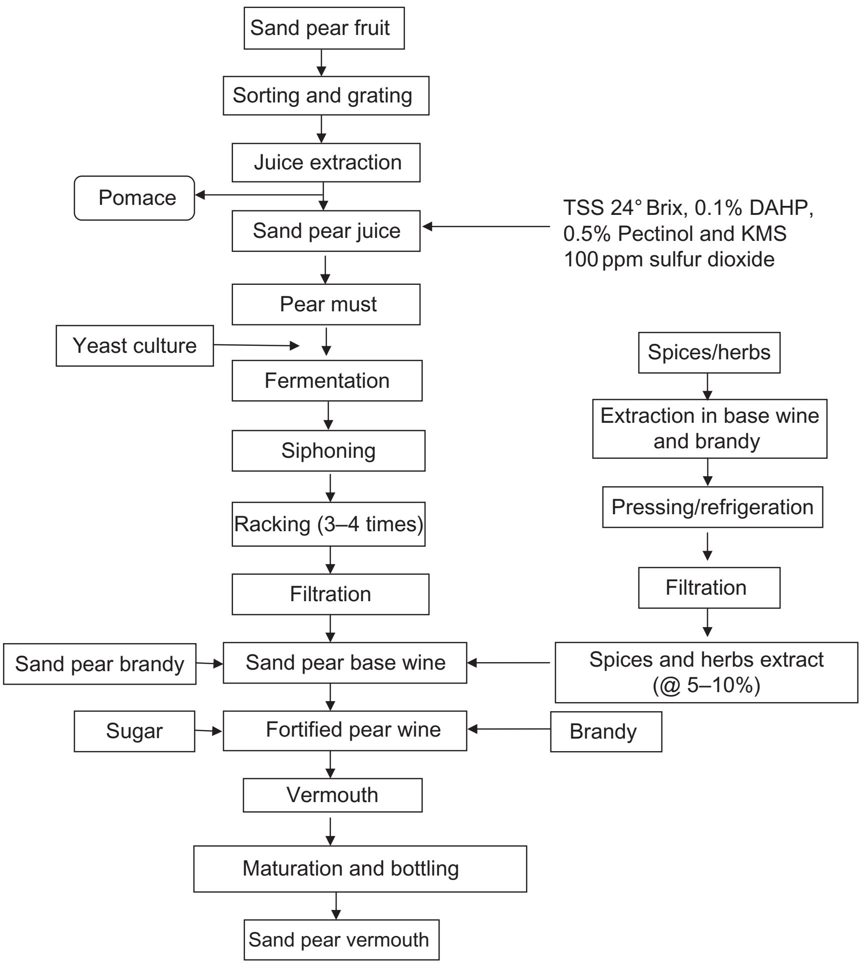

FIGURE 8.3 Flow-sheet for the preparation of Sand Pear Base Vermouth (source: Joshi *et al.*, 1999).

result of the addition of the herb/spice extract. The sweet product with 15% alcohol appeared to be the most acceptable. The herbs and spices used, and their respective quantities, were the same as that used for plum vermouth.

E. Tamarind vermouth

Tamarind (*Tamarindus indica* L.) is an important tropical tree widely grown in India. Although its fruit can be used for wine production, its wine is not preferred due to its high acidity. An attempt has been made to convert its wine into vermouth of acceptable quality (Lingappa *et al.*, 1993). In this process, the base wine was made from tamarind fruit (50 g/L), at 0.9% acidity, followed by raising the TSS to 23 °Brix and adding 150 ppm sulfur dioxide. Fermentation was conducted by *S. cerevisiae* var. *ellipsoideus* at 27 ± 1 °C. Both dry and sweet vermouths, with 17% alcohol content, were found acceptable.

