A Review of Méthode Champenoise Production

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"Méthode champenoise represents the best expression of the vine."

Learning Outcomes. The reader will learn about processing considerations in Methode Champenoise and the factors influencing each production step.

Chapter Outline

- **Viticultural Considerations**
- **Cuvée Production**
- **Liqueur de Tirage**
- **Bottle Fermentation**
- **Aging Sur Lie**
- **Remuage**
- **Disgorgement**
- **Dosage**
- **Gushing**
- **Chemical Analysis**

Section 1.

Centuries of experience have enabled the sparkling wine producer to refine the art of bottle-fermented sparkling winemaking to the system known as méthode champenoise. This system, however, is not a rigid one. Certain steps are prescribed by law in France, while few are required in America.

Within certain guidelines, there is considerable variation in production philosophy and technique regarding méthode champenoise. Stylistic decisions are vast and include the following:

- viticultural practices
- cultivars
- maturity
- pressing vs. crushing
- types of press and press pressures
- press fractions
- phenol levels
- use of SO_2 and the oxidative condition of the base wine
- yeast for primary and secondary fermentation
- barrel fermentation and aging
- fermentation temperatures
- malolactic fermentation
- post-primary fermentation lees contact
- age of cuvée
- reserve wine
- blending
- time spent sur lie
- nature of the dosage
- CO_2 pressure

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This chapter describes production philosophy and practices of méthode champenoise producers.

Viticultural Considerations

The array of viticultural parameters affecting méthode champenoise palatability is broad. Environmental and viticultural factors influencing cuvée chemistry include the following:

- mesoclimate
- canopy climate
- soil moisture
- temperature
- berry size
- rootstock
- asynchronous development
- fruit maturity
- leaf area per unit fruit weight or fruit weight per unit pruning weight

For the producer, understanding the relationships between vineyard management and wine quality may be even more difficult for sparkling wines than for table wines. Cuvées are evaluated and blended when they have the better part of their lives ahead to age and develop. This requires considerable insight, and may tend to obscure the relationships between vineyard management activities and sparkling wine palatability.

In warm regions such as Virginia, great care must be given to harvesting early enough to retain desirable acidities and pH values. A primary problem in warm climates is the production of a base wine that is not too heavy in body or varietal character, too alcoholic, or too colored. Warm climate wines, by and large, offer more definitive fruit flavors, less complexity and lower acidity than Champagne and develops more quickly.

Among the viticultural options affecting grape components either directly or indirectly, mesoclimate (site climate) is considered one of the most important. Mesoclimate has been divided into two general temperature zones, Alpha and Beta (Jackson, 1987). In Alpha zones, maturity occurs just before the mean *monthly* temperature drops to 10°C (Jackson, 1991). Specifically, Alpha zones are those where the mean temperature at the time of ripening, for a particular variety, is 9-15°C.

In warm climates the length of the growing season is more than adequate to ripen most grape varieties which, therefore, mature in the warm part of the season. In Alpha zones, day temperatures are moderate and night temperatures usually cool, creating desirable conditions for the development of important secondary grape metabolites. On the other hand, Beta zones are those with a mean temperature above 16°C at the time of ripening for a particular variety. In Beta zones, the majority of grapes ripen well before temperatures begin to drop.

It is generally accepted that a cool climate that allows the fruit to stay on the vine longer, while retaining desirable acidities, is important in the production of base wine which will develop the needed complexity during aging sur lie. If the field temperatures and heat summation units were the sole parameters affecting the grapevine climate, then we need only consider the macroclimate in analyzing the temperature effects on quality.

The real situation, of course, is not that simple. Solar radiation, wind velocity and, to a lesser extent, sky temperature, can give ranges of berry temperatures of more than 15°C above to 3°C below the air temperature (Kliewer and Lider, 1968). These variables are further influenced by row orientation, training system, trellis height, and vine vigor.

There are several reasons why comparisons between climates, secondary metabolite production, and grape and wine quality have been confounded. First is the effect of crop load. Crop load and, most significantly, the ratio of exposed leaf area-to-crop load, can have a profound effect on the rate of maturity. Fruit maturity and the rate of fruit maturity can influence grape and wine quality. Another factor often overlooked is asynchronous growth in either berry, cluster, or vine (Due, 1994). This will also delay maturity, yet few comparisons of climate and wine quality have taken this into account.

To some méthode champenoise producers, a high malic acid level in the grape is considered a desirable characteristic. Malic acid is principally influenced by maturity, crop level, and temperatures (day and night). Short term exposure to high temperatures is significant to fruit malic acid levels, as well as phenols and aroma components. The effect of brief exposure to high temperature may raise serious doubts about how one integrates, over time, climatic parameters such as heat summation to fruit composition. For a review comparing climate factors see Bloodworth (1976), Jackson (1995), Poinsaut (1989), Pool (1989), Reynolds (1997), and Riedlin (1989).

Varieties

Some of the many cultivars utilized in various growing regions for méthode champenoise are given in Table 1. Chardonnay, Pinot noir, Pinot meunier, and Pinot blanc are among the more popular varieties. The concentrations of amino nitrogen, acetates, diethyl succinates, and organic acids are strongly affected by the varieties used in base wine production.

Table 1. Varieties Used for Méthode Champenoise

Cool Regions	Warm Regions	Hot Regions	
Pinot noir	Chenin blanc	Parallada	Chardonnay
Chardonnay	Chardonnay	Xarello	Pinot noir
Meunier	Gamay	Macabeo	Meunier
Gamay	Pinot noir	Chenin blanc	
Pinot blanc	Meunier	Semillon	

Source: Dry and Ewart (1985). Regions based on UCD heat summation units.

Grapes used in the Champagne region of France for méthode champenoise are almost exclusively Pinot noir, Chardonnay, and Pinot meunier. There is a tendency for Pinot meunier to be replaced by Chardonnay or Pinot noir, both of which give greater yield and produce higher quality (Hardy, 1989). Chardonnay gives life, acid, freshness, and aging potential, too. Care must be taken to avoid excess maturity (in warmer climates particularly), which produces a dominant, aggressively-varietal character.

Warm climate Chardonnay cuvées may suffer from a narrow flavor profile, high melony aroma notes, and lack of freshness, liveliness, and length. Additionally, rich fertile soils can cause this variety to produce grassy and foliage aromas. When combined with Pinot meunier, Chardonnay has a greater capacity to age harmoniously and for a longer time (Hardy, 1989).

Pinot noir adds depth, complexity, backbone, strength, and fullness (what the French call charpenterie to méthode champenoise wines. These generalizations are broad and become nebulous when one considers, for example, that there are over 82 different clones of Pinot noir in the Champagne viticole, and clonal selection continues.

Pinot noir is seldom used by itself, even in Blanc de noirs. Uneven ripening in Pinot noir is often a problem for producers trying to minimize excessive color extraction. Pinot noir at the same °Brix as Chardonnay generally has less varietal character.

Pinot blanc, like Pinot meunier, is a clonal variant of Pinot noir. It is generally neutral, but has some Chardonnay traits, with a bright fruit character that is somewhat thin. Pinot blanc, like the Pinot meunier used in France, ages more quickly that Chardonnay, yet adds fullness, body and length to the finish. It may be a desirable blend constituent. Pinot blanc has a tendency to lose acidity more quickly on the vine and, like Pinot meunier, usually has a lower titratable acidity than Chardonnay. It is, therefore, harvested somewhat early.

Fruit Maturity

The chemistry at maturity of several California sparkling wine cultivars is given in Table 2. Grape harvests should be based upon a determination of desired style. Méthode champenoise producers harvest based upon the flavor and aroma of the juice, as well as analysis of °Brix, acid, and pH. Producers are generally striving for base wines that are clean, delicate, not varietally assertive, yet not dull or lifeless. A desired cuvée is one with body, substance, and structure. Immature fruit produces wines that are green or grassy in aroma.

Table 2. Fruit Chemistry of Some Grapes for Méthode Champenoise

Parameter	Chardonnay	Pinot Noir	French Columbard	Chenin Blanc
^{o}Brix	18-19	18-20	17.5-20	17.5-19
Titratable Acid (g/L)	11.0-14.0	10.0-13.0	12.0-14.0	10.0-11.0
pH	2.9-3.15	2.9-3.15	2.9-3.20	3.1-3.2

Source: average of several California viticultural regions.

Overripe fruit can produce a base wine that is excessively varietal or assertive. Often the producer is looking for bouquet in the finished product, but not for extensive varietal aroma. This is a stylistic consideration. However, the winemaker should never lose sight of the effect carbon dioxide has on one's perception of wine character. The "sparkle" significantly magnifies the odorous components of the wine.

Early harvest in warmer climates helps minimize excessive varietal character, which can be overpowering. Changes in aroma range from low intensity, green-herbaceous characters, toward more intense fruit characters. Chardonnay aroma can be described as melon, floral, pear, or smoky; Pinot noir as strawberry floral, tobacco, toffee; and Pinot meunier as confectionery. In warm climates, mature fruit aromas/flavors can be noted when the sugar concentrations are low (< 16°Brix). The CIVC (Comité Interprofessionnel du Vin de Champagne, a trade association that represents the grape growers and houses of Champagne, France) bases its picking decisions on sugar:acid ratios with the preferred ratio between 15-20. This means grapes reach optimum maturity at 14.5 - 18°Brix and a titratable acidity of 12-18 g/L (tartaric). At this acidity, the malic acid is 50-65% of the total acid content. The traditional importance of acid may be partly the result of the fact that, in Champagne, sugar addition is legal, but acid addition is not. At bottling, 11.5% alcohol (v/v) is desired. Alcohol helps foam and bubble retention. Also, in warm climates, a sugar:acid ratio of 15-20 may be reached after some mature fruit flavors have developed (Jordan and Shaw, 1985).

Cuvée Production

The desirable chemical attributes of the cuvée usually include alcohol (about 10.5-11.5%), high acid, low pH, low flavonoid phenol content, low aldehydes, low metal content, low volatile acidity, and little color (see Tables 3 and 4, later). Many producers carefully hand-harvest into small containers (30-1000 pound boxes or bins) to avoid berry breakage, then bring the fruit in from the field as quickly as possible. The least possible skin contact is sought, particularly with red varieties used for Blanc de Noirs.

Proximity to the processing facility is, therefore, important. This aids in preventing undue extraction of phenolics from berries possibly broken during transport. Oxidation will reduce desirable aroma/flavor and provide excessive phenols, which may cause bitterness and reduced aging capacity. Grapes must be harvested as cool as possible to avoid excessive phenolic pickup and loss of fruit quality. This makes long transport of warm, machine-harvested fruit undesirable for méthode champenoise.

