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GRAPE VINEGAR.

I. INTRODUCTION.

With the ever increasing extension of the grape-growing industry in California it is desirable that every possible profitable outlet for the crops should be utilized. One important outlet which at present is but incompletely utilized is the manufacture of high class vinegar.

Many grapes which are unsuitable for drying, shipping, or wine-making can be turned into excellent vinegar. Vinegar of high quality is in fact so rare and so difficult to procure that this may be the most profitable use, in some cases, to which even the best grapes can be put. Wine vinegar, however, can not, even under the most favorable conditions, compete in cheapness with vinegar made from distilled alcohol or the numerous waste products which at present are the source of the main bulk of the vinegar found in commerce. Good wine vinegar is as costly to make as good wine and more costly than poor. It can be sold at a profit, therefore, only at a price comparable with that of good wine, which is considerably higher than that of ordinary vinegar.

If wine vinegar is to be produced at a profit, it must be made intelligently and in such a manner as to produce and preserve those qualities to which it owes its reputation for superiority over all other classes of vinegar.

Good vinegar can not be made from moldy grapes or spoiled wine and its manufacture requires as much knowledge and care as that of good wine. Unlike the latter, however, it can be successfully produced on a small scale for domestic purposes. With a few boxes of good grapes and some small casks, vinegar of the best quality can be made for home use, far superior in wholesomeness and palatability to any that can be bought in the general market without paying extravagant prices. To serve as an outlet for any considerable portion of the grape crop, however, vinegar must be made on an industrial scale.

In the open market, wine vinegar can compete with other vinegars only on the score of quality. To attain this quality the best methods of vinegar making must be understood and intelligently applied.

II. DEFINITIONS AND STANDARDS.

Vinegar has been defined as: "A condiment made from various sugary or starchy substances by alcoholic and subsequent acetic fermentation." It is defined more fully by the United States "Standards of purity for Food Products," as follows:

1. Vinegar, cider vinegar, apple vinegar, is the product made by the alcoholic and subsequent acetous fermentations of the juice of ap-

ples, is lævo-rotatory, and contains not less than four (4) grams of acetic acid, not less than one and six tenths (1.6) grams of apple solids, of which not more than fifty (50) per cent are reducing sugars, and not less than twenty-five hundredths (0.25) grams of apple ash in one hundred (100) cubic centimeters, (20°C.); and the water-soluble ash from one hundred (100) cubic centimeters (20°C.) of the vinegar contains not less than ten (10) milligrams of phosphoric acid (P_2O_5) and requires not less than thirty (30) cubic centimeters of decinormal acid to neutralize its alkalinity.

2. Wine vinegar, grape vinegar, is the product made by the alcoholic and subsequent acetous fermentations of the juice of grapes and contains, in one hundred (100) cubic centimeters (20°C.), not less than four (4) grams of acetic acid, not less than one (1.0) gram of grape solids, and not less than thirteen hundredths (0.13) gram of grape ash.

3. Malt vinegar is the product made by the alcoholic and subsequent acetous fermentations, without distillation, of an infusion of barley malt or cereals whose starch has been converted by malt, is dextro-rotatory, and contains, in one hundred (100) cubic centimeters (20°C.) not less than four (4) grams of acetic acid, not less than two (2) grams of solids, and not less than two tenths (0.2) gram of ash; and the water-soluble ash from one hundred (100) cubic centimeters (20°C.) of the vinegar contains not less than nine (9) milligrams of phosphoric acid (P_2O_5) and requires not less than four (4) cubic centimeters of decinormal acid to neutralize its alkalinity.

4. Sugar vinegar is the product made by the alcoholic and subsequent acetous fermentations of solutions of sugar, sirup, molasses, or refiners' sirup, and contains, in one hundred (100) cubic centimeters (20°C.) not less than four (4) grams of acetic acid.

5. Glucose vinegar is the product made by the alcoholic and subsequent acetous fermentations of solutions of starch sugar or glucose, is dextro-rotatory, and contains, in one hundred (100) cubic centimeters (20°C.), not less than four (4) grams of acetic acid.

6. Spirit vinegar, distilled vinegar, grain vinegar, is the product made by the acetous fermentation of dilute distilled alcohol, and contains, in one hundred (100) cubic centimeters (20°C.) not less than four (4) grams of acetic acid.

According to these standards the word "vinegar," without qualification can be applied only to the product made from apples or cider. This is not in accord with the most extended usage nor with the fundamental meaning of the word. The word "vinegar" is derived from the French "vinaigre" which means literally "sour wine," as shown by its derivation from the two Latin words *vinum*=wine and *acer*=sour.

If the word vinegar, unqualified, be used at all as a legal term, it should apply only to the product of grapes and wine. This is justified by the facts that historically the first vinegar was wine vinegar and that wine vinegar is still considered by most competent authorities as the best vinegar. The error in the United States Standards is due to the fact that, in the Eastern States, most of the best vinegar is made from apples. It is possible that good cider vinegar is better than that made from Labrusca varieties of grapes such as are grown in the East. It is, however, inferior in flavor and strength to vinegar made from Vinifera grapes such as are grown on the Pacific coast and in the principal grape growing regions of Europe and Asia.

III. CLASSES OF VINEGAR AND RAW MATERIALS.

The various kinds of vinegar are usually classed in accordance with the raw materials from which they are derived.

The best vinegars are those which are made from grapes and apples. They contain besides acetic acid to which they owe their "sourness," certain agreeable flavors and aromas derived either directly from the fruit or produced from substances contained in the fruit by the alcoholic and acetic fermentations.

Excellent vinegars are also made from malt and from honey. These are wholesome and pleasing but of less character or quality than those made from wine or cider. All these vinegars are suitable for domestic or table use.

Vinegars made from sugar, molasses or glucose are inferior, lacking in flavor or quality and unsatisfactory for table use.

Spirit vinegar, made from distilled alcohol, is little more than dilute acetic acid and lacks the aromas and flavors which are characteristic of good table vinegar. It can be produced very easily and cheaply and where pure food laws are not enforced it is used to counterfeit better vinegar by adding various coloring and flavoring matters. It seems doubtful whether this product should be entitled to the appellation of vinegar at all.

IV. WINE VINEGAR.

Wine vinegar has a specific gravity of 1.014 to 1.022 and contains generally from 6 per cent to 10 per cent of acetic acid and from 1.7 per cent to 2.4 per cent of extract. It contains also organic acids derived directly from the grape, of which the principal is tartaric in the form of bitartrate of potash. By the presence of bitartrate, wine vinegar is distinguished from all others. The acidity due to these organic acids averages about .5 per cent. In the best vinegar, from 1 per cent to 1½ per cent of alcohol remains unconverted into acetic acid. The alcohol is necessary to prevent loss of acetic acid during

the making and to increase the quality in aging by the production of acetic ether and other aromatic compounds.

Wine vinegar, in common with all others, must contain at least 4 per cent of acetic acid to conform with the legal standard. Most wine vinegar contains more than this amount—6 per cent to 10 per cent—and is stronger than either cider or malt vinegar. The *strength* of commercial vinegars is expressed in *"grains"* or numbers which indicate the number of grains of sodium bicarbonate neutralized by one fluid ounce wine measure. The *percentage* of acetic acid, that is, the number of grams of absolute acid in 100 cubic centimeters of vinegar, is obtained by multiplying the "grains," or "number," by 0.1565. Table VI on page 350 shows the percentage represented by the numbers most commonly used.

