Better Wine and Bread by Scientific Fermentation

Fermentation practices and advances in the food industry were surveyed in a symposium presented by the Fermentation Subdivision of the Division of Agricultural and Food Chemistry at 123rd Meeting of the American Chemical Society in Los Angeles. Two of the papers are presented in this issue. Others will appear in future issues.

FERMENTATION

Present Practices in the California Wine Industry

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The current fermentation practices of the California wine industry are reviewed and evaluated, and suggestions for their improvement are offered.

A NUMBER OF FACTORS are involved in the selection of grapes to be used in the production of the various types of wine. The suitability of the variety for the type of wine to be made, the yield of the wine, the ease with which it can be aged, clarified, and prepared for the market, and the economic and engineering factors involved must be considered.

The more important factors influencing quality and suitability are: the amount of sugar and acid present, the ratio of acid to sugar, the response of the grape to the climatic conditions of the region where grown, and the physical and chemical characteristics, other than sugar and acid, of the variety of grape. A high total acid with moderate sugar content is desired for table wines, and a moderate acid with high sugar content for dessert wines.

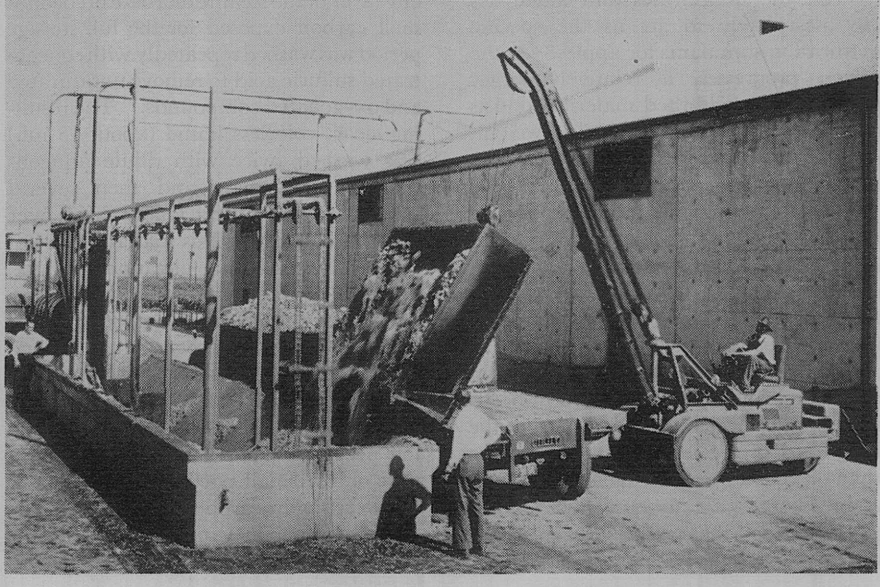
The varieties of grapes differ markedly in the amount of sugar and acid present at full maturity. Amerine and Winkler (*3*) have shown that the climatic conditions, particularly temperature, of the region where the grapes are grown have a decisive effect on the ratio of sugar to acid; increasing temperature causes a corresponding increase in this ratio. On this basis they have classified the varieties according to the region to which they are best adapted. Amerine and Joslyn (*7*) have listed the varieties according to their desirability for the production of the various types of table wines. It has long been known that the acid decreases as the grape becomes riper. Amerine and Winkler (*2*) showed that the stage of maturity at which the grapes were harvested had a decided bearing on the suitability of that grape for producing a given type of wine. Resistance to disease, intensity of varietal flavor, level of production, and ease of training, picking, and crushing are other factors which need to be considered in selecting a variety.

The producer of premium-quality wines usually considers all these factors in his selection of grapes. The producer of standard wines, because of the price he receives for his product, is more limited in his choice of varieties, as he cannot compete on a price basis with the premium wine producer. However, of the large number of varieties remaining to him, he too often fails to make an intelligent choice. One of the greatest improvements which could be made in the quality of California wines would be the utilization by all producers of the available knowledge in making their selections of grapes. This could be accomplished by selecting from the available grapes those best suited for each type of wine, and then harvesting them at the optimum stage of maturity.

Harvesting and Transporting

Three methods of harvesting and transporting grapes are in general use. In one the grapes are picked into wooden boxes, placed on a flat bed truck, and hauled to the winery, and each box is individually emptied into the crusher-conveyor. This method is the most costly, but it permits the least damage to

Figure 1. Gondola truck and unloading crane



the grapes, provided the boxes are kept clean.