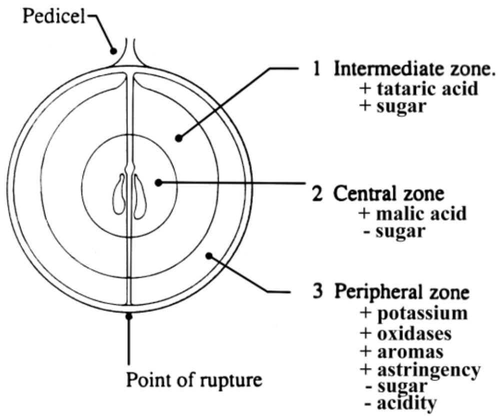
Grapes are weighed and either pressed, or crushed and pressed. Crushing and pressing may be satisfactory, provided the contact of the skins with the juice is brief. For premium méthode champenoise, however, the grapes are usually pressed, rather than crushed and pressed. Lack of skin contact produces a more elegant, less varietally-dominant base wine. Skin contact releases more aroma, but may also extract coarser undesirable components.

There is, of course, a yield reduction by pressing the fruit, rather than crushing and pressing. The economics, the targeted market, and the style desired must be carefully reviewed.

Pressage

As Figure 1 indicates, there are three juice zones in the grape berry: the juice of the pulp (Zone 1), the juice of the pulp area around the seeds (Zone 2), and the juice from just beneath the skins (Zone 3). In order to obtain the desirable cuvée chemistry, traditional producers of méthode champenoise press, rather than crush and press. The point of rupture is usually opposite the pedicel (stem).

Figure 1. The Grape Berry



Adapted from Dunsford and Sneyd (1989).

The intermediate zone (1), which contains the most fragile cells, is extracted before the central zone (2), and finally the peripheral zone (3) (Dunsford and Sneyd, 1989). The concentration of tartaric acid is highest in zone 1 and lowest in zone 3, and hence should be extracted initially. Malic acid concentration decreases from the center (zone 2) to the skin, and so is also extracted fairly quickly.

By contrast, the concentration of potassium, the dominant cation (positively-charged ion), is highest in zone 3, which is extracted last. A juice extracted from the first two zones will, therefore, have the highest acidity, lowest potassium, lowest pH, and the lowest susceptibility to oxidation, which will result in a wine of greater freshness.

The goal is usually to preserve the integrity of the berry so that the components of the different zones are not mixed. Thus, mechanical harvesters and crushers are not used. Owing to the way in which the sugars and acids are positioned in the grape, the juice flowing out of the berry comes from the juice of the intermediate-zone pulp during the early stages of pressing, and is usually better suited for méthode champenoise.

Conveyors and delivery systems that may break the berries prior to either pressing, or crushing and draining, tend to extract more phenolics and may be considered undesirable. One sparkling wine house developed a vacuum system capable of moving 20 tons/hour of whole grapes into the press. This avoids berry breakage and can reduce the phenol level by 100 mg/L G.A.E. or more (Fowler, 1983a, b).

Table 3 shows the chemistry of various press fractions from a study conducted in Champagne (Francot, 1950). In Champagne, only the first 2,666L (70 gal) extracted from a marc (4,000 kg, or a little more than 8,800 lbs) has the right to the appellation. At least several press fractions are taken, fermented, and aged separately. Some of the later press fractions may be blended with the primary fractions as a result of economic and/or sensory considerations.

Table 3. Composition of Eight Successive Fractions from Chardonnay Grapes in a Champagne Press

	Fraction	**Press No.**	**Amoun t (L)**	**Sugar (g/L)**	**Titratable acidity (g/L)**	**pH**	**Tartaric acid (g/L)**	**Potassium acid tartrate (g/L)**
Vin de cuvée	1	200	193.	7.9	2.98	6.12	4.71	
	Premier cuvée	2	220	192.	8.5	2.94	7.28	5.75
		3	600	193.	9.6	2.87	8.10	5.98
	Deuxieme cuvée	4	600	191.	9.3	2.94	7.77	6.50
	Troisieme cuvée	5	400	193.	8.2	2.96	6.87	6.78
Vin de taille	*Premiere taille*	6	400	192.	6.6	3.12	5.17	6.03
	Deuxieme taille	7	2.70	191.	5.1	3.43	4.10	6.55
	Troisieme taille	8	2.00	183.	4.5	3.69	3.49	8.74

Source: Francot (1950).

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Section 2.

Table 4 summarizes the volume breakdown of the fractions frequently separated in Champagne. The first fraction contains dust and residues and is frequently oxidized as a result of inadvertent bruising during harvest. The cuvée portion is the best for sparkling wine production, being the least fruity, highest in acidity, and sweetest, while not being oxidized. Fast pressing risks higher extraction of polyphenols.

Table 4. Method of Fractionating a 4,000 kg Lot of Champagne Grapes

Fraction	Liters	Gallons
First fraction	200	52
The Cuvée	2,050	529
The 1st Taille	400	103
The 2nd Taille	200	52
Total	2,850	736

Source: Hardy (1989)

Juices extracted slowly at low pressure to give low solids are, therefore, less vulnerable to oxidation. The integrity of the pressing can be measured by comparing the differences in titratable acidity (ΔTA) between the fractions (Dunsford and Sneyd, 1989).

ΔTA (Cuvée – 1st taille)
= ΔTA (1st – 2nd taille)
= 1.5 g/L tartaric acid

Table 5 gives press data for a California Pinot noir. Segregation of press fractions is frequently based upon taste, which is affected by the significant drop in acidity with continued pressing following approximately 110 gallons per ton. Each press fraction differs in acid, pH, and phenolic and aroma/flavor components. In years of *Botrytis* degradation of greater than 15% of the berries, a first press fraction of about 10 gallons per ton is also separated. Crusher-stemmers mix the juice fractions and can result in ≤100 mg/L more phenolics than pressing whole grapes.

Table 5. Pinot Noir Press Fractions

Press Fraction	Total Phenols (mg/L GAE)	TA (g/L)	pH	Absorbance (520 nm)	Yield (Gallons/Ton)
1	200	13.0	2.80 - 3.10	0.25	110
2	250	11.0	3.10 - 3.25	0.62	20
3	320	9.5	3.30 - 3.45	1.10	7

Source: Data averaged from several California sources.

The trend in the sparkling wine industry is to employ tank presses, champagne ram presses, and traditional basket presses. The cocquard champagne basket press is still used by some houses in Europe. This unit is unique in that it has a very shallow maie or press basket, rarely over two feet deep, with a diameter of 10 feet. The shallowness of the base relative to its width allows for grapes to be spread out in a fairly thin layer which reduces skin contact with the juice as it flows through the pressed mass of grapes. Thus, less press pressure is required.

The level of total phenols and the types of phenols present are a function of press pressures and the design of press among other factors. White wines with a total phenol count of 200 mg/L G.A.E. can expect to have approximately the following constituents: 100 mg/L nonflavonoid caffeoyl tartrate and related cinnamates; 30 mg/L nonflavonoid tyrosol and small molecular weight derivatives; 50 mg/L flavonoids - especially catechins (flavon-3 diols) and flavon polymers (tannins); and 15 mg/L SO_2 and other interferences (Singleton, 1985).

The nonflavonoid fraction is relatively constant in the initial pressing of white and red grapes because these compounds are present mainly in the easily extracted juice. The nonflavonoid fraction of cuvées not exposed to wood cooperage totals about the same as that in the juice. There is, however, considerable modification of phenols, and some may be lost or gained with aging (Singleton et al., 1980). Most nonflavonoid phenols are individually present below their sensory threshold, but their additive effects are believed to contribute to bitterness and spiciness.

Flavonoids such as catechins are extracted from the skins with increased press pressure and may vary with the type of press employed. Catechins account for most of the flavor in white wines with limited skin contact. *Vin de cuvées* (first press cuts) produced by low press pressures and thin layer presses can be low in total phenols, and particularly in flavonoid phenols, resulting in low extracts. This is an important production consideration. In Bruts, especially, finesse must be in balance with the liveliness and the body of the wine.

An extract of approximately 25 g/L gives body without heaviness (Schopfer, 1981). Moderate pressures, or combining portions of later press fractions, are methods of stylistic input that can affect such things as the tactile base of the aroma/flavor character of the cuvée. Most producers are looking for delicate aromas/flavors in the cuvée, which are associated with the initial juice extracted. Thus, a low volume gives a base wine that is low in extract and may, therefore, be elegant but lack depth.

No separation of the stems need occur before pressing. The stems ensure efficient and improved draining and pressing of the whole grapes at lower pressures. Ultimately, this aids in obtaining a higher quality, more delicate first-cut press juice. Francot (1950), found that the Williams press produced juice with composition similar to the traditional basket press. Unlike the basket press, newer tank presses are pneumatic, give complete control, higher yields, produce fewer nonsoluble solids, low phenols, and require much lower press pressures (Downs, 1983).

Low pressure minimizes the chance of macerating the stems and releasing bitter compounds into the juice. Gentle pressing of cool fruit extracts fewer flavonoid phenols. These compounds are responsible for astringency, bitterness, and color. The juice near the skins and seeds, released by heavier press pressures, has more intense aromas/flavors and more flavonoid phenols. A tank press can press to dryness at two atmospheres or less and take press cuts. The rules of thumb in Champagne for pressure maxima during pressing are the following:

- the cuvée extraction at < 1 bar;
- the first taille (1°T) at < 1.2 bar; and
- the final fraction (2°T) at < 1.4 bar

Many ram-type presses require higher pressures to reach dryness. Filling the press with whole clusters reduces the press load. For example, a Bucher 100 RPM tank press that is rated for a charge of 20 tons will hold about 12 tons of whole clusters.

Pressing Chardonnay and Pinot noir may produce an average yield of 140 and 120 gallons per ton, respectively. The Chardonnay grape contains slightly more pulp than the Pinot noir. As stated, press fractions are often segregated by taste by monitoring the reduction in juice acidity. For Chardonnay and Pinot noir, dramatic drops in acidity occur between the extraction of 110-120 gallons/ton.

For red varieties such as Pinot noir and Pinot meunier, care is often taken to avoid excessive color extraction. Excess color will affect the sparkling wine character, degree of foaming, and rate of secondary fermentation (Schanderl, 1943). Color extraction is minimized by pressing cool fruit and segregating pressing fractions. The ability to increase the extraction of colored vs. noncolored phenols may be an advantage in producing sparkling rosés.