F. Pomegranate vermouth

Attempts to prepare pomegranate vermouths of commercial quality have been made (Patil *et al.*, 2004). Three types of vermouth were prepared, each with different spices (clove, cardamom, and ginger), at rates of 0.25, 0.50, and 1.00 g/L. The sweet base wine was prepared from the Ganesha cultivar of pomegranate. Maturation lasted for 3 months. Organoleptic evaluation used a sensory scale. Vermouth with cardamom was given maximum points with respect to bouquet, vinegar, total acidity, sweetness, body, and general quality, and obtained the highest overall acceptability rating, followed by the ginger and clove versions.

G. Wild apricot vermouth

Wild apricot (*Prunus armenica* L.) grows naturally in hilly areas of northern India. It is highly acidic, fibrous, and low in TSS, and, thus, not utilized commercially. Preparation and evaluation of a vermouth from its fruit was undertaken (Abrol, 2009). Vermouths at different sugar (8, 10, and 12 °Brix), alcohol (15%, 17%, and 19%), and spices levels (2.5% and 5%) were prepared. Those used in extract preparation are shown in Plate 8.1. The base wine was prepared from crushed fruit, adjusted to 24 °Brix, and diluted in a 1:2 ratio with water. To this mixture was added 200 ppm sulfur dioxide, 0.1% diammonium hydrogen phosphate (DAHP), and 0.5% pectinase enzyme. A 24-h active yeast culture initiated fermentation. The procedure is illustrated in Fig. 8.4. A maturation period of 6 months improved the quality of the vermouth.

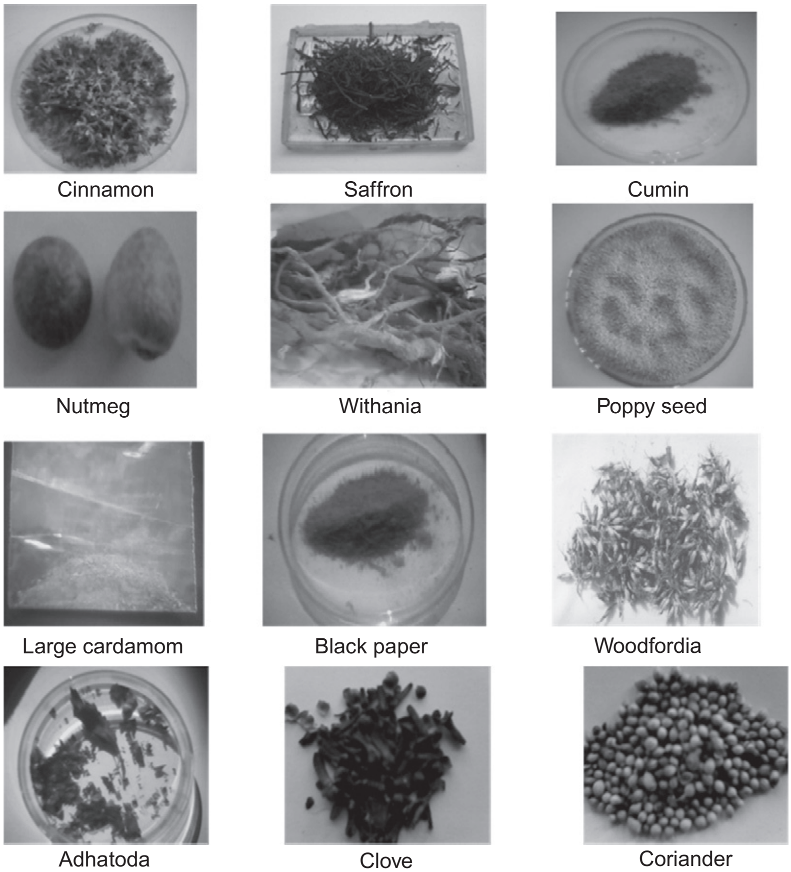

PLATE 8.1 Spices and herbs used in the preparation of extract (Source: Abrol, 2009).