In the second method the boxes are emptied into rectangular steel tanks mounted on a flat bed truck. These tanks, which are usually 8 × 10 × 4 feet with a capacity of approximately 5 tons, are transported to the winery, where they are emptied into the crusher-conveyor by tipping the tank with a power hoist attached to one side of the tank (see Figure 1). This method is considerably cheaper than the first method, though much less satisfactory because the bottom layers of grapes are usually partially crushed in transit; the extent of the crushing depends upon the variety and maturity of the fruit. As this method is generally used for long hauls, sufficient time can elapse for the crushed grapes to ferment partially, particularly when there is a delay in unloading at the winery.

In the third method the grapes are picked into buckets which are emptied directly into a 5-ton steel tank mounted on a low trailer frame. One or more of these tank trailers are then towed to the winery, where they are emptied by dumping with a hoist. This method is the least costly of the three and more satisfactory than the second method in terms of damage suffered by the grapes. Because it is adapted only to short hauls, the grapes usually reach the winery soon after being picked, and because of the small distance covered less crushing with its attendant damage occurs. Long-distance travel, however, will probably continue to be used for a long time because of the advantages of large scale wineries in centrally located locations.

Crushing

Garolla-type crushers which vary in capacity from 5 to 100 tons per hour are used most commonly. These macerate the flesh of the grape without breaking the seeds, and separate the stems from the crushed grapes by the beating action of a revolving paddle inside a counter-rotating screen. A recent innovation is the use of disintegrators instead of crushers. These reduce the grape bunches, including pulp, skins, seeds, and stems, to a finely divided mass. They offer the advantages of slightly increased yield, since the stems and raisined berries are incorporated with the must (crushed grapes), and more efficient handling. As they have been used at only one winery for less than 2 years, it is too soon to evaluate their effect on the quality of the resultant products of the fermentation. Unfortunately, the amount of suspended insoluble material which later settles out of the wine as lees is increased by their use.

Prefermentation Treatment

The prefermentation treatment which the must receives is dependent upon the type of wine and cost of grapes from which it is made. Thus white and red table and dessert wines are made from either standard or premium-quality grapes.

Color Extraction In the production of white table wine it is essential that the juice be separated from the pomace (skin, pulp, and seeds) soon after crushing to avoid undesirable pickup of color, tannin, and stemmy flavor. With premium-quality grapes, because of their cost, it is essential that as much juice as possible be recovered for the production of wine. Thus these grapes are always pressed immediately after the separation of the free-run juice. Separation is commonly accomplished by pumping the must into a tank with a lattice-frame false bottom, or into a conventional tank and allowing the pomace to rise to the top before withdrawing the juice. Following separation of the free-run juice the pomace is shoveled or conveyed into wooden baskets resting on wheeled steel trays. These are pushed into position under hydraulic presses which reduce the moisture content to 65 to 70%. A newly devised method (*8*) eliminates the double handling and produces as much free-run juice as the above described methods by the use of a removable metal collar placed on top of the press basket (see Figure 2). The must is pumped into the basket with collar attached and allowed to stand 4 to 5 hours until the free-run juice has drained off, the collar is removed, and the pomace is pressed in the usual manner. This method, though requiring approximately four times as many baskets and wheeled trays, is the most economical of the three methods because of the reduction in labor costs. None of these methods is entirely satisfactory because of the costly handling and the recovery of only 60 to 70% of the available juice as free-run and press.

In an entirely new approach to the problem the crushed grapes are fed into a modified disintegrator which separates the juice and discharges the pomace at approximately 60% moisture. Though nearly all the juice is obtained, it contains most of the pulp in a finely divided form. Unfortunately, it is not possible with the available equipment to separate the pulp from the juice prior to fermentation. This procedure, because of the yields obtained and low handling cost, warrants further investigation.

With standard grapes the juice is separated from the skins by pumping into tanks and allowing the pomace to rise before drawing, or, as described by Berg and Marsh (*6*), by pumping into a drag conveyor box equipped with a screened bottom. The latter method eliminates one operation, produces a lighter-colored juice, but incorporates more suspended material, which later settles out of the wine. The pomace from standard grapes is usually not pressed after the separation of the free-run juice. Instead, it receives an addition of water and yeast starter and is fermented to produce distilling material.