In the production of rosé by cuvaison, it is essential that color extraction occur without extraction of excess astringent phenols. The use of cold soak with or without pectinolytic enzymes helps to attain this goal (Zoecklein et al., 1995). The other method of producing a sparkling rosé is by *rougissement*, or blending. Subsequent color modifications may occur in the dosage stage to produce a sparkling rosé which is said to “reflect the color of rubies.”

The *Premier taille* (Table 3) is fruitier, less fresh and less elegant than the *Vin de cuvée*. The later press fractions possess the following attributes: high pH, excess color, high total phenolic content, often excessive varietal character, harshness, usually higher nonsoluble solids, and a lesser quality aroma. The harshness, color, and nonsoluble solids of later press fractions can be reduced by fining with protein agents, occasionally in conjunction with bentonite and kieselsol.

All or portions of the second press fractions may be blended with the primary fraction due to sensory and economic necessity. The third fraction is seldom employed in premium méthode champenoise production. For a review of méthode champenoise grape handling, see Hardy (1989) and Dunsford and Sneyd (1989).

Juice Treatments

Sulfur dioxide (SO_2) is added to the juice expelled from the press, but never directly into the press in order to avoid extraction of phenols. Although it is considered desirable to use SO_2 to help control oxidation, there is no industry consensus regarding optimum amounts. In the US, 30 mg/L is added to the first cut press fraction, though such a decision must be made based upon the freedom from rot, juice chemistry, temperature, and malolactic fermentation desires.

Phenols are oxidized in the absence of sulfur dioxide and, therefore, some pass from the colorless to the colored or brown form. This results in some juice browning. Less soluble or insoluble phenols precipitate and may be removed during fermentation due to the absorbent capacity of yeast.

Muller-Spath (1981) originally suggested the desirability of low sulfur dioxide additions (20-25 mg/L) to the juice under the right microbiological and temperature conditions, to encourage some oxidation. Singleton et al. (1980) showed that oxygenation of must for white table wine production increases resistance to further browning, but results in less fruity wines. The use of sulfur dioxide in base wine production may be important to minimize oxidative loss of aroma precursors needed for bottle aging (Hardy, 1989).

The press juice fractions are often cold-settled (*débourbage*) or centrifuged to reach a nonsoluble solids level of 0.5-2.5% prior to fermentation. The primary press fraction from a thin layer press, such as a Bucher, may already be sufficiently low in nonsoluble solids. Grape solids are removed to minimize extraction of phenols that may occur during fermentation. This is frequently accomplished with the aid of pectinolytic enzymes. Bentonite is usually not used in the primary juice fractions (Munksgard, 1998). There is a significant reduction in yeast levels between centrifuged juice (95%) and cold-settled juice (50-60%) (Linton, 1985). The ability to rapidly settle is the result of the low pH in the primary press fractions. Some producers use prefermentation juice fining to aid settling and to modify the palate structure of the base wine (Zoecklein et al., 1995). The 1st taille often receives 60-70 mg/L SO_2 and 50 g/hL bentonite/casein (Hardy, 1989).

Primary Fermentation

The lower the nonsoluble solids content and the cooler the fermentation, the greater the production and retention of fatty acid esters (Williams et al., 1978). These compounds are responsible for the fruity, floral, aromatic nose of wines produced under such conditions. Some producers choose to ferment their cuvées warm (65-70°F) to reduce the floral intensity, thus making a more austere product. Elevated fermentation temperatures are desirable if a malolactic fermentation is sought. Vinification at 55-60°F is not uncommon in this country.

Many producers check the nitrogen status (total and NH_4 N) of juice prior to fermentation and make adjustments accordingly (Zoecklein et al., 1995). A standard addition of 5-10 g/100 L of diammonium phosphate is widely used in Champagne. An addition of 10-25 g/100 L of bentonite is made during the primary fermentation of the cuvée by some (see protein stability/bubble size section). Higher additions of up to 150 g/100 L of a bentonite/casein mixture is often added to the “tailles” or to the first cuvée fraction when a significant amount (greater than 15% of the berries) of rot is present.

The yeast employed is occasionally the same for the primary and secondary fermentation. Sparkling wine yeasts are selected for their ability, among other things, to produce esters. Using the same yeasts for both fermentations can result in an end product that is too floral and too high in volatile components. Those yeasts often used for primary fermentation include Montrachet UCD 522, Pasteur Champagne UCD 595, and California Champagne UCD 505. Yeasts infrequently used for primary fermentation include Epernay-2, Steinberg, and French White (Bannister, 1983).

The primary fermentation is generally conducted in stainless steel. Some European houses use small wooden casks and barrels to ferment all or part of the cuvée. Those who suggest that greater finesse and elegance results from wood are countered by the majority who fear the wine will pick up excess tannin and color.

Barrel fermentation results in added structure, often without significant harshness or astringency. Henry Krug ferments their entire vintage slowly at low temperatures in oak vats, believing this to add more bouquet. This is consistent with their desired style, which is full flavored, mature tasting, and complex.

Reserve Wine

For product consistency, and temperature and biological control, some producers blend a percentage of the previous year's cuvée into the fermenting juice. "Reserve wine" can also be added during *assemblage* or blending, and may be a component of the dosage. Such practices are based upon production and vintage dating considerations. In the United States, vintage labeling requires that at least 95% of the wine comes from the vintage year.

Following primary fermentation, the goal of many méthode champenoise producers is to process the cuvée for the secondary fermentation as rapidly as possible. This enables the wine to reach the consumer sooner, and also takes advantage of the nutrient-rich young cuvées that support the secondary fermentation. Others counter that there is no need to rush the cuvée into the second fermentation. These winemakers usually prefer to allow their base wines to age and develop, noting that the secondary fermentation is a rejuvenating step.

Protein and protein-like fining agents can be used to clarify and lower the phenolic content of the base wines. Isinglass and gelatin are the most common fining agents. Schanderl (1962) recommended the use of polyvinyl-pyrolidone (PVP) to remove polyphenolic compounds from the base wine. It should be noted that juices are much more forgiving of the harsh action of protein fining agents than are wines. For a detailed discussion of fining and fining agents, see Zoecklein et al., 1995.

The total phenol content, as well as that of the phenolic fractions, can be determined by a number of analytical procedures such as HPLC, Folin-Ciocalteu, and permanganate method (Zoecklein et al., 1995). Schanderl (1962) recommended a simple pH 7 test for the determination of polyphenol levels in juice and wine (see Zoecklein et al., 1995 for details).

Potassium Bitartrate Stability

Most producers stabilize their base wines to prevent bitartrate precipitation which can influence taste (KHT – potassium bitartrate – is both salty and bitter) and gas release from sparkling wines. There is wide variation in procedures for determining KHT stability utilized in the industry. A freeze test relies on the formation of crystals as the result of holding wine samples at reduced temperatures for a specified time period. Often, a sample is frozen and then thawed to determine the development of bitartrate crystals, and whether or not those crystals return to solution.

Zoecklein et al. (1995) discussed some of the problems associated with using a freeze test to predict bitartrate stability. Several winemakers use a slight variation of the freeze test. Realizing that the *prise de mousse* will create anywhere from 1.1 - 1.5% additional alcohol (in *mouseux* production), they will fortify a small quantity of their cuvée and perform a freeze test on the fortified sample. Alcohol, among other factors, affects KHT precipitation. Fortification may be a desirable change to the freeze test procedure, but the inherent problems of the freeze test still exist even when the sample is fortified. An electrical conductivity test is a much more accurate method of determining bitartrate stability (Zoecklein et al., 1995).

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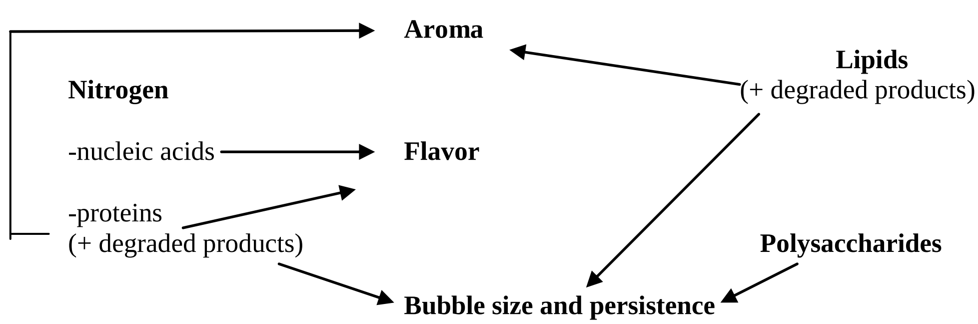
Protein Stability/Bubble Size, Retention and Foaming

Carbon dioxide is available in two forms, free gas and CO_2 electrostatically bound to constituents such as proteins, polysaccharides and lipids (see Figure 2). Makers of sparkling wine must manage their cuvée protein levels to obtain a product with minimum protein precipitation in the bottle, while not detrimentally affecting carbonation.

Figure 2. Reported Impact of Yeast Autolysis on Various Attributes of Sparkling Wine Quality.



Adapted from Todd (1996).

Precipitation of protein is affected not only by the exposure temperature, but also by the duration of heating. Since all cuvée proteins may be precipitated by heat, there are varying degrees of heat stability with regard to proteins. For example, heating a sample at 40°C for 24 hours precipitates about 40% of the wine proteins, whereas holding at 60°C for 24 hours precipitates 95-100% of the proteins (Pocock and Rankine, 1973). The time necessary for haze formation decreases with increasing temperature.

Several winemakers use a heat test and recommend chilling the wine sample following heat treatment. Visible haze formation is slightly greater than that seen in a sample without subsequent cooling. Protein precipitation, like potassium bitartrate precipitation, is affected by alcohol. Winemakers may choose to fortify their cuvée blends by 1.1-1.5% alcohol in the laboratory prior to running a heat test. This is to duplicate the alcohol level which will be achieved in the bottle.

Precipitation tests such as the TCA procedure are not uncommon methods for determination of protein stability. The makers of sparkling wines must look beyond stability to the effects proteins have on bubble size, bubble retention, and foaming. Indeed, the influence of cuvée proteins, fermentation rate, and yeast autolysis products may be greater than that of such traditional parameters, such as alcohol, on bubble size, retention, and foaming.

Gauging optimum cuvée protein is a matter of experience. Those using bentonite as a riddling aid may want to not fine with bentonite or purposely under-fine the juice or cuvée, knowing that additional protein will be bound in tirage. Little has been published about the influence of tirage fining agents on bubble and mousse. Munkegard (1998) noted the increase in mousse quality with the addition of tirage tannin. This may relate to protein tannin interaction (for additional information on bubble and foam quality see section on Liqueur de Tirage).

