The numbers preceding the names refer to the colors as listed in the Colour Index published in 1924 by the Society of Dyers and Colourists of England, which gives the composition of these dyes. Names not preceded by numbers are not listed in the Colour Index.

No description is here necessary of the materials which we have classified as group C above. A description of their specific employment will be found in subsequent chapters devoted to manufacturing operations. The same applies to a number of minor ingredients or materials used for special purposes such as souring, fining, preserving, sterilizing, etc.
CHAPTER V
YEASTS AND OTHER ORGANISMS

General Statement.—In the preceding chapter on Fermentation it was stated that the production of alcohol is performed by enzymes which act on the sugars present in the fermenting liquor. It was also indicated previously that the enzymes which accomplish this transformation are representative of a very large group of such materials which function in every chemical change involved in the life process. The enzymes of value to the fermentation industry are produced by living plants, yeasts, which are allowed to grow in the liquor to be fermented and which, as an incident of their own life process, achieve the desired production of alcohol.

Yeasts belong to the second broad group of vegetable growths: those which do not contain chlorophyll and are, therefore, unable to manufacture their own food. This group is distinguished from the first group of plants which can extract inorganic materials from the soil and the air and from these manufacture their own food. The ability to perform this function is ascribed to the presence in the plant of a green coloring matter, chlorophyll.

The group name of the non-chlorophyll bearing plants is fungi. They are all dependent for their food supply upon the materials built up by living plants of group one, or upon animal matter. Among the fungi, which naturally vary in complexity of structure, are a group of simply constructed plants having but one cell and which are called yeasts. The cells vary in shape and size, being round, oval or elongated, but of the order of 0.003 inches in diameter.

Each such cell consists of a transparent elastic sac or membrane enclosing a more or less granular mass of jelly-like substance which is called protoplasm. The name was originated by
Purkinje (ca. 1840) to apply to the formative material of young animal embryos. Later, von Mohl (ca. 1846) used the term to distinguish the substance of the cell body from that of the nucleus which he called cytoplasm. In modern usage dating from Strasburger (ca. 1882) the name protoplasm has been applied to all of the essential living substance within the cell wall and means the form of matter in or by which the phenomena of life are manifested. Protoplasm can exist in many modifications varying from its usual one of a thick, viscous, semi-fluid, colorless, translucent mass containing a high proportion of water and holding in suspension fine granular material. Chemical examination of protoplasm, necessarily after death, has shown that it is composed largely of protein material. During its life, however, it appears probable that the chemical composition is both more complex and more unstable. For our purpose it is only necessary to state that the protoplasm is that portion of the plant which is alive and which carries on the vital processes of the plant.

**Life Processes.**—All living organisms exemplify the cycle of birth, growth, multiplication and death. Starting, for yeast, at the stage of growth we see the process as follows: When the yeast is supplied with an abundance of nutrient material, it grows vigorously and the cellular protoplasm is homogeneous. As the growth continues and the nutrient material becomes exhausted, clear, apparently empty, spaces called vacuoles appear in the protoplasm. Actually these spaces are filled with serum or sap. At a little later stage, granules appear, some of which are fat globules while others are more condensed portions of protoplasm. Finally, as the cell nears the end of its life, the protoplasm shrinks to a thin layer against the cell wall while the balance of the cell is occupied by a large vacuole. The nucleus of the cell is rarely visible and does not, for this reason, enter into our consideration.

While this growth of the single cell continues, multiplication also takes place at a rapid rate. According as the life conditions are favorable or not multiplication takes place in one of two ways:

1. By budding or germination.
2. By endogenous division or ascospore formation.
The first process occurs under favorable conditions when the yeast is growing rapidly. It consists in a bulging of part of the cell wall and the pressing of part of the cell contents into the bulge which is formed. This is the bud. As the bud grows the wall between it and the mother cell constricts and finally closes and there are then two distinct cells. Whether the bud-cell stays in connection with the mother cell depends somewhat on the conditions of growth but more on the variety of yeast. With some varieties the bud stays in connection with the mother cell and itself multiplies through many generations so that long chains or branching clusters are formed. In all cases the rapidity of multiplication depends on the vigor of the yeast and the suitability of the conditions under which it is growing.