VII. VERMOUTH QUALITY

The quality of vermouth is influenced by many factors, some of which are listed below:

The type of fruit used to prepare the base wine; its quality and nature; the type, quality, and amounts of the herbs and spices used; its mineral composition; the sugar content and the sweetening agent used; and the final ethanol concentration.

A. Physicochemical characteristics of vermouth

Vermouth contains ethanol, sugars, acids, minerals, higher alcohols, phenols besides a large number of minor compounds that contribute to the unique taste and flavor of the beverage. However, it is the spices and

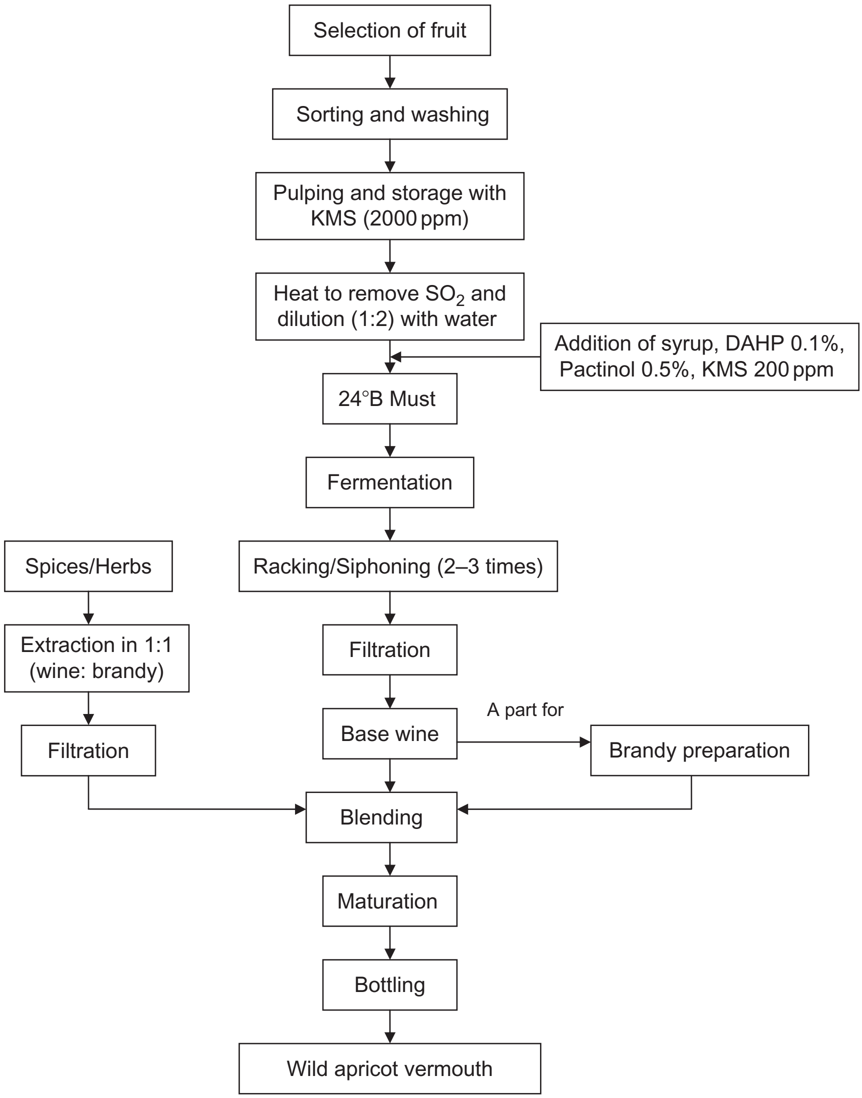

FIGURE 8.4 Flow sheet for the preparation of wild apricot vermouth (source: Abrol, 2009).

herbs used in its production that donate the compounds essential to the sensory distinctiveness of vermouth. A comparison of the composition of sweet and dry vermouth is provided in Table 8.5.