Assemblage

Because it is rare that a single wine of a single vintage from a single vineyard will be perfectly balanced in composition and flavor for a premium sparkling wine, blending is often performed. Blending is considered by most to be the key to the art of méthode champenoise. The selection of the cuvée components is conducted with three main objectives in view: the production of a sparkling wine of definite consistent flavor and quality; the enhancement of the quality of the individual wines; and the production of a base wine of sufficient quantity.

Blending is an important tool that produces a result that is greater than the sum of the parts. The art of blending depends in part on chemical formulae, but also relies heavily on the gift and talent of the blender. Winemakers must blend wines for sparkling wine production when the wines have the better part of their lives yet to come. This requires considerable insight. It is difficult to predict the final results of blends that will be consumed years later.

The first decision to make is whether the new wines are of sufficient palatability to produce méthode champenoise. The magnifying effect of carbon dioxide on sparkling wines significantly highlights any enological flaws in the product, so wines for cuvée selection should be tasted at room temperature and on several occasions.

The decision of whether the cuvée is to be non-vintage or vintage dated is an important one. Non-vintage products rely on product consistency and usually require *vin de reserve* (cuvée blending from previous years). Generally, at least one-eighth of the new wine is put into reserve for this purpose in Champagne. Reserve wine is either stored in magnums (as is the case with Bollenger) or in bulk, sometimes under a gas environment.

Some makers prepare cuvée blends prior to stabilization. When wines of different ages, grapes, and origins first meet, bitartrate and protein precipitation can occur. Cellar treatments, such as fining and filtration, can remove colloidal protectors, and thus affect potassium bitartrate stability. Due to the character of the wine, many prefer to make cuvée blending decisions following stabilization. It is essential that protein and bitartrate stability be evaluated just prior to cuvée bottling.

Technology dictates that producers rely on the chemical composition of the cuvée, as well as its taste, for blending determinations to aid in production consistency. For example, high alcohol, low pH, and/or low level of assimilable nitrogen cuvées may have difficulty completing the secondary fermentation, while low alcohol cuvées produce sparkling wines with poor bubble retention (Amerine and Joslyn, 1970). Many producers add a source of nitrogen, such as DAP (24 g/100 L), prior to tirage.

The primary requisites for a cuvée are a high titratable acidity (7.0 g/L or more expressed as tartaric acid), low pH (less than 3.3), low volatile acidity (less than 0.60 g/L), and moderate alcohol level (between 10.0 and 11.5% v/v). The cuvée should be light in color, with a balanced, fresh aroma. Many are looking for base wines with no single varietal character dominating, but with body, structure, substance, and length. Wines with a low acetaldehyde (< 75 mg/L), low copper (< 0.2 mg/L), and low iron (< 5 mg/L) content are sought. Additionally, wines with a relatively low phenolic content are often desired. An extract of 25 g/L adds body without making the wine heavy.

The concentration of aldehydes is a gauge by which general sparkling wine quality can be measured. Aldehyde concentration is primarily a function of the extent of oxidation, but also of the quantity of SO_2 added during primary and secondary fermentation. Concentrations of acetaldehyde greater than about 75 mg/L may add an overripe, bruised apple aroma (Zoecklein et al., 1995).

Another important blending consideration is the amount of second-cut press material to employ. This affects the phenolic content and is both a production and economic question. The goal is often to produce a cuvée that is delicate and “clean” and has structure to provide the framework for bottle bouquet. For “Vintage” years and Petillants, the alcohol level of the wine is usually somewhat higher (11-11.5% (v/v). Cuvée alcohols greater than about 12.6% can lead to sticking of the secondary fermentation. The base wine should be low in free sulfur dioxide content (< 20 mg/L) to ensure the ability to re-ferment. Additionally, both the total and free sulfur dioxide content must be kept low if a malolactic fermentation is desired.

Chardonnay alone can be highly perfumey and somewhat candy-like, with intense richness. Excessive varietal character is often reached in California. This is not a problem in the eastern U.S., which may make Chardonnay production for sparkling wine quite suitable for Virginia. Pinot noir often produces a light, earthy strawberry aroma. Our European colleagues use the analogy that the Pinot noir is the frame; the Chardonnay, the picture; and the Pinot meunier, the dressing for their Champagnes. Pinot noir, Pinot blanc, and Pinot meunier age more quickly than Chardonnay.

Some generalizations regarding palate profiles can be made of young wines produced in Champagne. Chardonnay is detected at first with its intensity and perfume. This is followed by Pinot meunier with broad mid-palate flavors, and finishes with Pinot noir which adds length and intensity. Both Pinot noir and Chardonnay take more time to develop than Pinot meunier. Often meunier is utilized to a greater degree if wines are aged 1 year or less sur lie. With increasing tirage age, Pinot noir will increasingly dominate the nose and palate. The lack of knowledge as to which cultivars to use and which blends will age needs particular attention.

Malolactic Fermentation

For some, the attitude is that a high malic acid level in the cuvée and a low pH add life and freshness to the sparkling wine. Malolactic fermentation is avoided because the wine then stays fresher and ages less quickly. Some French producers, however, believe that a malolactic fermentation of the cuvée, or a component part, can broaden and lengthen the finish and flavor. An elevation in pH and a reduction in acidity change the palate structure.

In Champagne, there are climatic differences that help explain a preference for malolactic fermentation. The days are warmer, the nights cooler, and the light intensity greater in Napa (Maudiere, 1980). Grapes ripen faster in California and generally have higher sugars and lower titratable acidity than in Champagne. Many French houses put their sparkling wine bases through a malolactic fermentation. The result is a wine with the same acidity as a California product in which the bacterial fermentation has been prevented. In most seasons the Virginia climate is somewhat in between the two regions sited above. As such the use of MLF is not used for deacidification as much as for added complexity.

Table 6 provides some analytical data from the Enology–Grape Chemistry Laboratory at Virginia Tech comparing European and American méthode champenoise. A major difference illustrated is the high malic acid content (low lactic acid) of some of the finished products. When malolactic bacteria grow in wine, they can reach population levels of 10^6 - 10^8 cells per milliliter. Such titers are equivalent to yeast populations during active fermentation. It seems likely that the significant production of proteases, lipases, and esterases caused by malolactic fermentation could significantly alter the finished product. Some méthode champenoise producers appear to be utilizing malolactic fermentations of the cuvée to control the palate structure. A malolactic fermentation may modify the sweet-sour perception one experiences occasionally with méthode champenoise produced from low pH, high acid cuvées. Malic acid is rather aggressive, while lactic acid is much softer on the palate. An increased number of

American producers are now experimenting with partial or complete M/L (malolactic) fermentations of their cuvées (Zoecklein, 1986b).

Table 6. Méthode Champenoise Analysis

	#1 NAPA	#2 EPERNAY	#3 SONOMA	#4 REIMS	#5 NAPA	#6 AY	#7 NAPA	#8 Wiesbaden Germany
Total phenols (mg/L GAE)	209	294	261	261	245	340	317	300
Nonflavonoid phenols (mg/L GAE)	183	282	229	239	218	270	227	290
Tartaric acid (g/L)	3.12	3.45	1.99	3.56	2.76	4.15	1.22	2.15
Malic acid (g/L)	4.78	2.03	2.79	0.33	3.32	0.25	1.00	2.96
Citric acid (g/L)	0.18	0.16	0.79	0.17	0.23	0.22	1.61	0.22
Lactic acid (g/L)	0.15	2.06	0.15	3.80	0.12	3.12	0.24	2.02
Acetic acid (g/L)	0.45	0.28	0.16	0.37	0.23	0.30	0.18	0.44
Succinic acid (g/L)	0.15	0.33	0.27	0.21	0.37	0.52	0.28	0.63

Cuvée Filtration

Immediately prior to bottling, many producers filter their cuvées. This occurs, of course, before yeasting. The purpose of such an operation is twofold: to help prevent malolactic fermentation, and to begin the secondary fermentation with a “clean” wine. Some do not filter at all, but simply clarify once with isinglass (Duijker, 1980).

Malolactic fermentations can easily transpire under pressure, such as might occur during the secondary fermentation. The result of such a bacterial fermentation is the reduction of malic acid, increase in lactic acid, raising the pH, and increase the titer of bacteria. The latter, particularly, results in riddling difficulty and possible loss of product palatability. The general nature of the cuvée usually helps prevent a spontaneous malolactic fermentation. Grapes are brought to the sparkling wine house at low pH levels and often pressed, avoiding skin contact, thus aiding in reducing the likelihood of a spontaneous fermentation. Those concerned with the possibility of a malolactic fermentation in the bottle generally sterile filter their cuvées. If a malolactic fermentation has been completed, a D.E. filtration, pad filtration, or no cuvée filtration may occur. An additional advantage of a completed malolactic fermentation of the cuvée is that it will not occur during secondary fermentation or storage.

Yeasts

Sparkling wine yeasts are available on slants, in liquid, and in active dry forms. The yeast volume employed for the secondary fermentation is usually a 2-5%-activity growing culture. Many traditional sparkling wine houses build up an active yeast innoculum from slant cultures, by either a step-wise volume increase, or by the use of yeast generators with or without oxygen sparging.

Yeast preparation for bottle fermentation is of obvious importance. Some believe it desirable to culture yeast under stressful conditions, such as higher SO_2 levels and cooler temperatures (the so-called step-down theory), so that when the secondary fermentation begins, the yeast will be more vigorous. Others have expressed the desirability of conditioning the yeast to the exact same conditions (except CO_2 pressure) that will be found in the bottle. Research continues in this regard.

A common preparation method is as follows (Bannister, 1983): 500 milliliters of a solution of sterile wine (the cuvée to be fermented) and sterile water are diluted to 7% alcohol. To this, 5% sugar and 1. 2 grams of yeast extract are added. This medium is inoculated from a slant yeast culture using strict aseptic techniques and incubated at approximately 80°F. When half the sugar is utilized, this culture is transferred directly into 1.5 liters of undiluted wine to which 5% sugar has been added. This is repeated using a 10% inoculum into a new-wine volume that has 5% sugar added. Transfers are made at 2.5% sugar.