In distinction to the method of reproduction just described, when a vigorous yeast growth is placed into adverse conditions it prepares to survive by a different mode. The protoplasm of the cells becomes granular, then divides so as to form separate masses. These round off and become invested with a wall so that the original cell wall acts merely as a sac to contain the new bodies. Because of this last fact the name ascospores is given them, meaning spores formed within a sac. The conditions required to bring about ascospore formation are not completely understood. Usually, however, a suitable temperature, plenty of moisture and lack of nutrient material will cause young, vigorously growing yeast cells to form from one to four ascospores each. The spores have remarkable ability to survive under conditions which would be fatal to ordinary cells; such as extremes of temperature, lack of food, drying out, etc.

When at some future time the spores are placed into favorable conditions for growth they germinate and start a new series of the ordinary type of yeast cells. In germinating they exert a pressure against the wall of the mother cell which finally breaks and permits the escape of the new cells. In some cases actual dissolution of the cell occurs during germination.

The changes described above are well illustrated in the accompanying figure, which shows stages in the life of a favorable pure culture yeast and also some of the mixed forms.
Classification of Yeasts.—Although the structure of yeasts is so exceedingly simple that it seems difficult for varieties to exist, nevertheless there are many different kinds or species. The distinctions are partly morphological, i.e., in the physical form of the cells, and partly chemical, i.e., in the enzymes elaborated by the cells which, of course, means that the products resulting from

![Diagram of yeast cells](image)

**Fig. 2.—True Wine yeast.**

1. Yeast cells in fermenting grape juice (*mixed forms*).
2. Saccharomyces ellipsoideus (*spores*).
3. Saccharomyces ellipsoideus (*old)*.
4. Saccharomyces ellipsoideus (*young)*.

the action of different yeasts on the same medium or substrate will be different. When a pure yeast is used in fermentation, an entirely different result is obtained than from the use of an impure. The flavor is different, as also the odor, and with a pure yeast the keeping properties are better. For the purposes of the fermentation industry, yeasts are divisible into two groups:
1. The wild yeasts—those which occur in nature; floating in the air, in the soil, and on the skins of fruits.

2. The cultivated yeasts—which have been selected from the wild yeasts for their favorable action and are carefully guarded in laboratory and factory to insure purity of strain.

There are two schools of thought in the fermentation industry and especially among wine makers as to whether it is preferable to use pure culture yeasts or to depend on wild yeasts. On the one hand it is claimed that pure culture yeast will result in a more accurately controlled fermentation, in a reduction in the time and labor required for racking and aging, a cleaner taste and flavor, and in the ability to select beforehand the flavor desired.

On the other hand, it is claimed that these advantages are offset by the necessity of sterilizing the must, pressed grapes and juice. In practice, however, the benefits derived from the use of pure culture yeast can often be had without resorting to the costly operation of sterilization. The pure culture yeasts are especially advantageous in the manufacture of white and sparkling wines and in the refermentation of the latter. They are used extensively abroad for these purposes and have secured some recognition and produced excellent results in some wineries in this country.

In whiskey distilleries, pure culture yeasts have been used extensively in recent years. The types are selected for high alcohol yields and propagated by the Hansen single-cell method. There can be no doubt at the present time but that pure culture yeasts are an absolute necessity for the manufacture of distilled spirits and very much preferable for the manufacture of wines.

The principal yeasts encountered in spirit and wine manufacture are:

*Saccharomyces cerevisiae.* The ordinary yeast of the brewer and the distiller. Two kinds are recognized: (a) top fermentation, and (b) bottom fermentation.

Top yeast, as its name implies, is a type which rises in a frothy mass to the top of the mash during fermentation. Bottom yeast sinks to the bottom of the vat during fermentation. Higher temperatures favor the for-
Micro-organisms Found on Grapes

Distillers' yeast is a high attenuating top variety.

Saccharomyces ellipsoideus. This is the yeast which converts must, or grape juice, into wine.

Saccharomyces pastorianus. This also occurs in wine making and when present during brewing gives a bitter taste to the beer.

Saccharomyces mycoderma. This yeast is the cause of "mother" which appears on the surface of wine or beer after exposure for some days to the air.

