Extension Bulletin No. 149 October, 1935

HONEY VINEGAR

FREDERICK W. FABIAN

MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

EXTENSION DIVISION

R. J. Baldwin, Director

Printed and distributed in furtherance of the purposes of the co-operative agricultural extension work provided for in Act of Congress, May 8, 1914, U. S. Department of Agriculture and Michigan State College of Agriculture and Applied Science cooperating.

Directions for Making Good Honey Vinegar

1. Use a good clean barrel or container properly prepared.
2. Unmarketable honey such as combs from brood combs, honey-dew honey, coniferous honey, washings from extractor, honey from hives infected with foul-brood, etc., may be used if properly sterilized before using.
3. Prepare starters of vinegar yeast and vinegar bacteria according to directions several weeks before the main honey solution is prepared.
4. Prepare the honey solution according to formula 1 or 2 using a saccharimeter to determine the correct percentage of sugar present.
5. Sterilize the honey solution by boiling ten minutes or longer to kill all undesirable micro-organisms.
6. Inoculate with pure cultures of vinegar yeast and when this fermentation has ceased, add the vinegar bacteria as directed.
7. Fill the barrel not over two-thirds full and provide for plenty of air by boring one-half inch holes in each end of the barrel. Cover all openings with several layers of cheese cloth to keep out flies and undesirable micro-organisms. (See Fig. 1.)
8. Store the barrel in a room having a temperature from 65° to 75° F.
9. Do not disturb the film of vinegar bacteria.
10. After the vinegar has been made, it will keep indefinitely if properly stored as directed.
    Vinegar will be tested *gratis* at this laboratory.

HONEY VINEGAR

FREDERICK W. FABIAN

The making of vinegar from wine is an age-old art. Vinegar is mentioned in the Old Testament, and Hippocrates used it as a medicine. Pliny relates that Cleopatra, to gain a wager that she could consume at a single meal the value of a million sesterces, dissolved pearls in vinegar which she drank.

In 1732, Boerhave, a Dutch chemist and physician, made known a method by which vinegar could be made quickly. About a century later, 1823, Schützenback introduced the quick method by which process most of the vinegar has since been made.

It remained, however, for Pasteur, the founder of Bacteriology, to establish the true nature of vinegar making and place it upon a scientific basis. He showed that certain microorganisms, known as yeasts, caused the conversion of sugar solutions to alcohol and that the alcohol in turn was converted into acetic acid by an entirely different group of microorganisms, called bacteria.

Definition and Laws

We, therefore, may define vinegar as a condiment produced by the successive alcoholic and acetic fermentation of sugar solutions by certain yeasts and bacteria.

The law in Michigan defines vinegar as follows: (Act 384, Sesssion Laws 1913, C. L. 6459, Sec. 2) "The word 'vinegar' as used herein is limited to a water solution of acetic acid derived by the alcoholic and subsequent acetous fermentations of fruits, grain, vegetables, sugar or syrups, and if not distilled must carry in solution the extractive matter derived solely from the substances indicated on the label as its source."

Sugar Vinegar—(Act 384, Session Laws 1913, C. L. 6461, Sec. 4) "All sugar vinegar sold or exposed for sale as such shall be strictly and distinctly fermented from sucrose, molasses or refiner's syrup."

Other parts of the law pertaining to the manufacture and sale of vinegar in general follow: (Act 384, Session Laws 1913, C. L. 6463, Sec. 6) "No vinegar shall be sold or exposed for sale in which foreign substances, drugs, or acids shall have been introduced. No vinegar shall contain any artificial coloring matter, and all vinegar shall have an acidity of not less than four per cent by weight of absolute acetic acid. If vinegar contains any artificial matter, or less than the required amount of acidity, it shall be deemed to be adulterated."

(Act 384, Session Laws 1913, C. L. 6464, Sec. 7.) "All vinegar made by fermentation and oxidation without the intervention of distillation shall be branded 'fermented' vinegar, with the name of the fruit or substance from which such vinegar has been made."

(Act 384, Session Laws 1913, C. L. 6465, Sec. 8.) "All vinegar made by acetous fermentation of dilute distilled alcohol shall be branded 'distilled' vinegar, together with the name of the substance or substances from which it is made, and all vinegar made wholly or in part from distilled vinegar shall be conspicuously labeled 'distilled vinegar'."