A 30 grain vinegar has 4.7 per cent of acidity and therefore would satisfy the legal requirements. Unless vinegars are bottled and pasteurized, however they lose strength with time. Under ordinary conditions of keeping in a partially filled cask, one per cent of acid may be lost in a few months. Dealers, therefore, have adopted a standard of 40 grains as the minimum for commercial vinegars. In determining the strength of a wine vinegar 3 grains or .5 per cent must be deducted from the observed reading on account of the fixed organic acids.

Vinegar is made from both white and red wine. White wine vinegar is generally preferred. Red wine vinegar is perhaps equally good but is usually not salable until it has been decolorized, and the process of decolorizing diminishes its flavor and aroma.

V. ALCOHOLIC FERMENTATION.

Vinegar can be made either from grapes or wine. In either case the acetifying process is the same. If grapes are used, they must be first made into good wine. The methods of wine-making described in Bulletin 213 may be used with one important exception. Sulfurous acid should not be used, as it interferes very materially with the transformation of the wine into vinegar. This makes it necessary, especially in warm regions, to take special precautions to avoid hot fermentation and the "sticking" of the fermenting must. This is accomplished by using small fermenting vats, by thorough aeration and by diluting the must to 20° B. when necessary. By these means it is easy to obtain a complete transformation of the sugar into alcohol in five or six days, and to avoid the injurious action of the anaerobic bacteria which produce undesirable flavors in the wine and consequently in the vinegar.

On the other hand, the great care used in wine-making to avoid the action of *aerobic* bacteria is not necessary if the wine is to be turned into vinegar. These *aerobic* bacteria are in fact the cause of the sub-

sequent fermentation which changes the alcohol of the wine into acetic acid of the vinegar.

The manufacture of vinegar from grapes, therefore, has two dist stages. First, the *alcoholic fermentation* by which the sugar is chan into alcohol and carbonic acid gas. The cause of this fermentatio *yeast.* Second, the *acetic fermentation* by which the alcohol is chan into acetic acid. The cause of this fermentation is *vinegar bacteri*

These two fermentations cannot take place together and care sh be used to prevent the beginning of the acetic fermentation before alcoholic fermentation is finished. While the yeast is working vi ously, it absorbs the oxygen dissolved in the must and replaces it v carbonic acid gas. This prevents the growth of vinegar bacteria wl are active only in the presence of abundant free oxygen. If anyth stops the work of the yeast before all the sugar is transformed, ac bacteria may develop and produce acetic acid. Acetic acid in qu tities approaching .5 per cent interferes with the work of the yeast at 1 per cent stops it entirely. These facts are shown by the follow experiments.

*TABLE I.

Influence of acetic acid on yeast fermentations.

Nature of experiment.		Volatile acid.		Sugar.	
		Added.	At end.	In must.	At e
Grape must 16.1% sugar and .5% fixed acid---	a	.10	.07	16.1	
Added various amounts acetic acid----------	b	.25	.26	16.1	
Inoculated with vigorous pure yeast--------	c	.40	.38	16.1	
Temperature 25° C. Duration of experiment 26 days ----------	d	.50	.51	16.1	
	e	1.00	1.01	16.1	

* Most of the experiment work of this bulletin was done by Mr. W. Cruess.

This shows that under the conditions of the experiment 1 per c of acetic acid completely prevented all alcoholic fermentation and t .5 per cent prevented its completion. Smaller amounts had no eff This indicates that the small amounts of acetic acid which would introduced into the must by the use of vinegar-sour barrels, buck or hoses would not prevent complete alcoholic fermentation if all ot conditions were favorable. The care used in wine-making to rem all traces of vinegar is therefore not necessary if the wine is to turned into vinegar. It shows, on the other hand, that the mixing vinegar and must would prevent the transformation of the sugar in latter.

TABLE II.

Influence of the presence of vinegar bacteria on yeast fermentation.

A. *Sterilized Must inoculated with Pure Yeast.*

	Temperature of fermentation.	Sugar in must.	Sugar remaining after five days.	
			Yeast No. 1.	Yeast No. 2.
a.	28° C	20% B.	.38%	.50%
B. *Sterilized Must inoculated with Pure Yeast and Vinegar Bacteria.*				
b.	30° C.	25% B.	2.16%	2.60%
c.	30° C.	20	.85	.81
d.	20° C.	20	.40	.52
e.	30° C.	15	.40	.42
f.	30° C.	10	.35	.40
g.	30° C.	5	.20	.21

Under the conditions of the experiment the yeast fermentation was just as complete in the presence of the bacteria as in their absence. Compare (*a*) and (*d*). The cause of this was that the conditions were favorable to yeast fermentation and that the latter produced conditions (absence of oxygen) unfavorable to the bacteria which therefore did not develop. In practice, therefore, if care is taken to keep conditions favorable to the yeast during the alcoholic fermentation the presence of vinegar bacteria is not harmful.

On the other hand, if conditions unfavorable to the yeast are allowed to exist, the bacteria may increase and produce sufficient acetic acid to stop alcoholic fermentation before the sugar is all transformed. This is shown by Experiment III.

TABLE III.

Influence of the presence of vinegar bacteria and acid on yeast fermentation.

Nature of experiment.		Volatile acid.		Sugar.	
		Added.	At end.	In must.	At end.
Grape must 16.1% sugar and .5% fixed acid	a	.10	.23	16.1	.28
Added various amounts acetic acid	b	.25	.49	16.1	.26
Inoculated with yeast and vinegar bacteria	c	.40	2.20	16.1	5.30
Temperature 24° C. Duration of experiment 26 days	d	.50	2.01	16.1	7.50

This shows that while .4 per cent of acetic acid alone was not enough to prevent a complete alcoholic fermentation (see Exp. Ic) it had sufficient unfavorable influence on the yeast to allow bacteria when present to grow and produce more acetic acid and thus prevent the transformation of all the sugar. This shows that in practice, where vinegar bac-

teria are always present, it is not safe to allow the must to be contaminated with even .4 per cent of acetic acid before the alcoholic fermentation is complete. Reasonable care, therefore, should be taken to prevent any notable quantities of acetic acid getting into the must or crushed grapes before alcoholic fermentation is complete.

This will be accomplished if all mixing of unfermented or partially fermented sweet juice with vinegar or partially acetified wine is avoided. Vessels and casks that have been used for the acetic fermentation or for holding vinegar can be used for the alcoholic fermentation providing they are well rinsed with water before use.

Under favorable conditions, vinegar bacteria will attack sugar and produce acetic acid directly. Under the conditions of vinegar making, however, this action is very slow and any sugar left in the wine after the start of acetification may be considered as lost. This is shown by the experiments summarized in the following table.

TABLE IV.

Influence of vinegar bacteria on the sugar in wine.

Culture.	Sample.	Wine.		At 3 weeks.			At 10 weeks.	
		Alcohol.	Sugar.	Volatile acid.	Sugar.	Volatile Acid.	Sugar.	Volatile Acid.
No. 78	A.	9.52	4.10	.06	4.10	.08	4.20	6.10
	B.	7.93	6.80	.05	6.60	.48	6.59	5.90
	C.	7.32	4.75	.05	4.54	5.40	4.60	6.40
No. 76	A.	9.50	4.10	.06	4.12	.16	4.26	.19
	B.	7.93	6.80	.05	6.66	.10	.10*	.20
	C.	7.32	4.75	.05	4.60	2.80	4.40	6.20

* Disappearance of sugar due to yeast contamination.

Culture No. 78 was isolated from wine vinegar and Culture No. 76 from cider vinegar. In ten weeks neither of them had had any appreciable action on the sugar. The cider vinegar bacteria, moreover, had been unable to attack the alcohol in the stronger wines.