This is repeated again until a 5% inoculum volume has been produced (5% of the cuvée volume that is to be fermented). Care must be taken not to allow the culture to go to dryness prior to transfer, because the alcohol level will increase and begin to inhibit the yeast. When all the sugar has been depleted in the medium, the yeast rapidly begins the death phase. Transferring the growing culture at 2.5% sugar will acclimate the yeast to being able to grow in a 2.5% sugared cuvée. Additionally, during the transfers, it is desirable to go from inoculation temperature to the temperature at which the cuvée will be fermented.

Aeration will produce yeast cell membranes rich in ergosterol which will result in increased alcohol tolerance. Optimally, the producer will examine the starter culture to assure that the culture is actively growing and not contaminated. A large percentage of budding yeast (70-80%) is desired. It is essential that the culture be free of contamination. Some use a methylene blue test to monitor yeast growth (see Zoecklein et al., 1995, or Fugelsang, 1997, for stain preparation).

To ensure secondary bottle fermentation, a minimum of 1 million cells per milliliter should be added to each bottle (Geoffroy and Perin, 1965). An actively growing culture is usually about 10^6 - 10^8 cells per milliliter. From 0.8 to 2.5 x 10^6 cells per milliliter is usually added for the secondary fermentation. Yeast cell titers can be determined as described by Fuglesang (1997).

Some producers prefer to simply add lyophilized yeast directly to the cuvée. Active dry yeast contains 20-30x10^9 live yeast cells per gram (Berti, 1981). If equipment is limited, the use of active dried yeast may be considered easier. It is preferable to feed and grow several generations of active dried yeast prior to the addition into the cuvée. This allows the producer to train the yeast to go in the cuvée, as well as monitor yeast viability and possible contamination. An increase in the number of yeast cells in the cuvée may give a fuller character and flavor to the sparkling wine (Berti, 1981). Care must be used, however, to avoid rapid secondary fermentation and the development of hydrogen sulfide and other off-odors. For additional information regarding yeast culture preparation, see Fugelsang (1997).

For the secondary fermentation (*prise de mousse*), a yeast with the following attributes is desirable: produces little SO_2, ferments to dryness, dies or becomes inactive following fermentation, does not stain the wall of the bottle, has desirable flocculating or agglutinating ability, produces no off flavors or odors, has a desirable effect on carbonation, and has tolerance to pressure, alcohol, cold, and SO_2.

Because the demands on the yeast are very specific, the vintner must be specific in yeast selection. For example, Chardonnay is sometimes difficult to ferment to dryness; therefore, a strong fermenter may be desirable. Some yeasts are very delicate, others assertive or defined, regarding the character they impart to the sparkling wine. This is another stylistic consideration.

There is significant variation in the ease of riddling with different yeast (Geoffroy, 1963). Several “champagne strains” of *Saccharomyces cerevisiae* and *S. bayanus* (formerly *oviformis*) have many of the above-mentioned properties, including enhanced agglutinating ability. *S. bayanus* has a slightly greater alcohol tolerance than does *S. cerevisiae*. Additionally, some producers use *S. unarium* for the secondary fermentation.

Epernay, also known as *Prise de Mousse*, is a highly flocculent yeast with good riddling ability. It is fairly assertive and is, therefore, usually not employed to carry out both the primary and secondary fermentation. This yeast is the same as Epernay 2, which is a low-foaming strain often employed when a sweet finish is desired. The Geisenheim strain of champagne Epernay does not produce SO_2 during fermentation, does not stick to the bottle, ferments at relatively low temperatures, and is sandy in its agglutinating ability (Becker, 1978).

California Champagne (UCD 505) and Pasteur Champagne (UCD 595) are popular yeasts for secondary fermentation. Both are available in dehydrated form. UCD 505 is a good flocculator and may be considered to be more delicate than UCD 595. Some sparkling wine producers use mixed cultures for the secondary fermentation, believing that such a procedure adds complexity. Many sparkling-wine houses employ their own proprietary yeast strains. New or prospective producers should do some in-house experimentation to determine the merits and deficiencies of different yeasts under their own conditions.

A REVIEW OF MÉTHODE CHAMPENOISE PRODUCTION

Section 4.

Riddling Aids

To enhance riddling ability, disgorgement, and possibly wine palatability, some vintners add riddling aids at the time of cuvée bottling. Such aids (fining agents) may enhance the riddler's ability to convey the yeast to the neck of the bottle. When there is sedimentation of the yeast with the proper fining agent, riddling can be much easier. Some common riddling aids are the following:

- Sodium and calcium bentonite
- Various Prosperity Adjuvants
- Isinglass
- Tannin
- Gelatin
- Diatomaceous earth

Bentonite is, perhaps, the most popular riddling aid in this country. It is added at the time of cuvée bottling in levels seldom exceeding 6 g/100 L (2 pound/1000 gallons). In

Europe, calcium bentonite (3.5 g/100 L (0.25 lb. per 1000 gallons) is frequently used. The choice of riddling aids should also be based upon the expected time sur lie. Clays are often preferred for young wines, while gelatins are for aged or older wines.

The major disadvantage with the use of riddling aids is that their effects on both riddling ease and sparkling wine palatability are not predictable. Riddling aids may influence foam and/or bubbles, as well as wine clarity. Tirage tannin, for example, may positively influence mousse quality (Munksgard, 1998). Further research in the area is needed. Because each cuvée is different, the winemaker must wait until riddling and disgorgement to review the merits or deficiency of the riddling aid(s) employed.

Bentonite is the most common riddling aid because of its relatively inert nature. It seldom has a detrimental effect on product palatability at the levels employed (usually less than 6 g/100 L or 2 pound/1000 gallons). Care must be taken to avoid the addition of too much riddling aid, which can make riddling, and particularly disgorgement, difficult (Zoecklein, 1987a).

Liqueur de Tirage

Different wineries use various sugar sources for the *prise de mousse* (secondary fermentation). Bottler-grade sucrose or dextrose are perhaps the most common in this country; however, larger operations may choose to employ sugar syrups. Many French producers use high-quality beet sugar. Some use a 50% sugar solution – 500 grams/liter of sugar in wine – with 1.5% citric acid frequently added to invert the sugar if sucrose is used.

Theoretically, 4.04 grams of glucose or 3.84 grams of sucrose upon fermentation will yield 1.00 liter CO_2 (at 760 mm pressure and 0°C) weighing 1.977 grams (Berti, 1981). The actual yield is less due to production of small amounts of aldehydes, volatile and fixed acids, glycerol, and other entities produced by the yeast. In actual practice, sparkling wine producers estimate that 4.0 to 4.3 grams of sugar per liter is needed to produce one gas volume (atmospere) of carbon dioxide (4.3 grams of sugar per liter is equal to 1 pound of sugar in 27.3 gallons).

If, for example, 6 gas volumes of CO_2 are required, then approximately 4.2 grams x 6 atmospheres, or 25.2 grams of sugar per liter, are added. This will produce 1.1-1.5% additional alcohol (v/v). If the cuvée already contains fermentable sugar, this must be taken into account.

In this country, sparkling wines are those that contain 0.392 grams CO_2 per 100 mL or more, at 60°F. A wine containing this amount of CO_2 will exert about 15 psi pressure at 15.56°C. In Europe, the minimum pressure for sparkling wines recommended by l'Office International de la Vigne et du Vin is 51 psig (pounds per square inch, relative to the surrounding atmosphere) at 20°C in bottles over 250 mL capacity. Accurate determination is therefore critical.

Carbon dioxide pressure in the US is more a stylistic consideration. Petillants possess about 2-2.5 atmospheres pressure at 1°C and have a fizzy character to the palate. Crémants, which are produced by the addition of 15-18 g/L sugar, reach about 3.5 atmospheres, while the more common Mousseuxs are produced by the addition of approximately 25 g/L sugar and reach pressures of > 4.5 atmospheres. Crémants were first produced in 1850 as meal complements. They should be consumed young for they age quickly. Perhaps the most famous of these products is the Crémant de Cramant of Mumms. This wine possesses a tactile creamy sensation.

Some producers add a limited amount of sulfur dioxide at the time of cuvée bottling. This helps protect the cuvée from the harmful effects of oxygen and biological degradation. In the base wine, sulfur dioxide binds with aldehydes, among other things, to produce an acetaldehyde-bisulfite complex. This complex helps inhibit lactic acid bacteria.

Additionally, the free sulfur dioxide (specifically the molecular free form) can have a significant antimicrobial activity. The free sulfur dioxide level is kept low (15-20 mg/L) to avoid yeast inhibition. Decisions regarding the addition of sulfur dioxide should be based upon an understanding of cuvée chemistry, particularly pH.

Nitrogen compounds are essential for the growth and development of yeast and for fermentation. The utilization of these compounds by yeast greatly affects wine palatability. Some choose to add a form of yeast nutrient either to the developing inoculum or the cuvée. The desirability of such an activity depends upon the age of the cuvée, its chemical nature, and perhaps production philosophy Schanderl (1941, 1943) outlined difficulties that can occur due to such additions.

According to Bidan and Salques (1981), diammonium phosphate (DAP) addition of < 250 mg/L favors the production of esters and diminishes the production of fusel oils, both of which enhance quality. Additionally, ammonium salts minimize the production of sulfites (Vos and Gray, 1979). Proprietary compounds produced in both Europe and America are not uncommon additives. The use of yeast nutrients may be highly significant in older cuvées that are nutritionally deficient. The addition of 24 g/100 L (2 pounds per 1000 gallons) of DAP is not uncommon as is the addition of complex nutrients.

At the cuvée bottling line, a uniform mixture of wine yeast, dissolved sugar, sulfur dioxide, possibly riddling aids, and nutrients is added to each bottle. This is usually accomplished by having a mixing tank with a guth-type mixer located just in front of a bottom tank valve leading to the cuvée bottling line. If this is properly designed and operational, the yeasted cuvée leaving the tank for the bottle will be uniform throughout the bottling run. The yeast cells and added sugar syrups have a greater density than the cuvée and can settle out of solution, resulting in bottle inconsistency. Cuvée homogeneity can be easily monitored during bottling by measuring density with the use of a hydrometer. Several sparkling wine houses have elaborate in-line nephelometric systems.

The temperature of the cuvée should be the same as the desired secondary fermentation temperature. Almost any bottling method is adequate for cuvée bottling. Some feel the necessity to slightly aerate the cuvée prior to bottle filling, although this should be done with caution. Oxygen is important to yeast as the final electron acceptor in oxidative phosphorylation and lipid synthesis.