(Act 384, Session Laws 1913, C. L. 6465, Sec. 9.) "Whoever violates any of the provisions of this act shall, upon conviction, be punished by a fine of not more than two hundred dollars or imprisonment in the county jail not to exceed six months or both such fine and imprisonment in the discretion of the court."

Preparation of the Barrel

The preparing of the container for the honey solution is a very important step in the making of good honey vinegar. Too often barrels are used that are dirty and unfit for use. The barrel should be in good physical condition. It should be thoroughly rinsed and soaked for several days before the honey solution is added. To clean the barrel fill it with clean water. Add two tablespoons full of chloride of lime and allow to stand half a day or longer. Then thoroughly rinse to get rid of all traces of the chloride of lime. This will kill all molds, yeasts and bacteria and leave the barrel sweet and clean.

Another good way is to lower a container containing burning sulphur into the barrel. Cork it tightly and allow to stand a day or so. The barrel should be thoroughly rinsed before and after this procedure. After the barrel is clean, the next step is to prepare the honey solution.

Kind of Honey Suitable for Vinegar Making

One of the main reasons for making honey vinegar is to provide an outlet for honey which would otherwise be lost. In many industries the margin of profit is realized by utilizing the by-products. Therefore, if the apiarist can convert what would otherwise be a loss or unsalable product into a salable one and realize thereby, he profits.

Unmarketable honey such as that from hives infected with American or European foul-brood, honey-dew honey, coniferous honey, honey from brood combs, washings from the extractor, etc., any or all of these, may be used for honey vinegar. The honey solution should be sterilized of course, to kill all undesirable microorganisms.

Composition of Honey

In order to make honey vinegar intelligently the composition of honey should be known; this differs somewhat in different parts of the United States, particularly in respect to the water content. Browne analyzed a large number of samples of honey and found the chemical compositions that are reported in Table 1.

The data in Table 1 show that honey has a large amount of sugar, approximately seventy per cent or over. The larger part of the sugar is present as invert sugar (glucose and fructose) and a smaller part as sucrose (cane sugar). Inasmuch as it would be impossible to make vinegar from so concentrated a sugar solution it is necessary to dilute the sugars to a concentration compatible with the life of the yeasts. Some care is necessary in diluting the honey. If the honey is made too weak, the yeasts will not make

COMPOSITION OF AMERICAN HONEYS

Table 1. (Bulletin 110, U. S. Bur. of Chem.)

Kind of honey	No. of samples	Polarization 20° Deg. V	Water (percent)	Invert sugar (percent)	Sucrose (percent)	Ash (percent)	Dextrin (percent)	Undetermined (percent)
Alfalfa	8	−15.10	16.56	76.90	4.42	0.07	0.34	1.71
Apple	2	− 8.55	15.67	73.16	3.69	0.08	0.39	7.01
Orange	1	−15.50	16.99	77.57	0.60	0.08	0.45	4.31
Sweet Clover	4	−17.61	17.49	76.20	2.24	0.12	0.45	3.50
Raspberry	2	−18.85	18.08	74.52	1.42	0.05	0.56	5.37
Mangrove	2	−22.80	19.18	76.49	1.73	0.20	0.56	1.84
White Clover	15	−13.10	17.64	74.92	1.77	0.07	0.82	4.78
Cotton	2	−17.50	18.35	75.43	1.38	0.21	1.10	3.53
Buckwheat	2	−16.80	18.54	76.85	0.03	0.09	1.22	3.27
Dandelion	2	−12.40	14.54	76.84	3.12	0.16	1.23	4.11
Tupelo	2	−24.00	17.34	72.24	3.01	0.07	2.08	5.26
Golden Rod	3	−12.33	19.88	72.02	1.68	0.16	2.18	4.08
Willow	1	−12.80	19.11	71.47	0.95	0.35	2.75	5.37
Basswood	6	− 8.90	17.42	75.14	0.72	0.20	3.07	3.45
Sumac	3	−10.47	18.85	71.11	0.92	0.44	3.57	5.11
Yellow Wood	1	− 7.00	18.12	71.51	0.19	0.39	4.10	5.69
White Wood	1	− 4.90	17.47	69.02	2.72	0.51	5.59	4.69
Poplar	1	+ 3.60	17.02	65.80	3.10	0.76	10.19	3.13
White Oak	1	+11.00	13.56	65.87	4.31	0.79	10.49	4.98
Hickory	1	+ 7.80	16.05	65.89	2.76	0.78	12.95	1.57

sufficient alcohol to produce good vinegar. On the other hand if more sugar is added than the yeasts can convert into alcohol, then it is wasted as far as vinegar making is concerned.