The composition of mango vermouths (Table 8.6) is comparable to values reported for grape-derived vermouths (Martinez *et al.*, 1987).

TABLE 8.5 Composition of dry and sweet vermouth

Source	No. of samples	Alcohol (%)			Extract (gm/100 mL)			Total acid (gm/100 mL)			Tannin (gm/100 mL)		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Dry													
France	6	17.4	19.3	18.3	3.7	6.1	4.8	0.55	0.66	0.61	0.05	0.08	0.07
United States	77	15.0	22.0	17.7	1.4	7.9	3.8	0.31	0.66	0.50	0.03	0.07	0.04
Sweet													
Italy	20	15.5	17.1	16.1	14.9	20.7	18.6	0.36	0.52	0.28	0.05	0.11	–
Italy	10	13.7	16.9	15.7	14.0	17.2	15.6	0.36	0.52	0.45	0.05	0.11	0.08
United States	100	14.0	21.0	17.1	10.0	19.0	13.8	0.26	0.63	0.45	0.03	0.10	0.06

Source: Valaer (1950) and Rizzo (1957).

TABLE 8.6 Physicochemical characteristics and sensory quality of mango vermouths

Herbs mixture formula and type of vermouth	Color (at 420 nm)	pH	Total acidity tartaric acid / 100 mL	Volatile acidity (g. AA/100 mL)	Alcohol (%, v/v)	Total aldehyde (ppm)	Total phenols (%)	Organoleptic scores (out of 20)
Dry vermouth								
Formula A	0.420	3.40	0.59	0.088	17.0	15.8	0.055	13.00
Formula B	0.658	3.50	0.60	0.087	17.5	20.9	0.064	11.50
Sweet vermouth								
Formula C	0.678	3.42	0.59	0.071	17.2	26.4	0.070	15.50
Formula D	0.690	3.50	0.61	0.091	18.0	56.3	0.075	13.60

Source: Onkarayya (1985).

TABLE 8.7 Physicochemical characteristics of sand pear base wine and sweet vermouth

Characteristics	Wine	Vermouth
Total soluble solids (°Brix)	6.1	13.0
Titratable acidity (%, MA)	0.37	0.43
pH	3.99	3.95
Reducing sugar (%)	–	4.17
Total sugar (%)	–	4.35
Alcohol (%, v/v)	10.80	14.95
Volatile acidity (%, AA)	0.04	0.04
Ascorbic acid (mg/100 mL)	6.6	5.5
Aldehydes (mg/L)	103.21	133.15
Total phenols (mg/L)	226.26	264.46
Esters (mg/L)	197.4	268.04
Optical density	0.64	0.58

Source: Attri *et al.* (1994).

TABLE 8.8 Physicochemical characteristics of dry and sweet plum vermouth

	Type of vermouth	
Physicochemical characteristics	Dry	Sweet
Total sugar (%)	N. D.	4.8
Titratable acidity (%, malic acid)	0.81	0.79
Ethanol (%, v/v)	15.0	14.5
Volatile acidity (%, acetic acid)	0.03	0.04
pH	3.38	3.34
Vitamin C (mg/100 mL)	3.5	3.2
Total phenols (mg/L)	417	390
Aldehydes (mg/L)	411	112
Esters (mg/L)	204	219

Source: Joshi *et al.* (1991); ND, not detected.

Typical compositions of sand pear and plum vermouths are given in Tables 8.7 and 8.8.

The influence of alcohol and sugar content in the composition of apple vermouth are shown in Tables 8.9 and 8.10, respectively.

The composition of wild apricot vermouth of different musts as influenced by the addition of spices extract is shown in Table 8.11.

As already noted, the sugar content of vermouth ranges from 2% to 4% (w/v) for dry vermouth and from 14% to 20% for sweet vermouth.