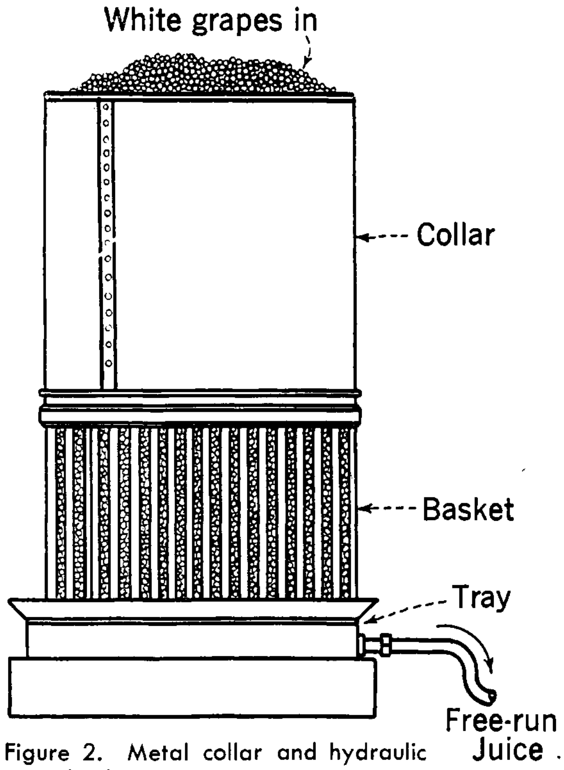


Figure 2. Metal collar and hydraulic press basket

Musts which are to be used for the production of sherries and white port are usually handled in the same manner as for standard white table wines. In the production of the other white dessert wines, with the exception of muscatel, the juice is not separated from the pomace prior to fermentation. Muscat musts may be handled in the usual manner or may be heat-treated prior to fermentation, using the procedure described below in the processing of red wines.

One of the principal concerns in making both red table and red dessert wines is the attainment of adequate color. Because, with a few exceptions, the color is contained in the cells in the grape skins, it is necessary to effect its release and subsequent dissolution by the juice. This may be done prior to or during the fermentation. In production of standard and premium table wines and premium dessert wines the color is extracted during the fermentation. Some type of prefermentation color extraction treatment is usually given standard quality dessert wine grapes. In the first method the tank of must is heated to 100° to 140° F., circulated until the juice reaches the desired color, then cooled to the correct fermentation temperature. This method does the most damage to the quality and results in a wine subject to later color precipitation and general colloidal instability. In another method given in a