The percentage of ash in honey, as shown in Table 1, averages about 0.28. In cider it averages about 0.30, while that of grape juice averages about 0.40. To the casual observer this seems insignificant but it must be remembered that the yeasts and bacteria that make honey vinegar cannot grow without minerals, although very small amounts suffice.

Since honey contains the sugars in too concentrated a form, it must be diluted. If this is done, the minerals are diluted to an extent insufficient for the growth of the organisms. They, therefore, must be replaced with suitable salts. For this reason it is desirable to use a formula that is known to produce good vinegar. Two such formulae follow:

Formula No. 1:

Liquid or extracted honey	40 to 45 lbs.
Water	30 gals.
Potassium tartrate	2 oz.
Ammonium phosphate	2 oz.

Formula No. 2:

Liquid or extracted honey	40 to 45 lbs.
Water	30 gals.
Ammonium chloride	4 oz.
Potassium bicarbonate	2 oz.
Sodium phosphate	2 oz.

The diluted honey solution containing the minerals is known as "stock" and should register 15 per cent sugar by the saccharimeter.

Substituting Cider for Chemicals

Very excellent results have been secured by the addition of chemicals to dilute honey in vinegar making. However, the chemicals may not always be accessible or easily obtained. For this reason experiments have been conducted in which cider was substituted for the chemicals. In these experiments the ratio of cider to the honey solution that gave the best results was 1:4. If more cider was used, the finished product lost the characteristics of honey vinegar. When cider was used in lesser amounts, there was not sufficient mineral food and the fermentation was slow. This ratio of cider made from most varieties of apples contains sufficient acid to form a more favorable medium for the growth of the yeasts.

Formula No. 3:

Liquid honey	30 to 35 lbs.
Cider	7 to 8 gals.
Water	18 to 22 gals.

The resulting solution should always be tested with a saccharimeter which should register approximately 15 per cent. It is necessary to test the solution since the amount of sugar present in both the honey and cider may vary. A great many different lots of cider were tested and the Balling reading varied from 10.5 to 12.5. The moisture content of honey is also variable. The resulting acidity of the solution is usually between 0.3 and 0.4 per cent acid, calculated as acetic acid.

A specific example of how the formula works in practice is as follows:

32 lbs. of honey + 18 gallons of water gave a Balling reading of 17. To this was added 8 gallons of cider with a Balling reading of 12 and a titratable acidity of 0.6 per cent, as acetic acid. The resulting solution had a Balling reading of 14.5 and a titratable acidity of 0.4 per cent. When fermented with a pure culture of wine yeast, there was produced 6.8 per cent alcohol. At the end of the acetic fermentation, it titrated 8.2 per cent acid, calculated as acetic.

The Saccharimeter

The saccharimeter is an instrument used to measure the amount of sugar in a solution. It is a hydrometer, reading directly or indirectly in percentages of sugar. Its use is almost essential to the production of honey vinegar in large amounts. There are several makes on the market. The Brix or Balling's hydrometers read directly in percentages of sugar. Beaume's hydrometer scale readings do not read directly and Table 2 should be consulted if this type is used.

For diluting and making the honey solutions to the desired sugar strength the following equipment should be available.

1 Brix hydrometer for sugar	$0.75
1 Hydrometer jar	.50
1 Thermometer (very accurate)	1.80

The above equipment may be purchased at any scientific supply house.

Table 2. Comparative readings on the Brix (or Balling*) and Baume Saccharimeter, with the approximate percentages of alcohol and acetic acid which may be obtained theoretically in the vinegar fermentation.