TABLE 8.9 Physicochemical characteristics of apple vermouth of different levels of alcohol

	Alcohol level (%)[a]			
Characteristics	12	15	18	C.D.$_{P=0.05}$
Total sugar (%)	9.2	7.8	7.3	0.4
Total soluble solids (°Brix)	16.0	16.2	16.3	N. S.
Titratable acidity (%, MA)	0.43	0.39	0.37	N. S.
pH	3.36	3.29	3.26	0.04
Ethanol (%, v/v)	11.9	15.2	19.2	0.36
Color (units)				
Red	3.75	2.92	2.40	0.38
Yellow	20.75	20.00	10.60	0.47
Apparent viscosity (flow)	1.62	1.95	2.02	0.03
Free aldehyde (mg/L)	46	46	68	60.3
Total esters (mg/L)	175.7	181.0	246.7	10.60
Volatile acidity (%)	0.046	0.040	0.040	N. A.

[a] Means are irrespective of sugar and spices extract level
Source: Joshi and Sandhu, 2000.

TABLE 8.10 Physicochemical characteristics of apple vermouth of different sugar levels

	Sugar level (%)	
Characteristics	4	8
Total sugar (%)	5.9	10.1
Total soluble solids (°B)	36.9	18.4
Titratable acidity (%, MA)	0.41	0.39
pH	3.31	3.28
Ethanol (%, v/v)	15.4	15.5
Color (units)		
Red	3.13	2.91
Yellow	17.37	16.87
Total esters (mg/L)	198.0	210.5
Volatile acidity (%)	0.041	0.043
Total tannins (mg/L)	581.0	524.0

Source: Joshi and Sandhu (2000).

Alcohol content typically ranges from 14% to 22% (v/v) (Amerine *et al.*, 1980). Ethanol and dry extract are the constituents that mainly affect viscosity, while glycerol has a negligible effect.

In general, the viscosity of wine (associated with perceived ''body'') is influenced by parameters such ethanol and dry extract concentration (Joshi and Sandhu, 2000; Nurgel and Pickering, 2005; Yanniotis *et al.*, 2007). Sugar content is also important to the perception of viscousness. Burns and Noble (1985) noted that when comparing vermouths of identical viscosity, those with higher sucrose concentrations were judged to be more viscous. Sucrose also increased perceived ''acceptability'' in a concentration range up to 14%, both in aqueous and 16% ethanolic solutions (Panovsk *et al.*, 2008). In contrast, ethanol content did not affect perceived sweetness at concentrations of up to 16% but decreased at a concentration of 32%. Ethanol enhanced bitterness only at high concentrations. Interactions were similar in samples containing 10% and 16% sucrose.

Minerals such as Na, K, Ca, and Mg constitute the macroelement in vermouth, whereas Cu, Fe, Mn, and Zn are the major microelements. A comparison of grape vermouth with other vermouths in terms of mineral composition is illustrated in Table 8.12.

TABLE 8.11 Effect of spices level on wild apricot vermouth

		Spices extract (%)		
Characteristics	Base wine (mean ± SD)	2.5	5.0	$CD_{0.05}$
Total soluble solids (°Brix)	8.20 ± 0.07	17.23	17.28	0.04
Reducing sugars (%)	0.34 ± 0.01	5.49	5.43	0.01
Total sugars (%)	1.11 ± 0.02	10.04	10.32	0.06
Titratable acidity (%, MA)	0.76 ± 0.02	0.79	0.82	0.01
pH	3.15 ± 0.02	3.340	3.321	0.005
Ethanol (%, v/v)	10.64 ± 0.09	17.11	17.04	0.04
Total esters (mg/L)	135.40 ± 0.55	260.5	266.8	0.9
Total phenols (mg/L)	253.60 ± 0.8	449.6	452.1	1.3

Source: Abrol (2009).