Alcoholic fermentation consists of two overlapping phases. In the aerobic phase, or respiration, oxygen stimulates the production of cellular material and, therefore, yeast growth. In the anaerobic phase, sugars are enzymatically broken down to ethanol, carbon dioxide, and other constituents. The stimulation of yeast cell growth by oxygen was discovered by Pasteur and is known as the Pasteur effect. Many premium méthode champagne winemakers do not believe that purposeful oxidation of the cuvée is necessary for yeast growth, but rather that it may detrimentally affect product palatability and gushing.

The bottle fill level should be based upon an understanding of disgorgement volume loss and the desired dosage volume. Disgorgement volume loss should not exceed 2%. After the cuvée has been placed in the bottle, a bedule is inserted into the bottle. A bedule is a hollow polyethylene cup usually 17 mm diameter x 14 mm high. Bedules help prevent leakage and metal contact from the crown, give a better seal, and aid in disgorgement.

Following the insertion of the bedule, which is performed by hand or by machine, a closure is placed on the bottle. This usually consists of a crown cap. Crown caps for sparkling wine must be especially designed to have the proper skirt length to grip over the bead of the bottle for a proper seal, be malleable enough to adequately crimp over the bead, and have a proper liner. Crown caps are generally stainless steel, coated mild steel, or aluminum.

In this country, some use plastic-lined crown caps rather than the cork-lined ones that are more popular in Europe. Plastic seals in the crown hold as much pressure as cork, but do not provide a seal as long-lasting as cork. An additional problem with plastic seals is that they do not hold the bedule down into the bottle as firmly as cork, and they may reduce the effectiveness of the bedule (Zepponi, 1983).

To avoid corrosion of crowns in damp cellars, some producers use stainless steel crowns. These corrosion-resistant crowns are often rigid and, therefore, difficult to seal tightly on the bottle, and are expensive. Aluminum-alloy crowns, which are corrosion resistant and fairly malleable, are available. Hand-operated crown cappers must be capable of applying enough pressure to the crown to give a proper seal. Significant losses have occurred from improper sealing.

Bottle Fermentation

Following sealing, sparkling wines are stored for the prise de mousse. The storage method is dictated by general economics, the intended riddling system, and space considerations. There are several bottle storage systems (Zoecklein, 1986d). Sur lattes (stacking bottles on the floor) is labor-intensive, although it can add an aesthetic appeal to the cellar. One person can stack approximately 2000 bottles a day (Berti, 1981). This system requires considerable bottle handling going from cuvée line to stack, to poinitage (bottle shaking), then to the riddling system.

Another choice of bottle handling is to use bins. Wooden or caged bins, often holding 380-504 bottles, are available. These can be stacked, thus requiring much less floor space. A third method of bottle storage is to place bottles into cartons (the same cartons that will go to market) and allow the secondary fermentation and riddling to transpire in those cartons. In a system designed and patented by California’s Korbel, twenty-pallet loads at a time are tied down on a conveyor that employs a shaft to shake the wine gently and evenly on a programmed cycle and air bags that inflate and tilt the bottles by lifting one side of the pallet.

During binning, in either cases or cartons, most producers at some time store their bottles with the neck slightly down so the air bubble in the bottle moves away from the neck toward the back of the bottle. This helps avoid any staining in the bottle’s neck and allows the winemaker to use the bubble as a “scrubber” to free stuck yeast deposits prior to remuage (riddling). The bottle storage area should be cool and have minimum temperature fluctuations and minimal lighting.

The rate of the secondary fermentation is a function of the yeast, yeast volume, temperature, and cuvée chemistry. The rate is increased by high pH, high yeast nutrients, low phenolic content, low alcohol content, low sulphur, and low carbon dioxide pressure (Reed and Peppler, 1973). Winemakers, to a degree, can control the fermentation rate by processing techniques. The fermentation temperature is usually not lower than 8.89°C (48°F) and not greater than 12.78°C (55°F). Some prefer a cool secondary fermentation temperature of 12°C (54°F), believing this to affect the amount of carbon dioxide chemically and physically bound (Merzhanian, 1963).

A secondary fermentation at 12-15°C can be expected to last 0.5-1.5 months. Rouges often ferment more slowly due to the increased phenolic content. A high secondary fermentation temperature is believed to result in coarse bubbles that are larger, with less retention (Brusilovski et al., 1977). Growth at low temperatures is believed to increase the production of lipids which favor bubble retention. Bottles dissipate heat quickly, so heat buildup is not usually a problem.

Other factors affecting bubble retention include yeast strain, the nature of the still wine, and the length of time under pressure in contact with yeast (Berti, 1981). Fermentation within the bottle can often be observed as a ring of CO_2 bubbles around the base of the air bubble. The progress of the fermentation is usually noted by examination of either the reducing sugar, the bottle pressure, or both. Poor fermentation in the bottle can be attributed to a poor starter (low inoculum, poor budding, contamination), low temperatures, and/or undesirable cuvée chemistry.

Méthode champenoise bouquet is a function of both yeast autolysis and aging. Storage of sparkling wine sur lie allows yeast protolytic enzymes, such as proteases and hydrolases within the storage vacuoles of the cells, to damage the cells. These vacuoles exist in different stages of lysis (cell rupture), and the rate of lysis can vary significantly with different yeast species and strains.

As a result of storing wine in contact with yeast, there is an enrichment of the wine with amino acids (Bergner and Wagner, 1965). While amino acid enrichment receives the most attention, other compounds are increasing, too. Esters, amides, fatty acids, and terpenoids are all shown to increase due to yeast autolysis. The products of yeast autolysis and aging not only improve flavor, bouquet, complexity, and depth, but perhaps also CO_2 retention and bubble size (Amerine and Monagham, 1950).

A REVIEW OF MÉTHODE CHAMPENOISE PRODUCTION

Section 5.

Aging *Sur lie*

During the secondary fermentation, there is an accumulation of amino acids from the cuvée into the yeast cell. At the end of fermentation, when the sugar has been depleted, the yeast restores the amino acids back to the medium. This is not autolysis, but simply a free exchange back to the wine. This exchange occurs at a more rapid rate if a source of ammonia nitrogen is added to the cuvée (Sarishville et al., 1976). The addition of ammonium phosphate reduces the uptake of amino acids by the yeast and favors their excretion (Bidan, 1975).

After this excretion of amino acids, the concentration of amino acids remains stable for several months. Yeast autolysis then begins with a slow rise in the amino acid concentration. The concentration of amino acids during yeast contact does not vary significantly between the third and twelfth month of contact. The concentration of amino acids does increase between the 12th and the 43rd month sur lie.

Feuillot and Charpentier (1982) outlined in detail the changes in amino acids during aging. They found that after six months, the sparkling wine contained 12% greater amino acid content than the cuvée; after 12 months, 24.5 greater; and in four years, the sparkling wine contained a 25% greater amino acid content than its base wine. The proline, lysine, leucine, glutamic acid, isoleucine, phenylalanine, serine, and valine content significantly increase with age in bottle-fermented sparkling wine (Bergner and Wagner, 1965).

Yeast autolysis is dependent upon such parameters as pH, ethanol concentration, and temperature (Feuillot and Charpentier, 1982). Some producers prefer to utilize cuvées which have undergone a malolactic fermentation and, therefore, have higher pH values (3.2 vs. 2.9-3.1). Elevated pH significantly increases the rate of autolysis.

Feuillot and Charpentier (1982) showed an increase in nitrogen released into the champagne at elevated temperatures. It is believed that all yeast cells will be dead when aged for twelve months at temperatures of 15°C or below (Stashak, 1983). Aging bottles at elevated temperatures accelerates the autolysis process, but is believed to have a detrimental affect on both bubble retention and sensory attributes. Codrington (1985) discussed the effects of alcohol, protein and fermentation rate on bubble size.

The difference in amino acid constituents of the cuvée and the final wine contribute to the character and complexity of méthode champenoise wines (Schanderl, 1943). These differences, along with the changes that occur during aging, help explain the sensory differences between méthode champenoise and charmat-produced sparkling wine (Janke and Rohr, 1960). Adequate aging sur lie is needed to develop roundness in the body and general flavor and complexity.

The development of what some call a “yeasty” character does not refer to bread-type yeasty fermentation aromas, but to a toasty-like note that is the result of aging and yeast autolysis. Feuillot and Charpentier (1982) report that the addition of yeast autolysates to wines at tirage shorten the aging and improve the “quality” of the foam.

Ways of developing the *le gout champenoise* or bouquet in a shorter time span continue to be investigated. The maturation period is most important in the making of good “sparkler” and must take place during the making of méthode champenoise and before the disgorgement and dosage. If this maturation is not carried out during the aging in contact with the yeast, it cannot be attained later. The dosage liqueur can add only a slight attenuation to the sparkling wine palatability. In fact, wines cannot be sold as Champagnes in France if they have not been kept on the yeast for at least nine months.

Not all of the critical factors that influence bubble size have been defined. Conditions of the secondary fermentation, concentration of nitrogenous compounds in the cuvée, and yeast autolysis appear to play an important role. It is suggested that the bubbles carry a negative charge and attract positively-charged particles such as proteins (Eschenbruch and Molan, 1982). Many of the premium Champagnes of France have a higher protein level than many sparkling wines produced elsewhere. This is believed to be the result of time spent sur lie, as well as possible cuvée nitrogen constituents.

There may be a positive correlation between the care taken during harvest and pressing, and the foaming properties of sparkling wines (Hardy, 1989). It is also recognized that Chardonnays have better foaming properties than Pinot noirs and Pinot meuniers.

Wines that are designed for long-term aging undergo poignetage (shaking) once a year. This helps dislodge sediments from the bottle to avoid crusting and aids in detecting leaks. The process mixes the three layers of sediment that include the organic material from the wine, dead yeast, and riddling aids.

However, if the bottles are excessively shaken, lipids (fats) within the yeast cells may separate from the cell walls and float to the surface. Reduction of sulfates or sulfides leads to free sulfur dioxide that is stored with lipids. According to Schanderl (1941), if the bottle fermentation occurs with excess oxygen, enough fat can be produced to form egg-shaped marks on the side of the bottle. Neither disgorging nor filtration will remove the fat. The causes of masking, or solids sticking to the sides of the bottle, are discussed by Maujean et al. (1978).

Remuage

When the winemaker considers that his wine has matured for a significant length of time sur lie, the process of removing the sediment is begun. Most believe that the wine should be left in contact with the yeast at least a year before disgorging, in order to allow the yeast cells to die and to permit the development of the “champagne bouquet.” The sediment of young wines is much less homogeneous and therefore difficult to riddle.