Bakers use either compressed yeast (compressed cakes of top yeast) or dried yeast (a mixture of yeast cells with starch). The former has high fermenting capacity and gives uniform results, but it will keep only a day or two; while the latter retains its capacity to produce fermentation for a long period. Brewers' yeast is not desirable for bread making because it is likely to give a bitter flavor and its activity is slow in a dough mixture.

Pure Cultures.—To determine the properties due to a particular yeast, it must be separated from all other organisms with which it is associated and when grown thus, free from all contamination, it is then known as a "pure culture." A commercially pure yeast is different, as this simply means "free from added non-yeast matter." This is the condition of most compressed yeasts as found on the market; they are commercially, but not bacteriologically, pure, since they have numbers of bacteria and molds associated usually with more than one yeast variety.

Micro-Organisms Found on Grapes.—The surfaces of grapes in the vineyard will hold any or all of the bacteria and fungi usually carried in the air and by insects. Many of these, especially the bacteria, cannot grow in grape juice on account of its acidity. These, of course, have a negligible effect on the wine. Others, such as most yeasts and molds and a few varieties of bacteria find grape juice to be a favorable medium for their development. Wine is a somewhat less suitable medium than unfermented grape juice (must), owing to its alcohol content, but still, a large number of forms are capable of growing in the wine. As the wine ages, the less suitable it becomes for the growth of micro-organisms, but it is never quite immune.

Among the great variety of organisms the only ones desired
YEASTS AND OTHER ORGANISMS

are the wine yeasts. Many different types of wine yeast have been isolated and studied. It has been demonstrated that not only do slight morphological differences exist, but also that they vary in the flavor and quality of wine produced and also in the speed and completeness with which they split sugar and consume acids. The true yeasts occur much less abundantly on grapes than the molds. Until the grapes are ripe they are practically absent, as first shown by Pasteur. Later, they gradually increase in number; on very ripe grapes being often abundant. In all cases and at all seasons, however, their numbers are much inferior to those of the molds and pseudo-yeasts. The cause of this seems to be that, in the vineyard, the common molds find conditions favorable to their development at nearly all seasons of the year, but yeasts only during the vintage season.

Investigations of Hansen, Wortmann and others show that yeasts exist in the soil of the vineyard at all times, but in widely varying amounts. For a month or two following the vintage, a particle of soil added to nutritive solution contains so much yeast that it acts like a leaven. For the next few months the amount of yeast present decreases until a little before the vintage, when the soil must be carefully examined to find any yeast at all. As soon as the grapes are ripe, however, any rupture of the skin of the fruit will offer a favorable nidus for the development and increase of any yeast cells which reach it. Where these first cells come from has not been determined, but as there are still a few yeast cells in the soil, they may be brought by the wind, or bees and wasps may carry them from other fruits or from their hives and nests.

The increase of the amount of yeast present on the ripe grapes is often very rapid and seems to have (according to Wortmann) a direct relation to the abundance of wasps. These insects passing from vine to vine, crawling over the bunches to feed on the juice of ruptured berries, soon inoculate all exposed juice and pulp. New yeast colonies are thus produced and the resulting yeast cells quickly disseminated over the skins and other surfaces visited.

The more unsound or broken grapes present, the more honey-
dew or dust adhering to the skins, the larger the amount of yeast will be. The same is true, however, also of molds and other organisms.

**True Wine Yeasts—*Saccharomyces ellipsoideus.*—In the older wine-making districts, much of the yeast present on the grapes consists of the true wine yeast, *S. ellipsoideus.* The race or variety of this yeast differs, however, in different districts. Usually several varieties occur in each district. The idea prevalent at one time, that each variety of grape has its own variety of yeast seems to have been disproved, though there seems to be some basis for the idea that grapes differing very much in composition, varying in acidity and tannin contents, may vary also in the kind of yeast present. Several varieties of ellipsoideus may occur on the same grapes. In new grape-growing districts, where wine has never been made, ellipsoideus may be completely absent.

Besides the true wine yeast, other yeasts usually occur. The commonest forms are cylindrical cells grouped as *S. pasteurianus.* These forms are particularly abundant in the newer districts, where they may take a notable part in the fermentation. Their presence in large numbers is always undesirable, and results in inferior wine. Many other yeasts may occur occasionally, and are all more or less harmful. Some have been noted as producing sliminess in the wine. Many of these yeasts produce little or no alcohol and will grow only in the presence of oxygen.