TABLE 8.12 Mineral composition of different vermouth

Minerals	Na	K	Ca	Mg	Cu	Fe	Mn	Zn
Grape vermouth	111.64	735.64	89.25	62.18	0.53	6.95	0.58	–
Plum vermouth	41	973	101	17	1.07	1.3	1.07	0.82
Sand pear vermouth	45	967	43	15	1.23	7.11	1.23	2.39
Apple vermouth	33.6	2022	84	77	0.08	1.34	1.06	0.14

Source: Joshi and Sandhu (2000) and Joshi *et al.* (1999).

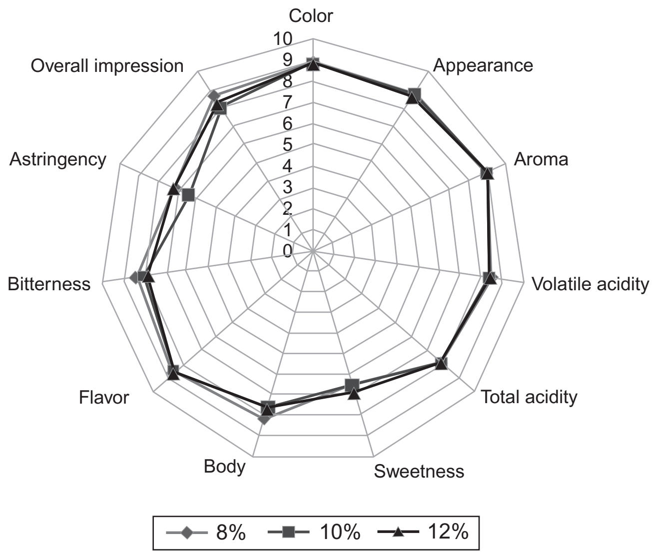

FIGURE 8.5 Spider web diagram of sensory qualities of wild apricot vermouth of different sugar levels (source: Abrol, 2009).

B. Sensory quality

Sensory quality is important to the final acceptance of any product. In case of vermouth, the type and quantity of the spices and herbs are particularly central to its sensory attributes. Nonetheless, alcohol and other constituents are also critical. For example, plum-based vermouths were considered optimal at 15% alcohol (Joshi *et al.*, 1991), and apple-based vermouths preferred at 5% alcohol, 4% sugar, and 2.5% spices extract (Joshi and Sandhu, 2000).

The complexities and interaction of composition on the quality perception of vermouth is illustrated with wild-apricot-based vermouth (Figs. 8.5–8.7). It shows that sweetness, flavor, and astringency are preferred at a sugar content of 8%, whereas body, appearance, and aroma were preferred at 12% sugar (Fig. 8.5). Body, flavor, aroma, and total acidity were scored better at an alcohol content of 19% (Fig. 8.6). The spice concentration preferred for volatile acidity, total acidity, flavor, and bitterness was 5% (Fig. 8.7), whereas body, sweetness, appearance, and astringency were preferred at a 2.5% level (Joshi *et al.*, 2011a,b).

1. Astringency and bitterness in vermouth

Astringency is an important sensation in most of the alcoholic beverages. Time–intensity measurements have been particularly useful in assessing this phenomenon (Lee and Lawless, 1991), as well as the bitterness of

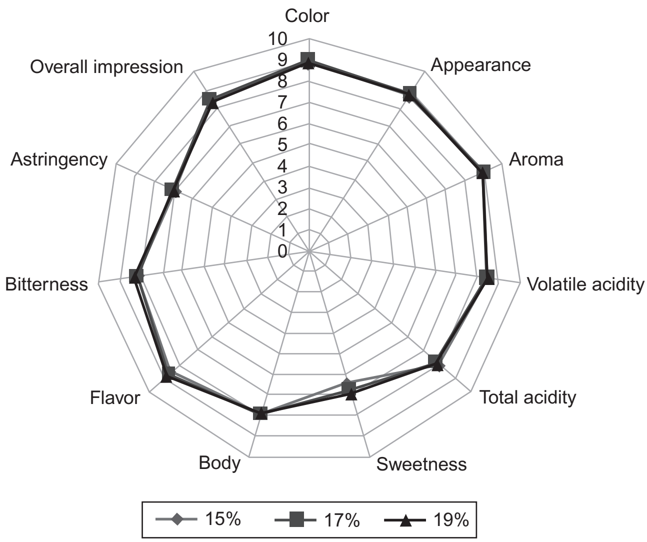

FIGURE 8.6 Spider web diagram of sensory qualities of wild apricot wines of different alcohols levels (source: Abrol, 2009).