Per cent cane sugar by wt. or degrees Brix or Balling.	Degrees Baume	Theoretical percentage of		Per cent cane sugar by wt. or degrees Brix or Balling.	Degrees Baume	Theoretical percentage of		Per cent cane sugar by wt. or degrees Brix or Balling.	Degrees Baume	Theoretical percentage of	
		Alcohol	Acetic acid			Alcohol	Acetic acid			Alcohol	Acetic acid
0.0	0.0	0.00	0.00	5.0	2.8	2.69	3.50	10.0	5.7	5.38	7.00
0.1	0.1	.....	.....	5.1	2.9	.....	.....	10.1	5.7	.....	.....
0.2	0.1	.....	.....	5.2	2.95	.....	.....	10.2	5.8	.....	.....
0.3	0.2	.....	.....	5.3	3.0	.....	.....	10.3	5.8	.....	.....
0.4	0.2	.....	.....	5.4	3.1	.....	.....	10.4	5.9	.....	.....
0.5	0.3	0.27	0.35	5.5	3.1	2.96	3.85	10.5	5.9	5.65	7.35
0.6	0.3	.....	.....	5.6	3.2	.....	.....	10.6	6.0	.....	.....
0.7	0.4	.....	.....	5.7	3.2	.....	.....	10.7	6.1	.....	.....
0.8	0.45	.....	.....	5.8	3.3	.....	.....	10.8	6.1	.....	.....
0.9	0.5	.....	.....	5.9	3.35	.....	.....	10.9	6.2	.....	.....
1.0	0.6	0.54	0.70	6.0	3.4	3.23	4.20	11.0	6.2	5.92	7.70
1.1	0.6	.....	.....	6.1	3.5	.....	.....	11.1	6.3	.....	.....
1.2	0.7	.....	.....	6.2	3.5	.....	.....	11.2	6.3	.....	.....
1.3	0.7	.....	.....	6.3	3.6	.....	.....	11.3	6.4	.....	.....
1.4	0.8	.....	.....	6.4	3.6	.....	.....	11.4	6.5	.....	.....
1.5	0.85	0.81	1.05	6.5	3.7	3.50	4.55	11.5	6.5	6.19	8.05
1.6	0.9	.....	.....	6.6	3.7	.....	.....	11.6	6.6	.....	.....
1.7	1.0	.....	.....	6.7	3.8	.....	.....	11.7	6.6	.....	.....
1.8	1.0	.....	.....	6.8	3.9	.....	.....	11.8	6.7	.....	.....
1.9	1.1	.....	.....	6.9	3.9	.....	.....	11.9	6.7	.....	.....
2.0	1.1	1.08	1.40	7.0	4.0	3.77	4.90	12.0	6.8	6.46	8.40
2.1	1.2	.....	.....	7.1	4.0	.....	.....	12.1	6.8	.....	.....
2.2	1.2	.....	.....	7.2	4.1	.....	.....	12.2	6.9	.....	.....
2.3	1.3	.....	.....	7.3	4.1	.....	.....	12.3	7.0	.....	.....
2.4	1.4	.....	.....	7.4	4.2	.....	.....	12.4	7.0	.....	.....
2.5	1.4	1.35	1.75	7.5	4.25	4.04	5.25	12.5	7.1	6.83	8.75
2.6	1.5	.....	.....	7.6	4.3	.....	.....	12.6	7.1	.....	.....
2.7	1.5	.....	.....	7.7	4.4	.....	.....	12.7	7.2	.....	.....
2.8	1.6	.....	.....	7.8	4.4	.....	.....	12.8	7.2	.....	.....
2.9	1.6	.....	.....	7.9	4.5	.....	.....	12.9	7.3	.....	.....
3.0	1.7	1.62	2.10	8.0	4.5	4.31	5.60	13.0	7.4	7.10	9.10
3.1	1.8	.....	.....	8.1	4.6	.....	.....	13.1	7.4	.....	.....
3.2	1.8	.....	.....	8.2	4.6	.....	.....	13.2	7.5	.....	.....
3.3	1.9	.....	.....	8.3	4.7	.....	.....	13.3	7.5	.....	.....
3.4	1.9	.....	.....	8.4	4.8	.....	.....	13.4	7.6	.....	.....
3.5	2.0	1.88	2.45	8.5	4.8	4.58	5.95	13.5	7.6	7.37	9.45
3.6	2.0	.....	.....	8.6	4.9	.....	.....	13.6	7.7	.....	.....
3.7	2.1	.....	.....	8.7	4.9	.....	.....	13.7	7.75	.....	.....
3.8	2.2	.....	.....	8.8	5.0	.....	.....	13.8	7.8	.....	.....
3.9	2.2	.....	.....	8.9	5.0	.....	.....	13.9	7.9	.....	.....
4.0	2.3	2.15	2.80	9.0	5.1	4.85	6.30	14.0	7.9	7.64	9.80
4.1	2.3	.....	.....	9.1	5.2	.....	.....	14.1	8.0	.....	.....
4.2	2.4	.....	.....	9.2	5.2	.....	.....	14.2	8.0	.....	.....
4.3	2.4	.....	.....	9.3	5.3	.....	.....	14.3	8.1	.....	.....
4.4	2.5	.....	.....	9.4	5.3	.....	.....	14.4	8.1	.....	.....
4.5	2.55	2.42	3.15	9.5	5.4	5.11	5.65	14.5	8.2	7.91	10.15
4.6	2.6	.....	.....	9.6	5.4	.....	.....	14.6	8.3	.....	.....
4.7	2.7	.....	.....	9.7	5.5	.....	.....	14.7	8.3	.....	.....
4.8	2.7	.....	.....	9.8	5.55	.....	.....	14.8	8.4	.....	.....
4.9	2.8	.....	.....	9.9	5.6	.....	.....	14.9	8.4	.....	.....
5.0	2.8	2.69	3.50	10.0	5.7	5.38	7.00	15.0	8.5	8.18	10.50