Further details of the methods of alcoholic fermentation may be obtained from Bulletin 213.

VI. ACETIC FERMENTATION.

If wine containing less than 14 per cent of alcohol is exposed freely to the air it soon becomes covered with a film, the alcohol disappears, is replaced by acetic acid, and the liquid is converted into vinegar.

This film, the *Mycoderma aceti* of Pasteur, consists of bacteria cohering by means of a glutinous sheath surrounding each cell. If the film is undisturbed, the liquid remains clear until converted into vinegar.

If disturbed, portions may sink, new films form and finally, a large gelatinous mass, the "mother of vinegar," may form in the liquid.

Sometimes, especially in liquids containing sugar and more than 14 per cent of alcohol, such as sweet wines, the film formed consists, not of bacteria, but of a yeast-like fungus known as "*Mycoderma vini,*" or "wine-flowers." This organism is totally different from the vinegar germ and is harmful, destroying the alcohol but not producing vinegar.

Films due to wine flowers are thicker and whiter than those due to vinegar bacteria, and are easily recognized by the experienced eye and with certainty by the use of a microscope.

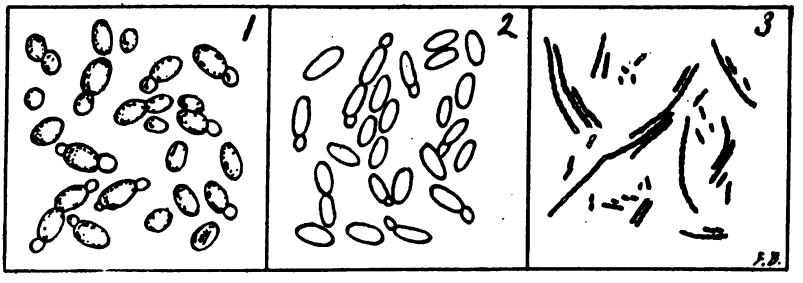


FIG. 1.—1. Yeast. 2. Wine Flowers. 3. Vinegar Bacteria.

Wines, which have been sterilized, often remain without acetifying for a considerable time. Those containing traces of sulfurous acid acetify slowly and with difficulty. Ordinarily, at warm temperatures, other exposed wines develop a bacterial film very rapidly owing to the presence of acetic bacteria in almost all wines. There are several or many species of vinegar bacteria, but those which occur usually in wine, and to which the spontaneous acetifying of wine is due, resemble each other very closely in their conditions of growth, and no differences have been noted in the quality of vinegar which they produce.

All species are strongly *aerobic,* that is, they grow rapidly only when freely supplied with air or oxygen. They grow best at a temperature of about 90° F. to 93° F. Some of them will grow near 40° F. but at low temperatures their growth is very slow. Above 93° F. their activity diminishes and at 107° or 108° all action ceases.

Their principal action on the wine is the formation of acetic acid from the ordinary or ethyl alcohol. They also attack other alcohols and even sugars with the production of various acids. These reactions, however, are less rapid and of little bearing on practice except in so far as they may account in part for the superior aroma and quality of vinegars made by the slow process.

The presence of too much alcohol prevents the growth of vinegar bacteria, the limit being about 14 per cent by volume under manufacturing conditions. At 14 per cent and above, the film forms with dif-

ficulty and the oxidation of the alcohol is incomplete, aldehyde and undesirable products being formed. Acetic acid in amounts above 10 per cent or 12 per cent is moreover antiseptic to the bacteria and prevents their growth. Below 14 per cent of alcohol, the bacteria develop readily and produce in suitable solutions, besides acetic acid, agreeable ethers which are more abundant when the oxidation is slow. When the alcohol falls below 1 per cent or 2 per cent the bacteria attack these ethers and finally the acetic acid itself which is completely oxidized to carbonic acid and water.

The addition of a new supply of wine containing alcohol, however, immediately arrests this action. In practice, the acetification should be stopped as soon as the alcohol has fallen to one or two per cent, otherwise there is a loss of flavor and of acetic acid which may continue until the vinegar is completely destroyed.

VII. YIELD OF VINEGAR.

In changing grapes into vinegar there is a certain amount of loss at every stage of the process. Some of this loss is unavoidable but some can be saved by careful work. There is, therefore, a theoretical maximum yield based on the composition of the grapes which can never be quite reached. There is also a maximum practical yield which the manufacturer should attempt to reach. The maximum theoretical and practical yields will differ for different grapes owing to differences in the amounts of stems, seeds and skins, and also owing to variations in the percentage of fermentable sugars. The following table gives an approximation of the average for grapes grown in California showing 20° Balling:

TABLE V.

Yield of 2,000 pounds of grapes of 20 Bal.

A. *Yield of Must from 2000 pounds of Grapes.*

Theoretical average yield of stems, seeds and stems	200 pounds
Theoretical average yield of pulp (or must)	200 gallons
Maximum yield of must in practice	140 to 160 gallons
Average maximum yield of must	150 gallons

B. *Yield of Wine from 150 gals. of Must at 20° Bal.*

Maximum yield of alcohol, in practice, 47% of sugar, = 8.78 by weight = 11% by volume.
Maximum yield of wine, = 143 gallons, at 8.78% by weight.

C. *Yield of Vinegar from 143 gals. of Wine of 8.78% Alcohol.*

Theoretical yield of acetic acid, = 11.4%.
Maximum yield in practice, 85% =9.8%.
Maximum yield of vinegar, 135 gals. of 9.8% = 63 grains.

One ton of grapes of 20° B. should then on the average yield 135 gallons of vinegar of 9.8 per cent acetic acid. It may be greater or less than this according as the grapes contain more or less sugar. This yield may be diminished by imperfect crushing and pressing of the grapes whereby more must is left in the pomace. Alcohol may be lost by imperfect or improper fermentation, in which case the vinegar

will be weaker. The greatest difference between the theoretical and the actual yield is in the change from wine into vinegar. This is because one or two per cent of alcohol remains unconverted in the vinegar, and because during the process there is a considerable loss of alcohol and acetic acid by evaporation, and by reactions within the liquid which produce other substances at the expense of the alcohol and acetic acid. If the temperature during acetification is too high, or if the acetic bacteria are allowed to act too long, this loss may be much increased.

By allowing the crushed grapes to ferment on the skins before pressing, a somewhat larger volume of wine and therefore of vinegar may be obtained. This may amount to 150 or 160 gallons of vinegar from a ton of grapes. The vinegar, however, will be darker colored and, in the case of red grapes, red. This color can be removed, but the decoloration is difficult and involves some loss of quality.

Fermentation for twenty-four hours on the skins will much facilitate the extraction of the juice without, except in the case of grapes very rich in coloring matter, reddening the juice very much.

TABLE VI.

Strength of vinegar from musts of various degrees Balling.

Must (sugar). Balling degrees.	Wine (alcohol).		Vinegar (acetic acid).	
	By volume, per cent.	By weight, per cent.	By weight, per cent.	Grains.
15.0	7.55	6.06	6.7	43
15.5	7.87	6.32	7.0	45
16.0	8.22	6.60	7.3	47
16.5	8.60	6.91	7.7	49
17.0	8.88	7.14	7.9	51
17.5	9.20	7.39	8.2	53
18.0	9.56	7.69	8.5	55
18.5	9.90	7.96	8.8	57
19.0	10.28	8.27	9.2	59
19.5	10.60	8.53	9.5	61
20.0	10.99	8.85	9.8	63
20.5	11.34	9.14	10.1	65
21.0	11.69	9.42	10.5	67
21.5	12.00	9.66	10.7	69
22.0	12.39	9.99	11.1	71
22.5	12.75	10.28	11.4	73
23.0	13.10	10.57	11.7	75

VIII. PROCESSES OF MANUFACTURE.

There are many processes by which an alcoholic liquid may be changed into vinegar but they all consist essentially in exposing the liquid to the action of vinegar bacteria in the presence of an abundant supply of air at a suitable temperature. Some of them are based on the old Orleans or slow process, others on the German or rapid process, and the remainder are attempts to combine the good qualities of both.