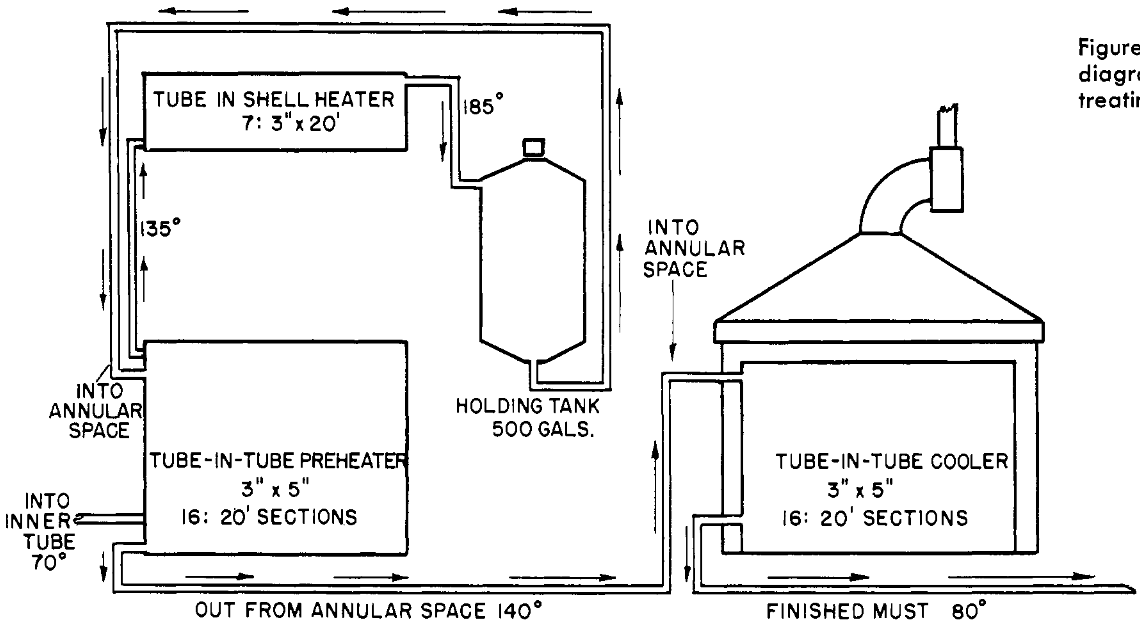


Figure 3. Flow diagram of must treating process

review of color extraction by Berg (*5*) one-third of the juice is withdrawn from the tank, heated to 175° F., and pumped back over the cap (floating pomace), the tank is circulated for 1 hour, and then cooled to fermentation temperature. This procedure results in a wine ultimately equal in color and superior in quality to that produced by the first method.

Overby (*10*) gives a detailed description of a must treating process shown in Figure 3, in which the freshly crushed grapes are passed through a closed, continuous, heating, regenerating, and cooling system which heats the must to 185° F., holds it at that temperature for 2 minutes, then cools it to 75° to 85° F. before discharging it from the system onto a screened-bottom drag conveyor which separates the juice from the pomace. This produces the most deeply colored and stable wines of the three methods. The organoleptic quality is equal to that of the wines produced from nonheat-treated musts. It has the disadvantage of requiring costly equipment and is thus not economically feasible except in a relatively large operation. The potentialities of the method have not been fully realized, since it offers the possibility of eliminating pomace handling from the fermenting cellar and allowing red juice to be fermented in the same manner as that from white grapes.

Sulfiting Except in the production of distilling material, from 50 to 150 p.p.m. of sulfur dioxide are added to the must or juice as soon as possible after crushing. From 0 to 50 p.p.m. are usually used in distilling material productions. Liquid sulfur dioxide, which is the least expensive, is most generally used. Potassium or sodium metabisulfite, though more expensive, is often used where only small additions of sulfur dioxide are needed. The addition of sulfur dioxide minimizes undesirable oxidative changes, inhibits the activity of the wild yeasts and bacteria usually found in the must, and aids in the settling of the suspended matter and its elimination by racking. It has the undesirable effect of increasing the amount of fixed aldehyde in the resulting wine, and therefore increasing the amount of total sulfur dioxide which must be added to attain a given free sulfur dioxide content.

Correction of Must Deficiencies It is the usual practice to correct any acid deficiencies which may occur in the musts of premium-quality grapes intended for table wine production by the addition of tartaric acid prior to fermentation. Acid deficiencies in standard quality table wine grapes are often corrected by the addition of either tartaric or citric acids. Tartaric, though the most expensive, is preferred to citric because the latter is subject under certain conditions to bacterial spoilage. Tannin, USP grade, in the amount of 0.125 to 1 pound per 1000 gallons is occasionally added to white juices to facilitate early clearing of the wine. Cruess, O'Neal, Chang, and Uchimoto (*7*) report the use of pectic enzymes by several premium wine producers to facilitate pressing of the pomace of white grapes and to promote clearing of the juice. However, an occasional marked increase in browning has been attributed to their use. They are also used by nearly all standard wine producers who heat-treat musts. Because of the destruction of the naturally occurring pectolytic enzymes, the addition of pectic enzymes after the heat treatment is almost mandatory if normal clearing is to occur.

Addition Of Yeast The use of pure yeast cultures in the fermentation of premium-quality wines is common practice in the California wine industry. Their use is less common in the fermentation of the standard wines. Selected strains of *Saccharomyces ellipsoideus* var. *cerevisiae* such as Burgundy, Champagne, Tokay, and Montrachet are used. Their use offers the advantages of a more easily controlled fermentation, less chance of production of off flavors, and usually more efficient conversion of the sugar to alcohol. Rate of fermentation, conversion efficiency, the type of by-products produced, rate of settling after completion of fermentation, and resistance to autolysis are some of the factors that must be considered in the selection of suitable cultures.