Remuage (riddling) is the process by which gravity conveys the sediment to the neck of the inverted bottle. Proper ridding causes the heavy particles to ride over and bring down the lighter, more flocculent, particles to the neck of the bottle. The sediment in the bottle is not homogenous, being composed of yeast, protein material, possibly some bitartrate, and riddling aids. The heavy substances are fairly willing to descend, but the lighter particles tend to float up into the wine very easily. This adds a significant degree of difficulty to the riddling process.

The longer the yeast has been in contact with the wine, the more homogeneous is the sediment. Some of the agents affecting riddling ease are listed here, with perhaps the most important being the final item:

- cuvée chemistry
- yeast species and strain
- yeast volume

- fermentation rate
- sur lie period
- storage conditions
- riddling aids
- riddling method
- skill of remueur (riddler)
- unknown factors

Why certain wines and certain vintages riddle easier than others is not fully understood (Zoecklein, 1987).

When the decision to riddle is made, bottles are usually shaken by hand or machine and allowed to rest prior to the riddling operation. This is done to dislodge the yeast from the glass in order to enhance riddling ease. After shaking, the bottles are allowed to rest before riddling to allow the lees to settle.

It is important that air currents in the riddling area be minimized. Air movement will cause convection currents within the bottle, which will make riddling more difficult. The use of air conditioning, therefore, is unwise. Temperature also affects riddling. Riddling is said to be easier at 65°F than at cooler cellar temperatures (Zepponi, 1983). Many wines appear to be easier to riddle shortly after fermentation, and again after about 12-14 months in sur lie.

Riddling is performed by hand, automatically, or semi-automatically. The widow Clicquot is credited with a way of removing the yeast sediment from mature bottles, which has changed little. In the hand-riddling operation, bottles are loaded into pupitres (A-frames) that are 6-feet high, 10-feet wide, spread out to approximately 40-42 inches, and hold 60 bottles per side. Hand remuage is said to have three phases. The bottles are first rotated, then oscillated, and finally tilted slightly. It is said to take years to learn how to properly perform these steps efficiently and effectively.

There are several remuage procedures. The bottles begin at an angle of approximately 25-30° from the horizontal. Generally, two bottles are grasped, lifted approximately one-quarter inch from the rack and twisted rapidly one-eighth turn to the right, then back to the left. The bottles are then placed back into the rack one-quarter inch to the right of the original position and at a slightly steeper angle. The twist/counter-twist is designed to create a backspin by causing the liquid to move one way and the glass another, and then stop abruptly. This rotative movement ensures that the main mass of sediment, as it descends toward the neck, does so at a different point on the circumference of the bottle each time.

The contact of the glass with the pupitres (rack) causes more oscillation. The bottle is placed back into the rack at a slightly steeper angle, and ends up at approximately 50-55° from the horizontal. Gravity causes the sediment to slide down a fraction of an inch toward the crown. Each bottle is turned every 8 hours or once per day. A skilled hand-riddler may turn as many as 25,000 bottles per day (Reventos, 1982). The process may take one week to three months, or longer, depending upon the nature of the sparkling wine and the skill of the remueur.

The remueur is perhaps slowly becoming an endangered species. Automatic riddling machines are becoming common in both Europe and the U.S. The gyropallete consists of a pallet basket that holds approximately 504 bottles. The pallet basket can shift in all directions – up and down, as well as from side to side – and stop abruptly. These units can be controlled by a computer system that can operate many units under different riddling cycles.

California’s Korbel winery perfected an early autoriddling system consisting of seven layers of double horizontal racks. The upper rack in each level is stationary, the lower movable. Bottles are placed into this system by hand at about a 20° angle from the vertical. The bottles are then flip-flopped back and forth four times a day by moving the lower movable rack, and are vibrated for several minutes. Riddling is often accomplished within 7 days (Berti, 1981).

Korbel's second innovation was a system allowing wine to be riddled in the same case that goes to market. Bottles undergo 12-18 months in the carton, neck-up. The cartons are then inverted and moved to special pallets that tilt 25° and vibrate briefly to loosen the yeast from the walls of the bottles. The elevated side of the pallet abruptly falls, thus jolting the bottles. One-thousand cases at a time are riddled, taking 5-7 days (Stashak, 1983).

Some small producers use a batch, semiautomatic system that consists of a metal frame rotated on a pivot. Each rocker holds approximately 500 bottles sur point in a metal bin that has a bottom which is mounted on an eight-sided fulcrum, enabling the bin to revolve by one-eighth of a turn in each movement. French and American companies are manufacturing a similar device commercially, which operates on an adjustable pivot pole. This allows the bottles within the bin to begin remuage at a lesser vertical angle and allows that angle to be adjusted. Riddling aids are generally utilized with rocker riddling.

Auto riddlers have several advantages. The remueur can transfer approximately 500 bottles per hour from aging bins or stacks to riddling racks. He can then turn them 20 times during a three-week period and remove them for disgorgement. In 56 hours of operation, the remuager may have completed 6,000 bottles. With an auto riddler, such as the gyropallette, an inexperienced worker can accomplish this same job in about 62 hours (Fritz-Stephens, 1981).

An auto riddler bin of 504 bottles requires about 16 feet of floor space. This is considerably less space than would be required by A-frames. One cellar of gyropalletes processed as many bottles as were handled in 70 cellars using hand *remuage* (Duijker, 1980).

Neither the auto-riddler nor the rocker systems universally do as good a job as the hand-riddler. This is principally due to the fact that in bin-riddlers, bottles are usually not given the same jolting action received by hand-riddling. Even those sparkling-wine houses heavily invested in auto-riddlers also rely on hand-riddling for those “difficult” wines. Some innovative small producers have adapted such things as paint shakers to aid riddling.

A production method originally patented by Moet has changed the industry’s concept of riddling. The system uses immobilized yeast during the secondary fermentation. About 300-400 immobilized yeast beads are added to each bottle. This allows the bottles to be stored sur point. The immobilization process means that the yeast can be removed from the bottle in less than 10 seconds. Selection of yeast with enhanced agglutinating ability has also reduced riddling difficulty.

When riddling is complete, the winemaker should review the clarity of the riddled bottles. When the sediment has been fully conveyed to the neck of each bottle, they are ready to be disgorged.

Disgorgement

Disgorgement is the removal of the sediment. Prior to disgorging, the wine is usually chilled to about 4-10°C. This aids in preventing any significant loss of either product or carbon dioxide. The lower the temperature, the less carbon dioxide that will be lost. While still sur point, the chilled bottles are placed into a brine of calcium chloride or a glycol solution (-15°C or 5°F), which freezes the sediment and a small portion of the liquid in the bottle neck. The top inch of the neck is usually frozen.

Care must be taken to avoid freezing too much liquid, which may make disgorging difficult. The yeast sediment is entrapped in the bedule and ice plug. The bedule helps to ensure that the yeast plug will be ejected uniformly and that no yeast residue will be left. Prior to disgorgement, brine or glycol should be rinsed off the bottle.

Small producers disgorge by hand. Holding a single bottle, neck-up at about a 45° angle, the crown cap is lifted from the bottle. The pressure within the bottle ejects the bedule and ice plug. The disgorger places his thumb over the mouth of the bottle to avoid excessive pressure loss. He then evaluates the wine for clarity and that all the yeast sediment has been expelled, and smells it to ensure there are no off-odors. If disgorgement is not complete, refermentation may occur. Wines with a reductive character (hydrogen sulfide, mercaptans, etc.) are separated and often discarded. The bottle is then placed on a tourniquet device for the dosage. If properly done, only about 1-2 atmospheres of carbon dioxide pressure should be lost. The volume loss should only be about 2%. One person can hand-disgorge about 1,500-2,000 bottles per day (Fowler, 1983b). Automatic units are available which can disgorge in excess of 2,700 bottles per hour.

A REVIEW OF MÉTHODE CHAMPENOISE PRODUCTION

Section 6.

Dosage

The structural profile of méthode champenoise is composed of three major stimulations:

- the tactile base influenced by the extract and astringent elements
- the acidity which depends upon the cations (positively-charged ions) present, buffering capacity, alcohol and sugar levels
- the sugar taste, which is produced by the interaction of acid, alcohol and sugar

The dosage (liqueur d'expedition) material is anything that alters the taste and composition of the sparkling wine. Each firm has a slightly different formula for the dosage, and some use no dosage at all in certain products. The dosage may consist of wine, sugar, brandy, sulfur dioxide, ascorbic acid, citric acid, copper sulfate, etc.

Sugar in the dosage is added for the purpose of sweetening, balancing the acidity, masking astringency-bitterness and slightly modifying flavor. The dosage permits a certain "rounding of the angles." In this country, the sugar source is often sucrose, invert sugar, or sugar syrup. Corn sugar is reported to add a candied-fruit character, but beet sugar may affect palatability. The sugar is dissolved in wine or occasionally water. Any water used should be deionized to help prevent casse (discoloration or turbidity) formation (Zoecklein et al., 1995). The amount (volume) of sugar syrup will alter not only the sugar/acid perception but also the character of the wine. In many cases, it seems to decelerate the aging process (Munksgard, 1998). Also, most wines are dosed with sucrose which, with time, will be inverted to glucose and fructose, which might change the level of perceptible sweetness, or dryness.

The sugar ranges and classifications employed for the finished product are the following:

Natural	g/L
Brut	0-15
Extra Dry	12-20
Sec	17-35
Demisec	33-50
Doux	> 50

Carbon dioxide can cause a reduction in one's perception of sugar. Only the best wines have the gentleness to be "perfect" without some added sweetness. It may be said that excessive sweetening conceals the qualities and helps to mask the defects of a champagne. Perhaps the best known naturals are the Brut Sauvage of Piper Heidsieck and the la Brut Zero of Laurent Perier. Naturals are usually made from the tete de cuvée and are frequently older-aged products.

Sweet dosages are made by initially preparing a sugar solution of known concentration. A 750 gram/liter sugar solution can be prepared by adding 75 kilograms of sugar into 50 liters of wine or water. To produce a 700 gram/liter solution, 70 kilograms of sugar is added to 56 liters of wine or water. To determine the amount of stock sugar solution to use in a dry wine to reach a certain sweetness, the following relationship can be used:

Milliliter of Dosage Required =

$$\frac{\text{(Bottle Volume mL) (Desired Sugar Level g/L)}}{\text{(Sugar Concentration of Stock Solution g/L)}}$$

For example, if the desired sugar level in the finished product is 6.5 grams/liter using a 700 gram/liter stock solution into a dry wine:

$$\frac{\text{(750 mL) (6.5 g/L)}}{\text{700 g/L}} = 6.96 \text{ mL dosage}$$

Sugar dosages are often employed in méthode champenoise produced from secondary and later press fractions. The use of wine in the dosage allows for minor attenuations of the sparkling-wine character. The addition of a recent vintage as part of the dosage can add life and freshness, and brighten up the finished product. Oak-aged wine can be used to add depth and complexity.