The slower processes give the best and most highly flavored vinegars and are alone to be recommended for the manufacture of wine vinegar of fine quality.

Whatever the process adopted, the wine should be clear and dry, that is, should contain no sediment nor unfermented sugar. Young wine should be kept and racked off until it has deposited all yeast and gross lees. Then, if necessary, it should be filtered and diluted with pure water to about 10 or 12 per cent of alcohol.

a. *Domestic process.* For home use or for manufacture on a small scale, the vinegar is most conveniently made in ordinary wooden casks. These casks may be of any convenient size from 10 to 50 gallons or even larger. Fifty gallon barrels are perhaps the best. These barrels should be furnished with some form of funnel for putting in the wine without disturbing the bacterial film and with a spigot for drawing off the vinegar. A hole for ventilation should be bored in each head, one just above the middle and the other near the top. These holes should be covered with varnished metal netting to prevent the entrance of vinegar flies. Fig. 2 shows a convenient arrangement.

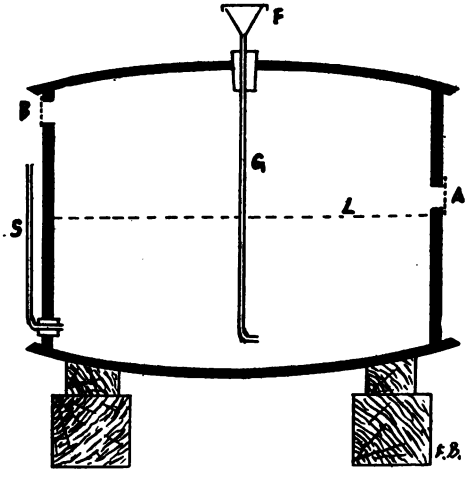


FIG. 2.—Cask for Vinegar Fermentation.

The wine is poured into the barrel through the funnel (F) which is furnished with a long glass tube (G) which extends nearly to the bottom of the cask. The barrel is filled only to the line (L), about the middle, in order to give as large a surface for the bacterial film to cover as possible. The bacteria are supplied with the necessary oxygen by a current of air which entering at A passes over the surface of the liquid and escapes at B. The tube S serves for drawing off the finished vinegar and as an indicator of level. It may be replaced by a wooden spigot.

In starting the process, about 10 per cent of good vinegar is first placed in the cask (2 to 3 gallons for a fifty gallon barrel). The clear wine is then poured in until the surface of the liquid is nearly level with the air hole in the head. The wine is best added in fractional parts of one fourth to one third of the total amount, at intervals of one week. The use of the vinegar is to render the liquid strongly acid and thus prevent the growth of injurious bacteria and other organisms. If young and unpasteurized, it also supplies an abundant inoculation of vinegar bacteria.

The cask should be placed on a solid stand and firmly fixed. Any movement of the cask is apt to disturb the surface film and interfere with the proper work of the bacteria. Bacteria which sink to the bottom do not produce acetic acid and, if plentiful, may seriously depreciate the quality of the vinegar.

The higher the temperature of the liquid, under 93° F., the more rapid the process of acetification. The vinegar room, therefore, should be kept near 70° F. if practicable. Lower temperatures retard the process unduly and much higher depreciate the quality. It is advisable to warm the wine to 85° F. or 90° F. before putting it in the casks.

At the end of one, two or three months, according to the temperature, the degree of aeration and the strength of alcohol, the vinegar fermentation should be finished. If the wine is very high in alcohol and the average temperature of the room below 60° F. the time may be much prolonged. In an ordinary barrel without the extra air holes in the ends it may require a year or longer to completely transform the wine into vinegar.

As soon as the acetic fermentation is complete, that is, when all the alcohol has been changed into acetic acid except about 1 per cent or 2 per cent the vinegar should be removed from the barrel.

This is done by drawing off through the spigot. About one tenth of the vinegar should be left in the barrel, which should be disturbed as little as possible in order not to destroy the bacterial surface film. A new supply of wine is then introduced by means of the funnel and glass tube. This wine should be introduced carefully, in order to disturb the sediment and bacterial film as little as possible. As soon as this new supply is acetified it should be removed and the process repeated until the accumulation of sediment makes it necessary to clean the barrel.

b. *Industrial methods.* The method just described is essentially the old Orleans method which is still used to produce fine vinegars on a large scale. It has, however, many defects for manufacturing on an industrial scale. It is slow and laborious, and there is a considerable loss of material by evaporation and by the formation of large masses

of gelatinous "mother of vinegar," which depreciates the quality and necessitates expensive cleanings of the casks.

Various methods, based on the researches of Pasteur, have been devised to overcome the defects of the old method while retaining its advantages. That of Claudon is one of the best and will serve to exemplify all. The vinegar vat shown in Fig. 3 illustrates the principle of the Claudon apparatus.

It consists essentially of a wide, shallow, covered, rectangular vat, furnished with numerous openings near the top (*a*) by which the entrance of air can be facilitated and regulated. This vat is filled to near the bottom of the air vents with a mixture of four parts of good new vinegar and six parts of wine which has been pasteurized at 140° F., and, when necessary, filtered. On top of this liquid is floated a light wooden grating (*f*) which helps to support the bacterial film and prevents its breaking and submerging during the various operations. When filled, the process is started by placing a small quantity of a

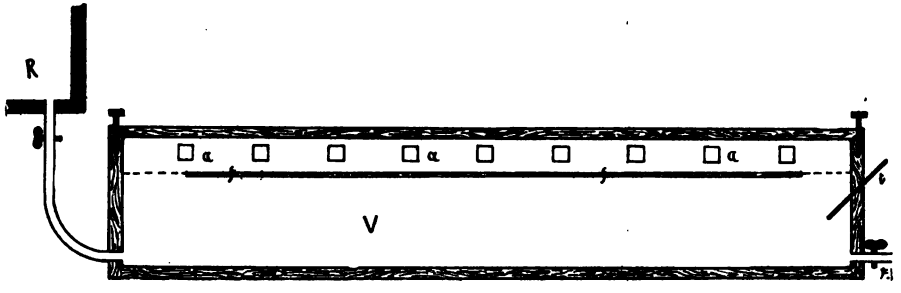


FIG. 3.—Sketch illustrating the principles of the Pasteur method.

good bacterial film on top of the liquid which soon becomes completely covered, when the proper conditions of temperature and aeration are maintained.

Each acetifying vat is connected with a small measuring vat (*R*) from which the proper amount of liquid is taken every day after a corresponding amount of vinegar has been removed. These two vats constitute a unit, several of which, usually six, are united in a battery. A factory includes several of these batteries.

The batteries are fed from a large vat or reservoir, where the mixture of wine and vinegar is prepared and stored. The vinegar drawn from the batteries runs directly to filters, from there to a pasteurizer, and thence to the storage casks. The output of these batteries is from two to five times as great per square yard of acetifying surface as that of the old methods; the cost of operation is considerably less, the loss by evaporation much reduced, and the quality equal and much more under the control of the manufacturer.

c. *Rapid or German process.* The chief advantage of the Claudon and similar improved methods is that a larger surface is exposed to the action of the bacterial film and the process thus hastened. The Rapid or German methods extend this principle further, and attempt to give the greatest surface possible for the action of the bacterial film.