Fermentation Treatment

Temperature control is of the greatest importance in the conduct of the fermentation. Wines from musts fermented under controlled temperature conditions are usually of better quality and higher alcohol content and are less subject to bacterial attack and other wine disorders (*12*). Temperature control involves cooling, since 1% of sugar fermented raises the temperature of the fermenting mass about 2.34° F. Though some of this heat is lost to the surroundings, it has been estimated by Marsh (*9*) that 50 to 70%, depending upon the size of the tank, material of construction, air temperature, and whether or not the fermenting liquid is covered with a pomace cap, must be removed by water cooling or mechanical refrigeration to prevent excessive temperature rise with the resultant danger of quality damage and sticking (stopping) of the fermentation.

Cooling Cooling is accomplished by pumping water through fixed coils in the fermentation tank, passing the fermenting liquid countercurrent to a flow of water in a tubular or plate-and-frame heat exchanger, passing the fermenting liquid through tubes cooled by the direct expansion of a refrigerant gas, or fermenting in tanks placed in a refrigerated room. A modification of the water-cooling method is the use of mechanical refrigeration or a forced-draft cooling tower to reduce the temperature of the water further. Each of these systems offers certain advantages as well as disadvantages. Fixed coils in tanks usually represent the lowest capital investment, require the least operating labor, and cause the least aeration of the wine, except fermentations with a cap, which require pumping over to control the cap temperature. They have the disadvantage of poor temperature control because of inefficient heat transfer. The use of a tubular or plate-and-frame heat exchanger affords more control of the fermentation temperature, but requires a more costly installation and greatly increased operating cost. Cooling by the direct expansion of a refrigerant gas has both the advantages and the disadvantages of the preceding method, and, in addition, requires more capital outlay and causes large fluctuations in the temperature of the fermenting liquid and in the fermentation rate. It does make possible low temperature (45° to 70° F.) fermentations which cannot be achieved by water cooling without supplemental refrigeration. Refrigerated rooms offer the most satisfactory temperature control and low labor cost. They require the greatest capital investment and are the most costly to operate.

White Wine Fermentation Free-run juice for the production of premium white table wines is usually fermented in closed tanks at temperatures ranging from 45° to 70° F. The juice is inoculated with a pure yeast culture at room temperature and allowed to stand until the fermentation is active. It is then cooled to the desired temperature by mechanical refrigeration and pumped into tanks in a refrigerated room where it remains until only 1 to 2% sugar remains unfermented. It is then allowed to ferment to dryness at cellar temperature. Standard white wine fermentations are usually conducted in closed tanks equipped with coils. The temperature may be controlled in the range of 45° to 70° F., but is usually between 70° and 85° F. owing to lax operation or insufficient cooler capacity. Water cooling with coils is used alone or in conjunction with water-cooled outside heat exchangers. In a variation of the procedure for standard white table wine fermentations the juice, after inoculation with the pure yeast culture, is passed through a mechanical refrigerator, brought out at 35° F., and placed in a closed storage tank where it is allowed to ferment to dryness without further cooling.

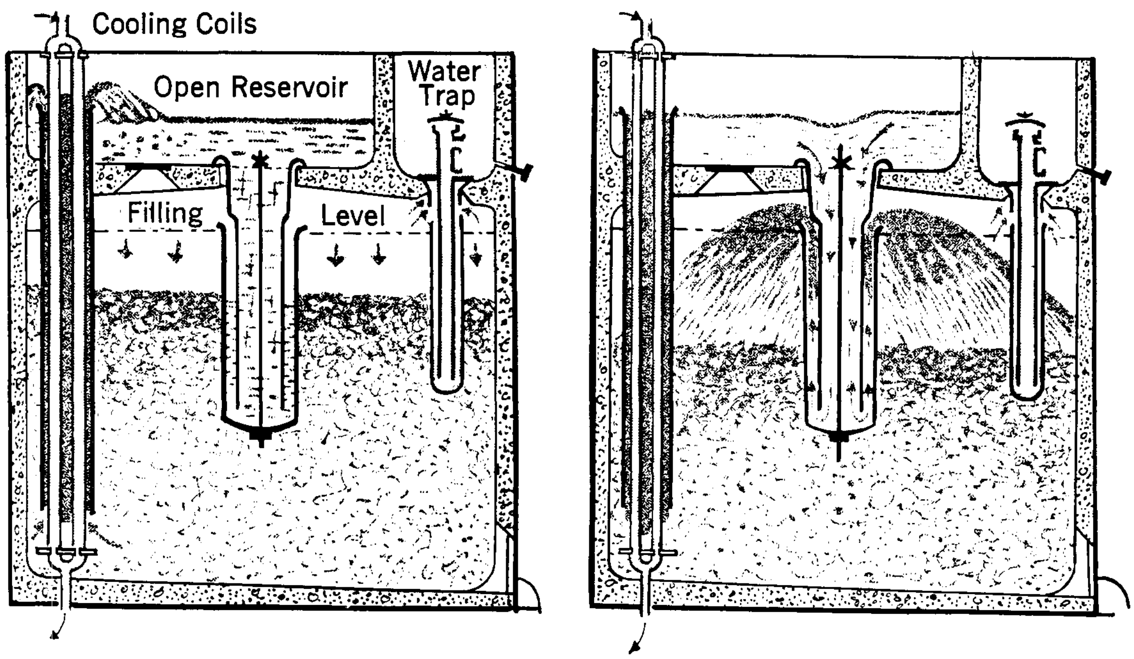
Free-run juices used in the production of sherry and white port are usually fermented in closed coil tanks at 70° to 80° F. Musts used in the production of the other white dessert wines are fermented either in open or closed coil-equipped fermenters at temperatures of 70° to 85° F. Fermentation is allowed to proceed with periodic pumping over until the desired degree of sugar is reached. The free-run liquid is then withdrawn and fortified.