**Pseudo-yeasts.**—Yeast-like organisms producing no endospores always occur on grapes. Their annual life cycle and their distribution are similar to those of the true yeast but some of them are much more abundant than the latter. They live at the expense of the food materials of the must and, when allowed to develop, cause cloudiness and various defects in the wine.

The most important and abundant is the apiculate yeast, *S. apiculatus* (according to Lindner this is a true yeast producing endospores). The cells of this organism are much smaller than those of *S. ellipsoideus* and very distinct in form. In pure cultures these cells show various forms, ranging from ellipsoidal to pear-shaped (apiculate at one end) and lemon-shaped (apiculate at both ends). These forms represent simple stages of de-
Yeasts and Other Organisms

Development. The apiculations are the first stage in the formation of daughter cells; the ellipsoidal cells, the newly separated daughter cells, which, later, produce apiculations and new cells in turn.

Many varieties of this yeast occur, similar in degree to those of *S. ellipsoideus*. They are widely distributed in nature, occurring on most fruits, and are particularly abundant on acid fruits such as grapes. Apiculate yeast appears on the partially ripe grapes before the true wine yeast and even on ripe grapes is more abundant than the latter. The rate of multiplication of this yeast is very rapid under favoring conditions and much exceeds that of wine yeast. The first part of the fermentation, especially at the beginning of the vintage and with acid grapes, is, therefore, often almost entirely the work of the apiculate yeast.

The amount of alcohol produced by this yeast is about 4 per cent, varying with the variety from 2 to 6 per cent. When the fermentation has produced this amount of alcohol, the activity of the yeast slackens and finally stops, allowing the more resistant ellipsoideus to multiply and finish the destruction of the sugar.
The growth of the apiculatus, however, has a deterring effect on that of the true yeast so that where much of the former has been present, during the first stages of the fermentation, the latter often fails to eliminate all the sugar during the final stages.

Wines in which the apiculate yeast has had a large part in the fermentation are apt to retain some unfermented sugar and are very liable to the attacks of disease organisms. Their taste and color are defective, often suggestive of cider, and they are difficult to clear. This yeast attacks the fixed acids of the must, the amount of which is therefore diminished in the wine while, on the other hand, the volatile acids are increased.

Many other yeast-like organisms may occur on grapes; but, under ordinary conditions, fail to develop sufficiently in competition with apiculatus to have any appreciable effect on the wine. Most of them are small round cells, classed usually as Torulae. They destroy the sugar but produce little or no alcohol.

A group of similar forms, known collectively as Mycoderma vini, occurs constantly on the grapes but, all being strongly aerobic, they do not develop in the fermenting vat. Under favoring conditions, however, they may be harmful to the fermented wine.

Bacteria of many kinds occur on grapes as on all surfaces exposed to the air. Most of these are unable to develop in solutions as acid as grape juice or wine. Of the acid-resisting kinds, a number may cause serious defects and even completely destroy the wine. These, the "disease bacteria" of wine are mostly anaerobic and can develop only after the grapes are crushed and the oxygen of the must exhausted by other organisms. Practically all grape-must contains some of these bacteria, which, unless the work of the wine-maker is properly done, will seriously interfere with the work of the yeast, and may finally spoil the wine. The only bacteria which may injure the grapes before crushing are the aerobic, vinegar bacteria, which may develop on injured or carelessly handled grapes sufficiently to interfere with fermentation and seriously impair the quality of the wine.

Among the organisms which can infect wine and cause so-called "diseases" are the following:
Molds. The spores of the common saprophytic molds, *Penicillium*, *Aspergilllus*, *Mucor*, *Dematium*, are always present on the grapes, boxes, and crushers, as on all surfaces exposed to dust laden air, and most of them find in grape must, excellent conditions for development. *Botrytis cinerea*, a facultative parasite of the leaves and fruit of the vine, is also nearly constantly present in larger or smaller quantities. All of these molds are harmful, in varying degrees, to the grapes and the wine. Some of them, such as *Penicillium*, may give a disagreeable moldy taste to the wine, sufficient to spoil its commercial value. Others, such as *Mucor* and *Aspergilllus* may affect the taste of the wine but slightly and injure it only by destroying some of the sugar and thereby diminishing the final alcohol content. *Dematium pullulans* may produce a slimy condition in weak white musts, and most of them injure the brightness and flavor to some extent and often render the wine more susceptible to the attacks of more destructive forms of micro-organisms.