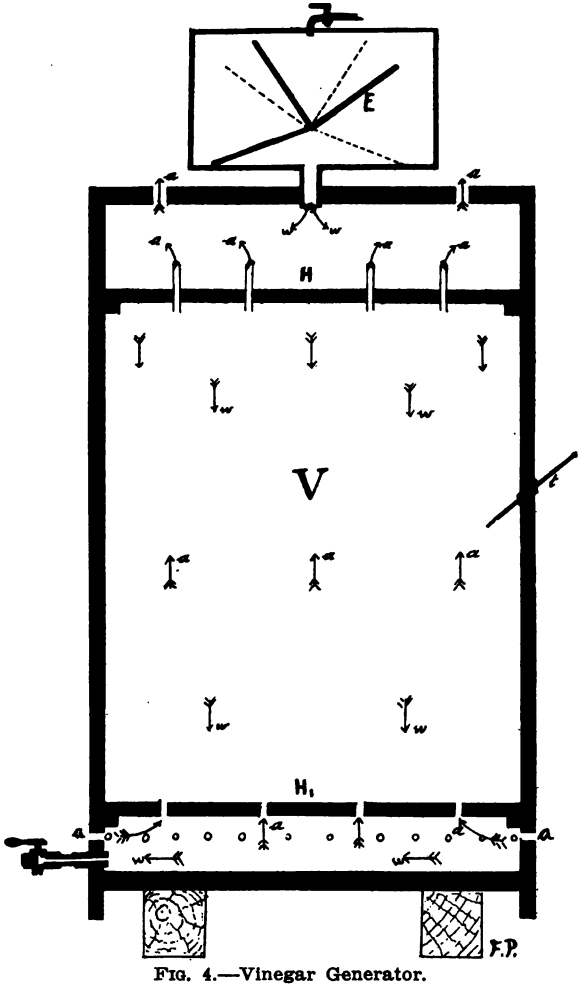


FIG. 4.—Vinegar Generator.

V. Mass of beech chips over which the wine trickles from the small holes in the false head H becoming acetified and passing through holes in the false bottom H. E. Tilting trough for the intermittent supply of wine. a. Course of air; w. course of wine; t. thermometer.

This is accomplished by what is known as a Vinegar Generator, of which there are many forms. A common form of generator consists of a tall cylindrical or slightly conical wooden vat provided with a perforated false head a few inches from the bottom, and another, similar in structure, at the same distance from the top. The space be-

tween these two false heads is filled with long thin chips or shavings of beech wood which have been thoroughly extracted first with water and then with good strong vinegar.

Instead of wood shavings, other substances such as corn cobs and grape stems have been used successfully. The material should be tasteless, finely divided and sufficiently resistant not to pack too tightly during the process.

In operation, the liquid to be acetified is distributed over the top false head intermittently in small amounts. This intermittent supply is accomplished by various automatic devices. If the supply is continuous, the liquid tends to run in streams or currents in certain parts of the vat and much of the acetifying surface is lost; if too rapid, the bacterial film is removed from the upper part of the mass of beech chips and only the lower part is effective.

From the false head, the liquid passes through numerous small holes to the mass of beech chips, over which it trickles slowly and is acetified by means of the bacterial film which covers them. By the time it reaches the lower false head, the alcohol is in greater or less amount converted into acetic acid. Usually, the liquid must pass through from two to five times or through an equal number of vats before it is completely changed into vinegar. The number of passages depends on the temperature, the amount of alcohol present, the height of the acetifying column, the rapidity of the flow, and on the perfection of the apparatus. The maximum vinegar strength is obtained when the alcohol has fallen to 1 per cent. A passage through the generator after this will decrease the strength by destroying acetic acid.

Oxygen is supplied by the air, which, entering holes in the vat below the lower false head, passes through numerous holes in the latter, through the interstices between the chips and out through short tubes fixed in the upper false head and holes in the top. The passage of air is insured by the heating of the interior due to the fermentation. It can be regulated by the number and diameter of the air holes.

The temperature, which should be close to 85° F., must be carefully regulated. If the temperature rises too high, the loss by evaporation will be much increased, if too low the acetification will be retarded. Many modifications of this method exist, having principally for their objects the more complete regulation of the temperature and air supply, the recuperation of the volatile matters, and the avoidance of the need of repassing the liquid through different acetifying columns.

IX. AFTER-TREATMENT.

a. *Clearing.* As soon as the acetic fermentation is complete, that is, when all the alcohol but 1 per cent to 2 per cent has been converted into acetic acid, all bacterial or other fermentative action should be stopped. The vinegar, as it comes from the casks or other acetifying vessels, will be nearly clear if it has been made from clear wine. In this case it may be used immediately without further treatment. It does not, however, attain its finest qualities until it has been aged. In any case, if not quite free from perceptible cloudiness it should be filtered. Bag, tissue, or pulp filters may be used, providing they are so constructed that the vinegar does not come in contact with any metal except pure tin in its passage.

b. *Decoloration.* Vinegar will be generally a little lighter in color than the wine from which it is made. If this is red wine, however, it will still be too dark for commercial purposes. Dark and red vinegar may be decolorized by means of animal charcoal. This charcoal should be pure and tasteless. That specially prepared for the decoloration of pink wines is the best. It is treated with acid, thoroughly washed with water and kept in the form of a moist paste. It varies very much in its decolorizing power and a preliminary test should be made to determine the amount to use. From 2 to 6 pounds for 100 gallons will usually be necessary according to the amount of color to be destroyed and the decolorizing power of the sample. The charcoal is thoroughly stirred up in the vinegar just before filtration. As charcoal diminishes the flavor and quality to some extent, it is better to decolorize the wine before acetification if white vinegar is required.

The color may be too light, in which case, it may be brought to any required depth by the use of a little caramel or burnt sugar.

c. *Pasteurization.* Strong, clear, well made vinegar may be stored in casks in a cool place until ready for use. Any unfavorable conditions of temperature or handling are, however, liable to depreciate its quality and strength.

This depreciation is due to the action of vinegar bacteria and other organisms. If the vinegar is to be aged, therefore, it is safer and better to pasteurize it as soon as acetification and clearing are complete. This is done by heating momentarily to 140° F. to destroy all organisms in the liquid. The barrels into which the sterilized vinegar passes should be freshly steamed before use. Any of the ordinary forms of pasteurizers may be used, providing all surfaces with which the vinegar comes in contact consist of pure tin or other metal attacked with difficulty by acetic acid. The vinegar should come out of the pasteurizer cool and the receiving barrel should be completely filled, bunged tight and stored in a cool cellar.

d. *Aging.* The aging of vinegar is very similar in its purpose and effects to the aging of wine. Stored under proper conditions, the quality of the vinegar improves very much for months, acquiring its maximum quality in one or two years. It is only by aging that it acquires the special aroma which distinguishes good wine vinegar from all others.

The clear, pasteurized vinegar, placed in sterilized, tightly-bunged casks, is stored immediately in a cool cellar where the temperature is fairly uniform. It is not necessary to rack it or draw it off more than once in six months as good vinegar should deposit but little sediment. If a large quantity of sediment is produced, it is usually a sign of unfavorable bacterial changes.

e. *Fining, Filtering and Bottling.* When a wine vinegar has been brought to perfection by careful manufacture and sufficient aging, it should be bottled. Only in this way can it usually be sold for a price commensurate with its quality and capable of giving a profit on the cost of preparation.