Red Wine Fermentation Red wine fermentations require different handling than white because of the necessity for extracting color from the skins. Premium-quality grapes are usually fermented at temperatures of 60° to 75° F. in small (1000 to 6000-gallon) open, coil-equipped fermenters. Color is extracted by punching, which is a periodic manual submerging of the cap with a wooden tamp, or, by pumping over, which consists of withdrawing the juice from the bottom of the tank and returning it by pumping over the cap. Punching, though requiring the most labor, is the best procedure from the standpoint of quality, because pumping over, unless carefully controlled, tends to aerate the wine unduly.

Standard quality grapes are usually fermented in large (12,000 to 60,000 gallon) coil-equipped tanks, either open or closed. Pumping over is used for extracting color, and the fermentation temperature ranges from 70° to 90° F. Sifnéos and Laurent (*11*) have described another procedure for the conduct of red wine fermentations involving the use of the "auto-vinificateur" (see Figure 4). This is a specially designed closed tank which utilizes the pressure of the carbon dioxide formed during the fermentation to force the juice through a heat exchanger tube into a basin above the cap. The basin is periodically emptied by the action of a hydraulic leg, permitting the juice to flow over the cap and thus achieving automatic pumping over. The system is used to some extent in Algeria but is still in the experimental stage in California. Its adoption by the California wine industry would require extensive alteration of existing fermenting tanks. However, its operation would be the least costly in labor and power of any of the present procedures for fermentation of red wine. Juices from musts which have passed through the continuous must heater are handled in the same manner as white juices.

Table wine fermentations are allowed to proceed on the pomace until the desired degree of color and astringency is attained by the wine, which is then drawn off and fermented to dryness in a storage tank. Dessert wine fermentations remain on the pomace until the desired degree of sugar is reached, when the wine is withdrawn and fortified.