A red wine in the dosage can be used to add depth and brightness to the color of sparkling rosés. Some sparkling rosés are made by cuvaison, a method in which the color comes from keeping the juice in contact with the skins for some time. The rather pale hue that develops can be corrected by adding red wine to the dosage. The advantage of such a practice is the customization of the desired color.

There are varying opinions about the desirability of espirit de cognac and its effects on méthode champenoise palatability. The limited use reflects the desire for natural grape flavors. In years when the cuvée alcohol is low, addition of spirits may be desirable. Usually, only very small quantities of brandy are now employed. Previously, brandy was added to a level of 5-6%.

The expedition liqueur varies with each individual Champagne house. Up to 3% Cognac is occasionally utilized in Europe. An example of a dosage utilized by one U.S. producer is 80 liters 60°Brix solution containing 1200 mL of oak-aged Chardonnay and 1200 mL of espirit de cognac.

Cognac additions can have very dramatic effects on the sensory quality of the finished product. The dosed wine will change quickly over a period of months; therefore, dosage trials should be conducted to determine desirable cognac levels, if it is used at all. Spirits addition may be a benefit if a wine is too young (Munkagard, 1998). The cognac or brandy should be chosen with the same degree of care. Diluted with deionized, distilled water, cognacs or brandies more readily reveal their true character.

Some winemakers add limited amounts of citric acid as an aid to increasing the freshness of older wines. Some sparkling-wine houses employ ascorbic acid in their dosage. Ascorbic acid is an antioxidant added in a range of 60 mg/L, in conjunction with sulfur dioxide in the range of 40 mg/L. The use of ascorbic acid allows for a reduction in the amount of sulfur dioxide required. This may be a benefit due to the fact that CO_2 will magnify one's perception of SO_2.

There is no standard recipe for an expedition liqueur. Occasional additives include ascorbic acid (up to 90 mg/L), citric acid (up to 500 mg/L), and copper sulfate up to 0.4 mg/L.

The dosage liqueur must be filtered brilliantly clear and free from suspended materials. If this is not done, gushing will occur (see below). With a hand-operated dosage machine, a piston adds a given amount of dosage to each bottle (0-45 mL). These machines also add sparkling wine from another bottle to bring the volume to the proper fill level.

Having the dosage and the sparkling wine at the same temperature, and chilling the bottle, helps reduce gushing. Following the dosage and corking, bottles are shaken to distribute the dosage liqueur. Many sparkling wine houses allow the wine and dosage to marry prior to release. Such empilage periods are frequently up to six months.

Storage of sparkling wine on the yeast is a reductive condition, whereas storage on the cork is an oxidative condition (Crane, 1983). At the time of disgorging, oxidation begins. It is usually desirable, therefore, that the sparkling wine be drunk a few months to perhaps a year from the time of disgorging. Further aging on the cork can result in excessive oxidation.

This perhaps explains the disappointment many have experienced when consuming sparkling wines from “renowned” European producers. By the time these products are exported, distributed, and finally consumed, they may be excessively oxidized. As stated, some producers age on the cork for several months prior to release. This allows the cork to be extracted more easily by the consumer.

Gushing

The appearance of sparkling wines is a very important quality feature affected by foaming and effervescence (amount, size, and duration of bubble formation). In sparkling wines, some of the gas is free, and some fixed, with an equilibrium between free dissolved gas and combined gas (Miller, 1966). Gushing in sparkling wine is a sporadic but significant problem. Particulate matter in the form of case dust, cork dust, fibers or particles from packaging materials, and possibly particles from the wine or dosage itself, can cause gushing (Rankine, 1979).

Such particles, particularly those present in the bottle before filling, occlude very small air bubbles that act as nuclei on which carbon dioxide comes out of solution when the pressure is released. The sharpness or jaggedness of the particles appears to be important in the occlusion of fine air bubbles (Rankine, 1979). Such conditions as incomplete yeast riddling and potassium bitartrate crystal formation can contribute to gushing. When bottles have imperfections on their inside walls, bubbles will originate from this area, due again to occluded air.

The need for strict control of glass and cork quality cannot be overemphasized. Shrink-wrapped glass and predusted corks are an asset. If gushing is sporadic, dirty-bottle particulates from packing or corks are often the cause. Entire batches that gush are often the result of one or more of the following (Rankine, 1979):

- air or nitrogen in the sparkling wine
- excessive CO_2
- insufficient chilling
- unknown factors involving wine chemistry

Gushing of red sparkling wines often occurs when they are opened. To help reduce this potential problem, some producers fine their young cuvées with gelatin to lower the tannin content.

If sparkling wine contains a lot of dissolved air or nitrogen under pressure, as well as carbon dioxide, gushing can occur (Rankine, 1979). For this reason, nitrogen sparging and excessive aeration of the cuvée wine is undesirable. The solubilities of air and nitrogen are very low under pressure. When bottles that contain air or nitrogen are opened, these gases immediately come out of solution as fine bubbles, that then gather carbon dioxide and gush. These gases make the system unstable because their escape rates may be higher than that of the carbon dioxide (Miller, 1966).

It is therefore imperative that cuvées not be nitrogen-sparged or undergo excessive aeration. There may be 15 psi or more of air in the wine at cuvée bottling (Miller, 1966); if too much additional air is dissolved in the wine, it may make the final bottle unstable or “wide” at the time of disgorgement and consumption. The use of lower sugar concentrations at tirage (base wine) bottling, and more efficient disgorgement, has helped to reduce the incidence of gushing.

Chemical Analysis

The alcohol content of the finished product is usually between 12 and 13% (v/v), the maximum legal concentration for Champagne. The residual sugar differs according to the dosage. The TA is expressed in g/L tartaric acid or g/L sulfuric acid in Champagne (g/L tartaric = g/L H_2SO_4 x 1.53). Low TAs (5.0 g/L) make the wine seem weak or flat, while high levels (11.5 g/L) add sharpness. Most sparkling wines contain 8 – 10 g/L CO_2, which raises the acidity by about 0.75 g/L tartaric acid (Hardy, 1989). An evaluation of several méthode champenoise is given in Table 7. This data indicates a broad range of processing variables and production philosophies.

Table 7. Méthode Champenoise Analysis

Product	Alcohol % (v/v)	TA g/L	pH	Malic mg/L	Sugar g/L	Lactic g/L	Total Phenols mg/L	Non-flavonoid Phenols mg/L
Extrella River Blanc de Blanc	11.9	8.25	2.94	2148	6.1	0.35	200	190
Maison Deutz Brut Cuvée	12.3	7.50	3.22	472	8.9	2.75	310	300
Mumm’s Cuvée Napa	12.4	8.40	2.98	3229	11.3	0.02	260	255
Tonio Conti Blanc de Blancs	11.4	8.70	3.01	1988	4.9	0.50	215	205
Tonio Conti Blanc de Noirs	11.7	8.70	3.03	2046	0.55	0.55	205	200

Source: Zoecklein (1986a,b)

“Light Struck”

Light struck is a sensory defect occasionally noted in wines as a result of methionine (an amino acid) decomposition. In the presence of UV light, methionine can be broken down to yield the following odor compounds:

- hydrogen sulfide
- methanethiol
- dimethyl disulfide
- dimethyl sulfide
- ethyl methyl sulfide

Light struck wines are characterized as having cheese, plastic, vegetable and/or honey-like aromas. Due to the magnifying effect of carbon dioxide, these compounds can pose a serious quality loss. Green glass is reported to help filter out ultraviolet light that can produce “off” compounds, but it does not assure control (Thoukis and Stern, 1962). Even limited exposure to light (including flourescent) can result in the production of light struck aromas.

Some Terms used in Méthode Champenoise Production

assemblage	A preliminary combining and blending of wines from different vineyards after the first racking.
Bead	A bubble forming in or on a beverage; used to mean CO_2 bubbles in general or sometimes to the ring of bubbles around the edge of the liquid.
blanc de blanc	Champagne made from white grapes.

blanc de noir	Champagne made from the juice of Pinot noir; may impart a light salmon color to the wine.
crémant	A very lightly sparkling, creamy, and frothy wine.
cuvée	Literally tubful or vatful, this refers to a particular blend to be used for sparkling wine.
dégorgement	The disgorging or removal of the plug of sediment which collected on the cork during riddling.
dosage	Same as dosage in English: an amount of sweetener added back to the bottle after dégorgement.
le goût champenois	Describes a special bouquet and flavoring in high quality sparkling wine; said to arise from the time spent in the bottle on yeast.
liqueur de expedition	The shipping liqueur - the mixture added in the dosage process; sometimes consists of a small amount of sugar, some vin de reserve, and a touch of brandy (approx. amounts may be 60 grams per 100 ml base wine; brandy may be up to 10% of this).
liqueur de tirage	The mixture of sugar added to the cuvée for the second fermentation.
méthode champenoise	Traditional champagne production method that promotes a second fermentation in the bottle.
mise sur point	Placing of the bottles upside down in the pupitres.
mousse	Froth, foam; frothy or sparkling; used as a synonym with crémant. (A vin non mousseux means a still wine.)
petillant	Means sparkling and refers to the fizz or bubbling of a wine; used as a synonym with crémant.
pupitres	The hinged sloping racks used to hold bottles during the riddling process.

remuage	Refers to the riddling or turning of the bottles to dislodge yeast sediment and allow it to collect on the cork.
remueur	Refers to the person who riddles the bottles.
tirage	Refers to drawing off the base wine, combined with sugar and yeast ,for second fermentation in the bottle or a tank.
vin de cru	A wine coming from a single town.
vin de cuvée	Usually used to refer to a top quality wine (tête de cuvée).
vin de reserve	Some of the base wine held in reserve in which the sugar for the dosage is dissolved.

Study Questions

1.Why would producers of MC not want to have the primary and secondary fermentations conducted by the same yeast strain?

2. Why is the rate of the secondary fermentation important?

3. What are the major quality features in MC that are different in tank fermented sparkling wines?

4. What are the primary considerations in determining maturity for fruit used in MC production?

5. Traditionally, warm climatic regions (defined by the UCD heat summation index) were considered undesirable for MC production. What has changed?

6. The economics of MC has been a limiting feature for many small producers.

What methods would you want to explore to help lower the cost of production?

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