Before bottling it must be perfectly bright. The requisite brightness may be obtained by filtration or fining. Vinegar is somewhat more difficult to fine than wine and the best results are obtained by the use of isinglass. This is used at the rate of from one half to three fourths of an ounce of isinglass to 100 gallons of vinegar.

The isinglass is cut into small pieces and soaked for twelve to twenty-four hours in a little water containing acetic or tartaric acid equal in weight to the isinglass used. When thoroughly soft it is then rubbed several times through a fine sieve, gradually adding a little more water until a perfectly fluid liquid is obtained. This fluid is then well mixed with a little vinegar and thoroughly stirred into the cask. With some vinegars it is necessary to add a little tannin, from one half to one seventh the amount of the isinglass used. This tannin should be added at least twenty-four hours before the finings.

When the finings have settled and the vinegar is perfectly bright it is ready for bottling. The bottles after filling and corking should be pasteurized by heating in a water bath to 140° F. Vinegar treated in this way will keep for years without deteriorating.

X. DISEASES.

Vinegars may show various defects, some of which are due to imperfections of the raw material and others to mistakes or accidents during the manufacture. The latter are known as diseases.

a. *Secondary fermentation.* The only fermentations which should take place in vinegar making are the yeast fermentation by which the sugar is changed into alcohol and the bacterial fermentation by which the alcohol is changed into acetic acid. Other fermentations may

occur, however, before, during or after these, and are all to be avoided as harmful. The injurious fermentations of grapes and wine are discussed in Bulletin 213.

As already pointed out the true, useful vinegar bacteria themselves, under certain circumstances, produce injurious fermentations. The bacteria of the acetifying film gradually sink as they grow old or are disturbed by shaking. They accumulate at the bottom of the liquid and form a gelatinous mass or zooglea. In this mass, which is called *"mother of vinegar,"* the action of the bacteria is very different from that of the surface film. They are deprived of oxygen and can not therefore, produce acetic acid. On the contrary, they destroy acetic acid, produce substances of disagreeable tastes and odors and in time may putrefy and destroy the flavor entirely.

The formation of the *"mother"* is delayed by using only clear wine and by avoiding all unnecessary disturbances of the film. Before it forms in any considerable amount the casks or vats should be emptied, cleaned and started afresh.

Towards the end of the acetic fermentation the vinegar bacteria may become harmful in another way. With the exhaustion of the alcohol the bacteria are obliged to attack the acetic acid. This they may do, under favoring conditions, so vigorously that 2 or 3 per cent of acetic acid may disappear in a few weeks. In a rapid process generator this loss may occur even in a few hours. Finally, the vinegar bacteria may destroy all the acetic acid. This destruction of the acetic acid does not occur until the alcoholic contents of the liquid have fallen nearly to 1 per cent and is immediately stopped by the addition of a new supply of wine. It is prevented by drawing off the vinegar into full, tightly closed casks with or without pasteurizing as soon as the alcohol has fallen below 2 per cent.

Other bacteria may produce injurious changes at the beginning before the vinegar bacteria have taken possession of the liquid. Their action is prevented by a preliminary acetification of the wine by means of an addition of 10 per cent of good vinegar, by prompt starting of the acetic fermentation by means of a strong culture of vinegar bacteria and, when necessary, by pasteurizing the wine before use.

Injurious bacteria may also attack the vinegar towards the end of the fermentation, producing putrid odors. These are prevented by prompt removal to the storage casks as soon as the acetic fermentation is complete and by pasteurizing at 140° F. or by running into barrels in which a stick of sulfur has been burned.

Mycoderma vini is a mold growing as a surface film like the vinegar bacteria. It attacks the alcohol, breaking it up into water and carbonic acid. If abundant it may destroy so much alcohol as to make

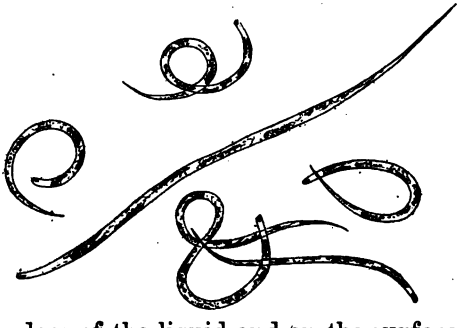
the wine unfit for vinegar. It is most troublesome on wines rich in albuminoids and extractive matters, especially those containing a remnant of unfermented sugar. It is controlled by the methods recommended for injurious bacteria and is less liable to occur if the wine is well fermented, not too young, and clear when used.

b. *Blackening.* Vinegars, after making, will often turn cloudy by the formation of a fine blackish precipitate on exposure to the air. This may be due to the same *oxydase* which produces the same trouble in wine and is cured in the same manner by a light sulfuring. (See Bulletin 213.)

It may also be caused by placing the vinegar in insufficiently cleaned new casks from which it extracts tannic substances which blacken on contact with the air. Contact with iron has the same effect. The acetic acid attacks the iron and forms colorless ferrous salts which change to dark-colored ferric salts on exposure to the air.

The tannins may be removed by treatment with gelatine and filtering through animal charcoal. The iron salts should first be oxydized by aeration and then removed by fining and filtration. The addition of a minute quantity of citric acid will prevent the recurrence of the trouble in the latter case.

c. *Animal parasites.* One of the commonest and most troublesome diseases of vinegar is caused by a nematode worm, the *"vinegar eel."* These are minute wormlike animals which can be seen easily under the microscope with a slight magnification and even with the unaided eye by holding the vinegar before a bright light in a small glass.



They may occur in the vats and generators or even in the finished vinegar. They accumulate most numerously around the edges of the liquid and on the surface film. They interfere with the acetification by destroying this film and causing it to sink. When numerous they are not only disgusting in themselves but are the cause of a putrid fermentation that may completely spoil the vinegar.

They are easily removed from the finished vinegar by filtration followed by pasteurization or sulfuring and fining. In the acetifying vats they are more difficult to control. An infected vat or cask should be emptied as soon as discovered, washed with boiling water and heavily sulfured. The source of the first infection is generally river or surface water.

Unless the vinegar factory is kept clean, *vinegar mites* may appear in large numbers and become troublesome. They are minute arachnids related to the sugar mites, and often accumulate in moist places around the vinegar casks or generators. They may even enter these, and, if numerous, may spoil the vinegar. They are more easily controlled than the vinegar eels and can be destroyed with hot water. They may be prevented from entering the casks by painting a ring of turpentine or kerosene oil around the openings.

Vinegar flies are also sometimes troublesome, especially in warm weather. They breed around the openings of vinegar containers and wherever they can find vinegar exposed to the air. If numerous, the maggots they produce may get into the vinegar and much deteriorate its quality. They can be controlled by cleanliness and by avoiding the spilling of vinegar and the leaking of casks. It is sometimes necessary to screen the openings of casks and generators with mosquito nettings.

XI. OUTLINE OF THE OPERATION OF VINEGAR MAKING.

A. *Gathering the grapes.*

The better the grapes, the better the vinegar. Grapes suitable for making good wine will make good vinegar. The grapes should be ripe and show (in California) from 20° B. to 23° B. They should be gathered and handled when cold or cooled by exposure to the night air before crushing.

B. *Crushing the grapes.*

As soon as possible after gathering, the grapes should be crushed. The crushing should be thorough but the seeds should not be broken. Any of the ordinary forms of roller crushers are suitable. Small hand crushers are made, suitable for small-scale operations.