Figure 4. Auto-vinificateur



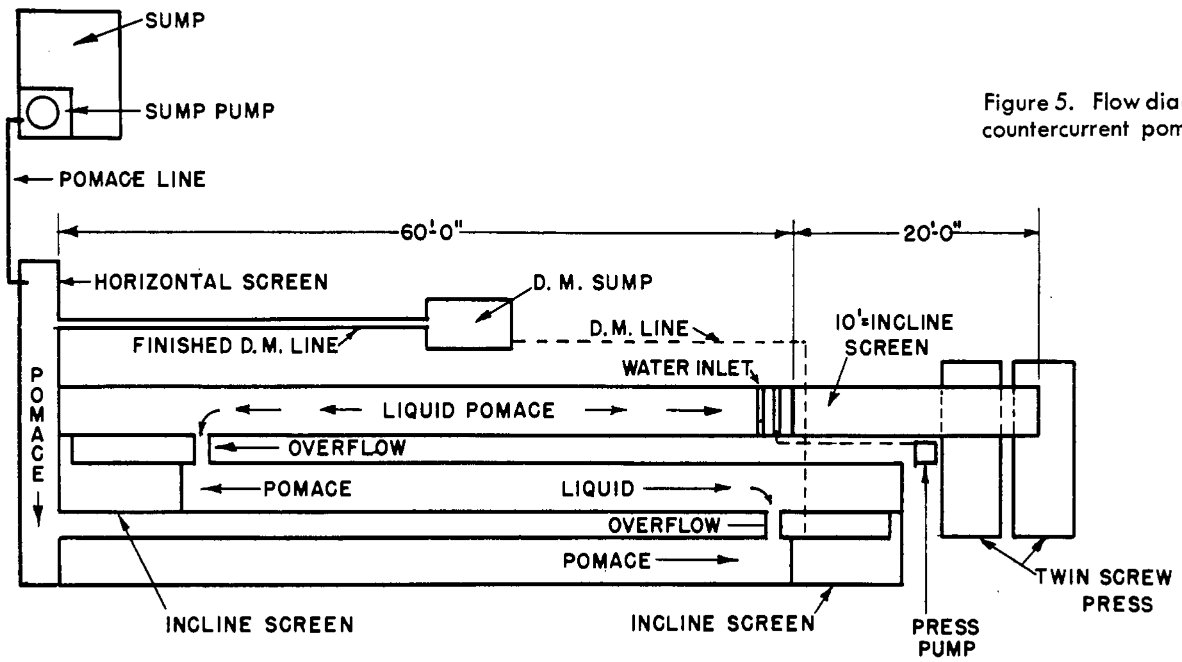


Figure 5. Flow diagram of 3-stage countercurrent pomace washer

Pomace Handling

Pomace handling is the most expensive and troublesome fermentation operation and, in addition, presents the greatest sanitation problem. This phase of fermentation procedure has received a great deal of attention, but an entirely satisfactory handling method has not yet been found.

Pomace from premium-quality grapes is basket-pressed to increase juice or wine yield and then usually discarded. Pomace from standard quality table wine grapes may be basket-pressed and then discarded, or may be used for the production of distilling material. Pomace from musts used for the production of standard dessert wines invariably receives an addition of water and is then fermented to dryness for the production of distilling material.

Recovery Of Alcohol Berg (*4*) and Berg and Marsh (*6*) have reviewed several methods used for the recovery of alcohol contained in the pomace. In the most generally used method the distilling material is drawn after completion of the fermentation and the pomace is then washed from one to three times with successive portions of water, each washing being followed by a draining period. On completion of the washing the pomace is removed from the tank and pressed to 60 to 70% moisture content in continuous-screw-type presses. This method has the highest labor cost, largest fermenter turnover time, and lowest alcohol recovery.

A second method, almost as generally used, requires no washing of the pomace. The pomace after withdrawal of the distilling material is reduced to fine particles by passage through a disintegrator, then mixed with distilling material and pumped to the distillery to be processed in "pomace" stills. With this procedure alcohol recovery is high and tank turnover time is reduced to the minimum. The disadvantages are the high power requirements of disintegration, increased difficulty of producing a satisfactory brandy, and the greatly increased stillage disposal problem.

A third method, less generally used, also requires no washing of the pomace. After withdrawal of the distilling material it is removed from the fermenter and conveyed to the top of a Metzner still, into which it is introduced by a screw conveyor. The alcohol is removed by steam passing countercurrently through the pomace, which is moved by flight conveyors over a series of perforated metal plates. The pomace is discharged from the still through a water seal at the bottom. The water-alcohol vapor leaves the top of the column, and is condensed and then added to distilling material to be distilled in the conventional type of still. Alcohol recovery is equal to that of the pomace still, fermenter turnover time is the same, and the stillage disposal problem is much less. Capital investment is high, and the problem of producing a satisfactory brandy from the products of the Metzner still is greatly increased.

A fourth method, less widely used than the other three, also does not require washing of the pomace in the fermenter. The pomace, after withdrawal of the distilling material, is conveyed to a series of continuous washers, usually three, and then through the system countercurrent to a flow of water (see Figure 5). After passage through each washer the pomace is drained by conveying over a perforated screen. It may be pressed in a continuous-screw-type press after each draining, or receive only one pressing at the end of the washing system. The capital investment requirements are less than for a Metzner still, alcohol recovery is nearly as good as that obtainable with a pomace still, distillation and stillage disposal problems are not increased, and fermenter turnover time is at the minimum. Unless pressing is employed after each washing stage, this procedure has the disadvantage of producing a distilling material of relatively low alcohol content with an attendant increase in distilling costs.