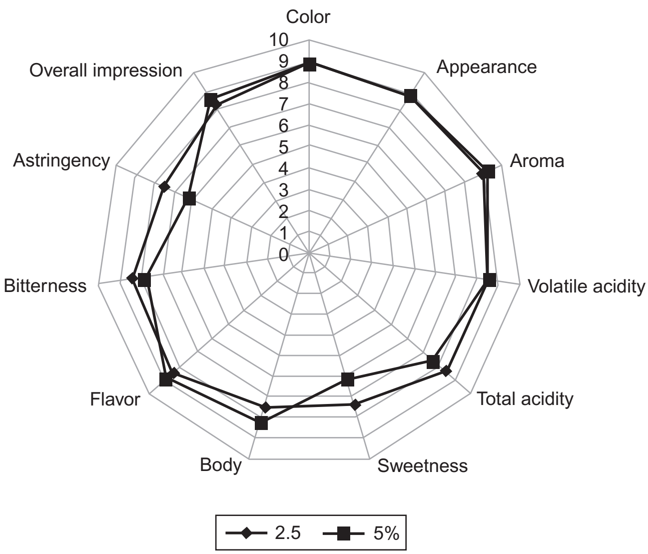

FIGURE 8.7 Spider web diagram of sensory qualities of wild apricot wines of different spices level (source: Abrol, 2009).

wine (Noble, 1995). Monomeric phenolic compounds were rated more bitter than astringent, whereas polymeric compounds were perceived more astringent than bitter. The results obtained using a solution of (+)-

TABLE 8.13 Time–intensity course in model astringent solutions

Time interval recorded	Tannic acid at 7 °C (% of scale)	Tannic acid at 18 °C (% of scale)	Catechin at 7 °C (% of scale)	Catechin at 18 °C (% of scale)
In the mouth	44	44	42	43
At swallowing	59	61	66	64
After 10 s	52	60	59	60
After 20 s	42	49	47	49
After 30 s	33	36	37	38
After 40 s	23	27	26	27
After 50 s	17	19	19	19
After 60 s	12	13	13	14
After 70 s	9	9	9	10
After 80 s	7	6	6	7
After 90 s	5	3	3	4
After 100 s	4	2	2	3

Source: Valentova *et al.* (2002).

catechin is given in Table 8.13. The maximum perceived intensity was reached at swallowing or shortly thereafter (10 s). The residence time in the mouth had influenced the maximum intensity and the rate of its decrease followed exponential relation. During this study, judges took a draught of 10–15 mL to record the astringency after 2–3 s while keeping the draught still in their mouth and moving slowly using their tongue for a total of 5 s. Astringency decreased on an exponential time course, with some residual astringency remaining after 100 s (Valentova *et al.*, 2002). The technique is also used in distinguishing between the dynamics of sweet, sour, bitter, and astringent perception (Jackson, 2002).

Vermouth contains not only multiple bitter constituents but sugar and alcohol that might influence the perception of astringency. Although the addition of ethanol did not show a pronounced effect, sucrose suppressed the perception of astringency. This may be related to increased salivary production (Lyman and Green, 1990) and cleansing of the palate. Another explanation could be the interaction of sucrose with complexes of salivary proteins with astringent substances (Jackson, 2002; Valentova *et al.*, 2002).