C. *Extraction of the juice.*

The grapes should pass from the crusher into an open vat where fermentation is allowed to commence. A culture of pure wine yeast is very useful in insuring a prompt and good fermentation. After twenty-four hours of fermentation (shown by the escape of gas bubbles) the juice should be separated by means of a press. The pomace in the press after the first pressing may be treated with water and pressed again if the grapes are sweet enough, and the juice thus obtained may be mixed with the rest. No more water should be used than will bring the mixed juices down to 18° or 20° B. A home-made lever press is efficient and satisfactory where small quantities of grapes are handled. When red grapes containing a large amount of coloring matter are used, it may be necessary to press out the juice immediately after crushing and without the preliminary twenty-four hours of fer-

mentation. The yield of juice will in this case be from 10 to 20 per cent less.

D. *Alcoholic fermentation.*

The transformation of the grape juice into wine may take place in open vats of any convenient size up to 1,000 gallons or in the casks which are to be used later for the acetic fermentation. In the latter case, the casks should be well cleaned to remove all vinegar.

Fermentation will commence spontaneously, but better results are obtained by using pure wine yeast. This yeast must be obtained from a reliable source. Bakers', brewers' or distillers' yeasts do not give good results and may spoil the vinegar.

The maximum temperature of the fermenting juice should not exceed 93° F. and if kept below 86° F. the results are better. In cold weather, it may be necessary to warm the fermenting room. In hot weather, the temperature requires no attention where very small casks or vats are used. With large casks or vats artificial cooling is sometimes necessary.

In from four to seven days all sugar perceptible to the taste should have disappeared and the juice has then become wine.

E. *Treatment of the wine.*

As soon as fermentation is over the wine should be placed in casks which should be filled completely and bunged up tight as soon as gas has ceased to be given off. At the end of two or three weeks most of the yeast and other solid matter will have settled into the lees. The clear wine should then be drawn off the sediment. It may be drawn directly into the vinegar casks and the acetic fermentation started immediately. If this is not convenient, it may be drawn into clean storage casks and kept for as long as desired. These storage casks should be kept quite full and the wine racked from the sediment which will form, every two or three months. At any time after it is clear, the wine may be turned into vinegar. The vinegar casks may be used for storage by closing the air vents with wooden bungs.

F. *Acetic fermentation.*

Before placing in the vinegar casks or generators, the wine should be free from all gross sediment. If very cloudy, it should be filtered. If too red, it is best decolorized before acetification. The best results are obtained by pasteurizing the wine before placing in the vinegar casks.

Enough good vinegar should be added to the wine to increase its volatile acidity to at least 1 per cent. One gallon of strong vinegar to nine gallons of wine will suffice. In replenishing the wine in a vinegar cask in operation, the vinegar remaining in the cask is sufficient. The vinegar added (if not pasteurized) supplies the necessary bacteria which are the cause of acetification.

The temperature should be fairly uniform and if possible between 65° F. and 75° F. Below 65° F. the process is unnecessarily slow; above 75° F. the quality suffers and the loss from evaporation is excessive. With rapid process generators, higher temperatures may be used, about 86° F. being the most favorable. In the slow process, the temperature of the fermenting vinegar will be that of the room. In the rapid process it will be 20° to 30° F. higher.

There must be free access of air to the surface of the liquid in the casks, but vinegar flies and dust must be excluded. After from one to three months the acetic fermentation should be complete in the slow processes, though this time may be much prolonged if the temperature of the vinegar room is too low.

G. *After-treatment and aging.*

The end of the acetic fermentation is determined by tasting and by measuring the amount of acetic acid present by means of an acidometer. Tests should be made at intervals in order to follow the progress of the fermentation. When the acidometer shows that the vinegar has approximately the maximum acidity to be expected from the sugar contents of the original must or from the alcoholic percentage of the wine, the process is finished. If a second test several days or weeks after the first shows a diminution of acidity, the process has gone too far. In either of these cases the vinegar should be taken out of the fermenting casks and all bacterial action stopped. This is done by placing it in completely-filled, tightly-bunged casks stored in a cool cellar. Pasteurization of the vinegar at 140° F. before placing in the storage casks is to be recommended.

In storage casks the vinegar requires no treatment except filling up and, if it is kept more than a few months, one or two rackings. The rackings should be done with as little exposure to the air as is practicable.

H. *Preparation for sale.*

The vinegar should be perfectly bright and free from bacteria when sold. This is accomplished by fining or filtering and when bottled by pasteurizing after bottling.

XII. TESTS OF USE TO VINEGAR MAKERS.

The vinegar manufacturer should have some reliable means of determining the amount of sugar in the grapes and of alcohol in the wine. He should also be able to test his vinegar during the process of acetification in order to determine the proper time for stopping the process.

NOTE.—Acetic acid attacks most metals very readily, forming poisonous salts. Pure tin and certain alloys consisting principally of tin are not attacked. All filters, presses, buckets, etc., used for handling vinegar should be of wood or earthenware. The hoops of buckets, tubs, or casks, and all metallic surfaces in the factory, should be well painted or varnished to protect them from the vinegar fumes which would otherwise quickly corrode them.

a. *Sugar.* The ordinary Balling saccharometer commonly used by ine makers is equally suitable for the vinegar maker. It consists of hydrometer or spindle (s) with a long neck graduated in degrees.

In using, it is floated in the solution (grape juice) to be tested contained in a long narrow glass cylinder. The more deeply it sinks, the ess sugar the solution contains. By noting the degree vhich corresponds to the surface of the liquid we have ı sufficiently accurate measure of the sugar contents. This degree represents the percentage of sugar by weight in a pure sugar solution of the same specific gravity as the juice. As this juice contains other substances beside sugar, the real sugar contents will be from .5 per cent to 2.5 per cent less than the indicated Balling per cent or degree. These non-saccharine substances will vary in different grapes, so that the Balling degree gives us only an approximation of the amount of sugar present. This is quite close enough for the purposes of the vinegar maker, however, and by reference to Table VI on page 350 he can determine very closely how much alcohol and how much acetic acid he should obtain by fermentation. This will enable him to make the calculations necessary in blending juices of various degrees of sweetness and in adding water to juices containing too much sugar.

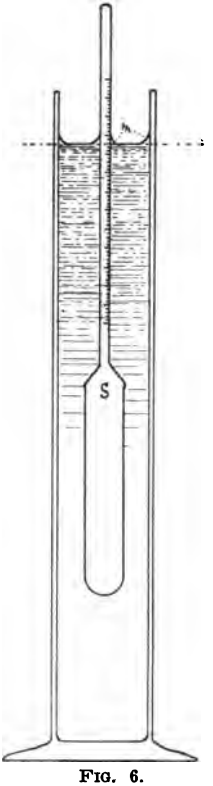


FIG. 6.
Method of reading a hydrometer.

The accuracy of the test depends on the care with which it is made. The juice should be quite fluid, that is, it should not contain enough floating solid matter to make it thick or slimy, otherwise the resting point of the saccharometer will be uncertain.

The test should be made before the commencement of fermentation, otherwise the alcohol formed and the bubbles of carbonic acid gas coming off may make the reading completely unreliable.

The saccharometer should be cleaned and dried each time before using. When greasy it should be cleaned with a little alcohol or bicarbonate of soda and warm water. It should be handled with clean dry hands or a clean cloth. Any grease or juice or water on the stem may notably change the result.