Removal of Pomace From Fermenters Where it is desired to recover the liquid in the pomace undiluted with water, it is necessary to remove the pomace from the fermenter by shoveling either into an overhead conveyor or into a portable elevator which discharges into the overhead conveyor. This is the most costly method of pomace removal. It is used in all wineries handling premium-quality grapes and in some of the older wineries producing standard wines. Another method, used by standard wine producers who have open-top fermenters, involves the use of a portable pomace pump which is lowered into the tank and pumps the mixture of pomace and distilling material directly to the distillery. This method, though less costly than shoveling, is used by only a few wineries because of the labor involved in handling the pumping, the overhead track system required for moving the pump, and the piping required to transport the pomace and distilling material.

The newest method now used in all the more modern dessert wine wineries employs neither shoveling nor pumping for pomace removal. With the construction of properly pitched tank floors and the installation of a hinged metal gate in the tank wall just above the floor, it is possible to flush out the pomace with a stream of either water or distilling material. This discharges into drag conveyors which carry it to dewatering screens. This method is the least costly and most satisfactory of the three.

None of the pomace-handling methods discussed is completely satisfactory. All involve fermentation of the pomace with its attendant problems. The ultimate in efficient processing would be the elimination of the pomace from the fermenting cellar. In the production of standard wines (some 90% of all those produced) this goal is now obtainable. Using the continuous must heater, it is no longer necessary to ferment the juice with the skins to effect color release and dissolution. The must of red grapes, following passage through the continuous heater, and the must of white grapes directly from the crusher can be screened and the sugar remaining in the screened pomace removed by conveying through the continuous washing system. With this system only juice and wash would enter the fermenting cellar. The savings in this method and the advantages offered are so great that it must be seriously considered by the wine industry.

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PANARY FERMENTATION

Current Status of Problems

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Current problems and trends with respect to fermentation in the production of yeast-leavened baked goods, principally bread, are more concerned with dough conditioning during the fermentation period and early stages of baking than with the actual production of leavening gas. Recent advances in knowledge concerning the action of amylases and proteinases on flour components during fermentation and baking have stimulated a rapidly increasing use of fungal enzymes in bread production. Judicious use of fungal enzymes in addition to the traditional diastatic agents derived from malted cereals permits efficient adaptation of a wider selection of flours to particular shop conditions.

PANARY FERMENTATION differs from most industrial fermentations in several respects, perhaps the most notable of which is that the gas produced is the most important product, although other products have an important function. The principal products of the fermentation are largely the means to an end, as only small amounts of the substances themselves are retained in the final product. The environment of the fermentation is somewhat unusual, in that free liquid content is held to a minimum, and the chief substrate, potentially at least, is present in great excess but is desirably utilized to only a small extent.

Much has been learned in recent years about mechanisms that are important in panary fermentation. Scientific experiment has disclosed the nature of fundamental processes by which sugars are converted by yeast into carbon dioxide (the leavening agent in all light breads) and into acids and alcohols which modify properties of the doughs and contribute to the flavor of finished products (*28*). The nutrient requirements of yeast appear to be well understood (*1*). Knowledge has been gained regarding the chemical and physical nature of the starch which, after enzymatic breakdown, becomes a principal substrate for the actively metabolizing yeast cells (*19*). The identity of the amylases and their mode of action on starch and its derivatives have been revealed (*8*, *15*).

Although production of leavening gas and proper retention of the gas may be the most important general considerations in the manufacture of bread, economic pressures for more efficient bakery production increasingly emphasize the importance of proper conditioning of doughs. With high-speed machinery and accelerated shop schedules, it is essential that suitable handling properties of doughs be realized. Treatments or formula additions which promote optimal gas production may sometimes have an adverse effect on gas retention or dough properties, and vice versa. It might be easy to establish adequate gas production under given circumstances, if that were the only consideration, but other features of the over-all process may limit the means by which this gas production can feasibly be established. It is this complexity and interrelatedness which require discussion of associated problems under the topic of panary fermentation.

General Features of Bread Production

The major product of commercial bread manufacture in this country is ordinary, white pan bread made by the sponge and dough process. The following discussion is concerned primarily with this product and process, although most of the material also applies to the straight dough method and production of other types of bread.