On sound, ripe grapes, these molds occur in relatively small number, and, being in the spore or dormant condition, they are unable to develop sufficiently to injure the wine under the conditions of proper wine-making. On grapes which are injured by diseases, insects or rain, they may develop in sufficient quantities to spoil the crop before it is gathered. On sound grapes which are gathered and handled carelessly, they may develop sufficiently before fermentation to injure or spoil the wine.

The molds are recognized by their white or grayish cobwebby growth over the surface of the fruit. This consists of fine branching and interlacing filaments known as mycelium. This is the vegetative stage of the fungus and the active part in the destruction of the material attacked. When mature, it produces spores which differ for each mold in form, size and color. The spores are the chief means of multiplication and distribution. They are minute, single celled bodies which are easily distributed as dust through the air, and are capable, after remaining dormant for a longer or shorter period, of germinating, under favorable conditions and giving rise to a new growth of mycelium.

The commonest molds on grapes in California are the Blue Mold, the Black Mold and the Gray Mold. Usually only one of these occurs plentifully at the same time. Which this one will be depends principally upon the temperature and humidity. In the hotter regions the Black Mold is most common during the earlier part of the vintage, later the Blue Mold takes its place. In the cooler regions only Gray and Blue Molds occur commonly.

Blue Mold (*Penicillium glaucum*). This is the common mold which attacks all kinds of fruit and foods kept for a length of time in a damp place. It is distinguished by the greenish or bluish color of its spores which cover the grapes attacked, and by its strong disagreeable moldy smell. It sometimes attacks late grapes in the vineyard after autumn rains
have caused some of them to split. Grapes lying on the ground are especially liable to attack. The principal damage of this mold occurs usually, after the grapes are gathered, while they lie in boxes or other containers. It will grow on almost any organic matter if supplied with sufficient moisture and at almost any ordinary temperature. It is almost the sole cause of all moldiness in boxes, hoses, and casks, and the most troublesome of all the molds with which the wine-maker has to deal.

The conditions most favorable to its development are an atmosphere saturated with moisture and the presence of oxygen.

Black Mold (Aspergillus niger). This is very common in the hotter and irrigated parts of California. It annually destroys many tons of grapes before they are gathered. It attacks the grapes just as they ripen and is distinguished by the black color of its spores, which sometimes fill the air with a black cloud at the wineries where the grapes are being crushed. It is especially harmful to varieties which have compact bunches and thin skins, such as Zinfandel. Its effect on the wine has not been well studied but it is much less harmful than Green Mold. Large quantities of grapes badly attacked are made every year into merchantable wine. The main damage done is in the destruction of crop and it is therefore a greater enemy to the grape-grower than to the wine-maker.

Gray Mold (Botrytis cinereā). This fungus in certain parts of Europe is a harmful parasite of the vine, injuring seriously leaves, shoots and growing fruit. The only injury of this kind noted in California is in the "callousing" beds of bench grafts.

As a saprophyte it may attack the ripe grapes in much the same manner as the Black Mold. It occurs apparently all over California but seldom does much damage. It attacks principally second crop and late table grapes.

Under certain circumstances this fungus may have a beneficial action. When the conditions of temperature and moisture are favorable, it will attack the skin of the grape, facilitating evaporation of water from the pulp. This results in a concentration of the juice. The mycelial threads of the fungus then penetrate the pulp, consuming both sugar and acid but principally the latter. The net result is a relative increase in the percentage of sugar and a decrease in that of acid. This, where grapes ripen with difficulty, is an advantage, as no moldy flavor is produced. Two harmful effects, however, follow: First, the growth of the mold results in the destruction of a certain amount of material and a consequent loss of quantity. This is, in certain circumstances, more than counterbalanced by an increase in quality, as is the case with the finest wines of the Rhine and Sauternes. For this reason, the fungus is called in those regions the "Noble Mold." Second, an oxydase is produced which tends to destroy the color brightness and flavor of the vine. This may be counteracted by the judicious use of sulfurous acid.
Fig. 4.—Wine grape molds.