The reading should be made at the true level of the liquid as indicated in Fig. 6. By capillarity, the liquid in contact with the glass rises more or less above the true surface, forming what is known as the *meniscus* (m.) The bottom of this meniscus is the true surface.

The specific gravity of the juice varies with the temperature. For this reason the juice must be brought to the standard temperature for

which the saccharometer is adjusted (usually 60° F.) or a temperature correction made. This correction is very nearly .1 per cent for every 3 degrees Fahrenheit above or below the standard. If the temperature is higher, this correction must be added, if lower, subtracted.

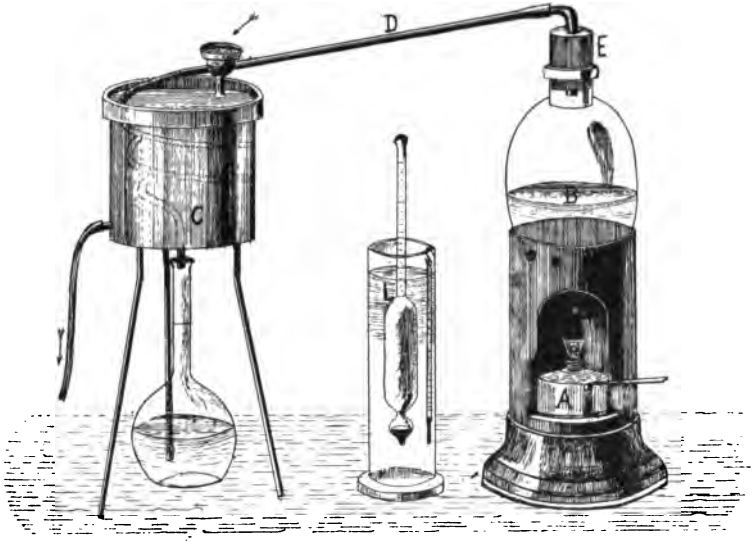


FIG. 7.—Still for Alcohol Tests.

b. *Alcohol.* When the fermentation of the must is complete the sugar has disappeared and has been replaced by alcohol which remains in the liquid and by carbonic acid gas which passes into the atmosphere. The end of the fermentation is determined accurately enough for our purpose by taste. When the wine is dry, that is, when no sweet taste can be perceived, the sugar has practically all disappeared. The wine should then show an amount of alcohol corresponding to the original Balling degree as shown in Table VI on page 350.

The actual amount of alcohol can be determined by means of a *small still* (Fig. 7). This still consists of a small glass or copper vessel in which the wine is boiled. The vapors given off are condensed by passing from the boiler, through a spiral tube immersed in cool water, and the liquid runs into a measuring flask.

To make a determination of alcohol, 100 cubic centimeters of the wine are measured exactly in the measuring flask. The liquid is then poured into a beaker and its acidity neutralized by adding a solution of caustic soda or potash. The point of neutralization is determined by means of a piece of red litmus paper. The neutralized wine is then poured into the boiler together with a little pure water with which the flask and beaker have been rinsed. The wine should be as near 60° F. as practicable when measured.

The boiler is now conected with the condenser, and the measuring

flask, after careful and thorough rinsing, is placed to catch the distillate. All connections must be perfectly tight. The boiler should be about one third full.

The heating should be gentle at first and more rapid later but any spurting of liquid into the condenser must be avoided. The water in the condenser should never exceed 70° F. When half of the liquid has distilled over the process may be stopped. After cooling to 60° F. water is added to the distillate in the measuring flask until the original volume is reached. The liquid is then poured into the cylinder and the degree of alcohol read off by means of the floating alcoholimeter.

The same care is necessary in reading the alcoholimeter as already described for the Balling saccharometer. (See page 363.) The temperature of the liquid should be as near 60° F. as possible, and any variation from this temperature allowed for by consulting the table of temperature corrections furnished with the still.

In determining the alcohol in vinegar, all the acidity must be neutralized before distillation. For this purpose the caustic soda solution must be very concentrated or the volume of the liquid necessary to add will be too great for the boiler. The 1 or 2 per cent of alcohol which it is desirable to leave at the end of the acetic fermentation can be determined with sufficient accuracy by this means.

c. *Acetic acid.* To determine exactly the strength of the vinegar, that is the exact amount of acetic acid it contains, requires time, skill and somewhat complicated apparatus. To determine its strength with sufficient accuracy for manufacturing and commercial purposes is very simply done by means of some of the forms of "vinegar testers."

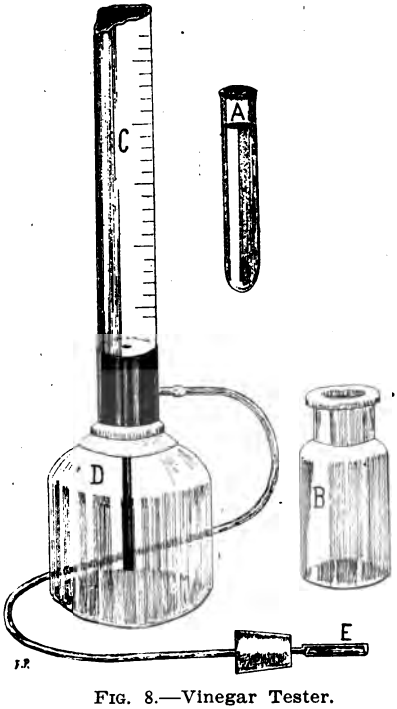


FIG. 8.—Vinegar Tester.

In the form shown in Fig. 8 the acetic acid is determined by the volume of gas given off by bicarbonate of soda when treated with a measured volume of vinegar.

The requisite volume of vinegar is measured in the small glass tube A, and poured into the bottle B. A sufficient amount of bicarbonate is then taken with the spoon E and introduced carefully into the bottle. As soon as the bottle is tightly closed with the cork the bicarbonate is shaken gradually into the vinegar and immediately carbonic acid gas commences to be given off. This gas, passing through the rubber tube, forces the water in the bottle D to rise in the large glass tube C. The

stronger the vinegar the more gas will be given off and the higher the water will rise in the tube C. This tube is marked with numbered lines. By reading the number of the line nearest the level reached by the water and adding the estimated height above or below this line, the strength of the vinegar is obtained directly in per cent. If the vinegar is made from wine .5 per cent must be deducted from the observed reading to allow for the tartaric acid of the wine.

To insure sufficient accuracy with these instruments certain precautions are necessary. The bicarbonate of soda sold for cooking purposes is sufficiently pure. In placing it in the bottle care should be taken that none get into the vinegar until the bottle is securely corked. There must be no leak in the apparatus. This is determined by allowing the column of water to remain for a few minutes in the cylinder after making a determination. If the column does not fall in this time there is no leak of importance.

The instruments are adjusted for water of ordinary temperature. If the water is either very cold or very warm the results are inaccurate. The following table shows some of the variations due to the use of too warm water.

TABLE VII.

Results with vinegar tester compared with accurate analyses.

Vinegar.	True acidity.	Reading of vinegar tester, at—		
		65° F.	75° F.	86° F.
1	3.02	2.9	3.2	3.3
2	4.55	4.4	4.6	4.7
3	6.50	6.4	6.6	6.9
4	7.04	7.0	7.4	7.7
5	8.49	8.5	8.7	9.1
6	10.15	10.1	10.7	11.2

No temperature correction is possible as the variations are irregular. At 65° F. as shown in the table the determinations agree very closely with the results of more accurate tests. There are other sources of error such as the atmospheric pressure, the pressure of the column of water and the absorption of gas by the water, but they are none of them large enough to be of any significance to the vinegar maker.

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