2. Sweetness and viscosity

Vermouth contains varying amount of sugar and alcohol. Both constituents singly and in combination influence both the perception of sweetness and viscosity. Polycose, a nonsweet, viscous substance has been used

(Burns and Noble, 1985) to investigate the effect of viscosity, separate from sweetness, on the perception of viscosity, sweetness, and the bitterness of vermouth. The separate effects of sweetness and viscosity of sucrose on the sensory properties of vermouth were evaluated. Both perceived sweetness and oral viscosity increased, while bitterness decreased as the concentration of sucrose was increased, and the physical viscosity of the vermouths increased. The samples in which viscosity was increased by the nonsweet Polycose® were rated sweeter and less bitter than vermouth solutions at the same sucrose concentration but lower physical viscosity. When vermouths of identical viscosities were compared, the products with higher sucrose concentration were judged to be more viscous. Viscosity alone contributed 20–30% of the perceived increase in sweetness due to sucrose addition. The effect of viscosity in reducing bitterness was of the same magnitude. The increase in perceived viscosity caused by addition of sucrose arose from approximately equal contributions of physical viscosity and sweetness of sucrose (Burns and Noble, 1985). Thus, clearly there is a scope for modifying the sweetness and bitterness properties of beverages like vermouth with the use of thickeners such as polycose, which in themselves are not sweet and are low in calorific value.

3. Flavor profiling of vermouth

The flavor of products like wine is of the utmost significance and is one of the quality parameter for its evaluation (Joshi, 2006).

Flavor can be evaluated by chemical and sensory evaluation methods. Descriptive methods of sensory evaluation are applied frequently to profile this important quality aspect (Jackson, 2002). To analyze flavor profile, the technique of descriptive analysis has been applied to a variety of beverages including vermouth.

For example, apple vermouths with different ethanol concentrations (12%, 15%, and 18%), sugar contents (4% and 8%), and levels of spice extracts (2.5% and 5.0%) were prepared and evaluated (Joshi and Sandhu, 2000). Using quantitative descriptive analysis (QDA), flavor profiling was carried out (Joshi and Sandhu, 2009).

PCA of the flavor profile of these apple vermouths, using a set of 45 attributes, was analyzed across 12 treatments. The PCA separated the 12 types of vermouths into three groups, mostly with respect to ethanol levels. Some interaction between the three parameters, viz. alcohol levels, spices extract, and sugar level was also observed as grouping along these lines did not take place very clearly. The sugar concentration must have also affected other parameters important in its sensory qualities, such as bitterness, as has also been demonstrated in earlier studies (Birch *et al.*, 1972; Pangborn *et al.*, 1973). Similarly, an increase in viscosity in the product with 8% sugar, and a decrease in perceived bitterness of vermouth must have taken place as found in an earlier study (Burns and Noble, 1985).

VIII. LEGAL REQUIREMENTS

Different legal requirements to produce vermouth have been prescribed (Amerine *et al.*, 1967) by the U.S. Treasury Department, Internal Revenue Service (1961) in United States, as detailed below.

A natural wine must be used in the making vermouth or the flavored special natural wines. Such a wine may also be made with the usual permitted cellar practices.

A number of botanicals, flavoring substances, and natural substances long used in wines have been regulated. It is mandatory that product should be free from thujone (In Europe, maximum admissible thujone concentrations are 0.5 mg/kg in food and beverages, 5–35 mg/kg in alcoholic drinks, and 25 mg/kg in food products containing sage; Schmandke, 2005.)

IX. FUTURE RESEARCH

At present, extensive research has been conducted on the antioxidant and antimicrobial properties of wines. Similar studies on vermouth should be conducted in-depth. Generally, red wine is considered better than white with respect to antioxidant effect. How red versus white vermouths compare in these regards needs to be determined. Though vermouth is a traditional commercial product, the relationship of its flavor attributes to its chemical constituents and is lacking. It could be a fertile field for future studies. In addition, few studies have been conducted on its maturation and the changes that occur during aging. The use of noncaloric sweeteners is another topic worthy of evaluation relative to its acceptability by diabetics.

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