1. Black mold (*Aspergillus niger*). (After Duclaux.)
   a. Fruiting hyphae.
   b. Sporecarp showing formation of spores.
   c. Spores.

2. Gray mold (*Botrytis cinerea*). (After Ravaz.)

3. Blue mold (*Penicillium glaucum*). (From skin of moldy grape.)
   a. Mycelium.
   b. Fruiting hypha.
   c. Chains of spores.
   d. Spores.
This mold is not of great importance in California as its beneficial effects are not needed and there is seldom enough to do much harm.

The special organisms which cause diseases in wine include:
Anaerobic organisms such as *Dematium pullulans* induce slimy fermentation which results in "ropiness." These bacteria attack the sugar, but not glycerin nor alcohol and produce mannite, carbon dioxide, lactic and acetic acids and alcohol. Their growth is entirely prevented by the presence of alcohol above thirteen per cent, free tartaric, tannic or small amounts of sulphurous acid. The infection is ordinarily not very serious and disappears under ordinary cellar treatment.

*Botrytis and Penicillium* which when present cause oxidation of the tannin causing a bitter taste. This is more common in red wines.

Acetic acid bacteria which cause the further oxidation of alcohol to acetic acid and result in a "pricking" taste. This taste
is noticeable even when there is only 0.1-0.15% of acetic acid. A dry wine becomes practically undrinkable at 0.25% of acetic acid.

*Saccharomyces apiculatus* will cause some production of alcohol but affects the flavor adversely.

*Mycoderma vini* attack the alcohol changing it to carbon dioxide and water and hence weaken the wine directly as well as rendering it more susceptible to infection by other disease organisms. It is sometimes the cause of film.

**Control of Yeasts.**—Control of the growth of these organisms and even to some extent selection of the variety which shall grow is largely possible by a consideration of the factors affecting their vigor.

**Nutrition.**—The preferred food of the yeasts is the sweet juice of more or less acid fruits. Most of them are active agents of alcoholic fermentation breaking up the sugar into alcohol and carbonic acid gas. Wine yeast may carry on the fermentation until the liquid contains 15 per cent or slightly more of alcohol. Other yeasts, such as ordinary beer yeast cease their activity when the alcoholic strength of the liquid reaches 8 to 10 per cent, while some wild yeasts are restrained by 2 to 3 per cent.

**Relation to Oxygen.**—They are aerobic, that is, they require the oxygen of the air for their development. Most of them are, however, capable of living and multiplying for a limited time in the anaerobic condition, that is, in the absence of atmospheric oxygen. It is in the latter condition that they exhibit their greatest power of alcoholic fermentation. They multiply most rapidly and attain their greatest vigor in the presence of a full supply of air. In fermentation, therefore, it is necessary, first, to promote their multiplication and vigor by growing in a nutritive solution containing a full supply of oxygen and, then, to make use of their numbers and vigor to produce alcoholic fermentation in a saccharine solution containing a limited supply of oxygen. These conditions are brought about automatically in the usual methods of wine-making. The stemming and crushing of the grapes thoroughly aerates the must. The yeast multiplies vigorously in this aerated nutritive solution until it has consumed most of the dissolved oxygen. It then exercises its fermentative power to break
up the sugar, with the production of alcohol. With many musts it is able in this way to completely destroy all the sugar without further oxygen. In other musts, especially those containing a high percentage of sugar, the yeast becomes debilitated before the fermentation is complete. In such cases it is generally necessary to reinvigorate it by pumping over the wine or by some other method of aeration before it can complete its work.

Relation to Temperature.—Yeast cells can not be killed or appreciably injured by any low temperature. They do not become active, however, until the temperature exceeds $32^\circ$ F. Wine yeast shows scarcely any activity below $50^\circ$ F., and multiplies very slowly below $60^\circ$ F. Above this temperature the activity of the yeast gradually increases. Between $70^\circ$ F. and $80^\circ$ F. it is very active and it attains its maximum degree of activity between $90^\circ$ F. and $93^\circ$ F. Above $93^\circ$ F. it is weakened, and between $95^\circ$ F. and $100^\circ$ F. its activity ceases. At still higher temperatures the yeast cell dies. The exact death point depends on the condition of the yeast, the nature of the solution and the time of exposure. In must and wine a temperature of $140^\circ$ F. to $145^\circ$ F. continued for one minute is usually enough to destroy the yeast.

The best temperature in wine-making will depend on the kind of wine to be made and will lie between $70^\circ$ F. and $90^\circ$ F.

Relation to Acids.—The natural acids of the grapes, in the amounts in which they occur in must, have little direct effect on wine yeast. Indirectly they may be favorable by discouraging the growth of competing organisms more sensitive to acidity. Acetic acid has a strong retarding influence which commences at about 0.2 per cent and increases with larger amounts until at 0.5 per cent to 1.0 per cent, according to the variety of the yeast, all activity ceases.

Relation to Sulfurous Acid.—Sulfurous acid is an antiseptic, mild or strong, according to the quantities used. The fumes of burning sulfur are used in various ways and for various purposes in wine-making. The active principle of these fumes is sulfurous acid gas of which the chemical formula $SO_2$ shows that it is composed of one atom of sulfur combined with two atoms of
oxygen. As sulfur has just twice the atomic weight of oxygen this means that one part by weight of sulfur combines with one part by weight of oxygen to produce two parts by weight of sulfurous acid gas. This combination takes place when sulfur is burned in free contact with air. The same substance can be obtained from certain salts, one of which is most suitable for use in wine-making. This is a potash salt known as potassium metabisulfite. This salt is composed of nearly equal weights of potash and sulfurous acid. In contact with the acids of the must, the sulfurous acid is set free and the potash combines with the tartaric acid of the must to form bi-tartrate of potash, some of which is already present as a natural constituent of the must.

Bacteria of all kinds are much more sensitive to the effects of sulfurous acid than are yeasts. If used, therefore, in properly regulated amounts it can be made a very efficient means of preventing bacterial action and thus indirectly of aiding the work of the yeast. It has also the very valuable property of preventing the injurious action of the oxydase produced by Botrytis and other molds. Finally, it is necessary in most cases to prevent the too rapid or overoxidation of the wine during aging.
CHAPTER VI

PRODUCTION OF YEAST

Commercial Yeast.—The application of the principles just developed is well illustrated in the manufacture of yeast for general use. The same niceties observed in this process must also be followed in the production of so-called “starters” for the fermentation of whiskey mashses or of wine must. Figure 6 is the flow sheet of such a process. The exact proportions of the various grains used are naturally varied according to the secret formula of the manufacturer.

It will be noted that the steps on this flow sheet may be divided by two horizontal lines into three broad divisions:

1. The first set of mechanical operations has for its object the conditioning of the raw materials for the next set. It includes very thorough cleaning and purification of all the materials, grinding the cereals to make them more reactive and steeping them in water to further ease the dissolution of the nutritive ingredients.

2. The next set of biochemical and chemical operations includes bringing the food for the yeast cells into the most readily assimilable form and then growing the yeast in the medium so produced under conditions which will result in the most vigorous and prolific production of yeast.

3. In the final set of mechanical operations the yeast cells are separated from the fermented liquor under the optimum conditions to ensure their survival and prepared for marketing. The actual operations involved in the process are somewhat as follows:

The cleaned, ground and steeped grains are cooked to pastify the starch. Usually the corn is cooked first at the highest temperature, then the rye is added and when the mash has cooled to the proper temperature for the most effective action of diastase (ca. 55° C., 130° F.) the malt is added.
FIG. 6. PRODUCTION OF YEAST

Barley Malt
Rye
Corn
Water
Sprouts

Cleaner
Cleaner
Cleaner
Filter
Cleaner

Mill
Mill
Mill

Corn Cooker

Mash Tub

Souring Tank

Filter Tub

Cooler

Fermenter where yeast grows

Yeast Separators

Receiving Tank

Filter Press

Shipping Boxes

Refrigerator

Cars to Agencies

Small Lactic Acid
Mash

FIG. 6.