*The Brix and Balling saccharimeters both read directly in percentages of cane sugar. They may differ, however, in the temperature at which they are to be read.
Adapted from Table 3, Appendix, of C. A. Browne's Handbook of Sugar Analysis (1912).

The readings to be accurate must be made at the temperature indicated on the hydrometer. Care should be taken in reading the hydrometer. It should float freely and not touch the bottom or walls of the cylinder. Adjust the surface of the solution at eye level and read where the true surface of the liquid intersects the scale. This will give you the true reading on the hydro-

meter. Disregard the film of liquid drawn up around the stem due to capillary attraction.

In case the above equipment is not available or you do not desire to adjust the percentage of sugar so accurately, this procedure may be omitted. Simply make the honey solution according to Formula 1, 2, or 3.

Heating the Honey Solution

After the solution has been prepared according to Formula 1, 2, or 3 and tested with the saccharimeter to see if the proper percentage of sugar is present, it should be boiled for ten minutes. This will do two things. First, it will kill all or most microorganisms present which would later cause trouble and, second, it will give a better color to the vinegar.

CONVERTING THE HONEY SOLUTION INTO VINEGAR

The Alcoholic Fermentation

The next step in the making of honey vinegar after the barrel has been cleaned and the honey solution prepared and placed in it, is to inoculate the solution with yeast. For this purpose it is best to use a starter prepared from a pure culture of yeast. The yeast best suited for this purpose is technically known as *Saccharomyces ellipsoideus*. This yeast under suitable conditions will produce 14 per cent or more alcohol. The conversion of sugar into alcohol takes place as follows:

I. $C_{12}H_{22}O_{11} + H_2O +$ *Sacch. ellipsoideus* $= C_6H_{12}O_6 + C_6H_{12}O_6$
Sucrose + Water + Yeast = Glucose + Fructose

The yeast uses the simple sugars (glucose and fructose) as food and gives off alcohol as a by-product which may be represented as follows:

II. $C_6H_{12}O_6 +$ *Sacch. ellipsoideus* $= 2\,C_2H_5OH + 2\,CO_2$
Glucose + Yeast = Alcohol + Carbon Dioxide (gas)

$C_6H_{12}O_6 +$ *Sacch. ellipsoideus* $= 2\,C_2H_5OH + 2\,CO_2$
Fructose + Yeast = Alcohol + Carbon Dioxide (gas)

Inasmuch as honey contains a great deal more glucose and fructose than sucrose, it makes an ideal food for the yeast. The amount of alcohol that should be produced from 100 parts of sugar is theoretically 51 parts. However, actually it is only about 45 to 47 parts because some of the sugar is used by the yeast for other purposes. Thus, if there is 15 per cent sugar in the honey solution, there should be produced about 7 per cent alcohol. The alcoholic fermentation should be completed within three to four weeks, depending upon the conditions.

The Acetic Fermentation

The second fermentation that takes place in vinegar making is known as the acetic fermentation. In this the alcohol, which is produced in the

previous fermentation by yeasts is changed into acetic acid by a bacterium, technically known as *Acetobacter aceti.* The change that takes place may be written as follows:

$C_2H_5OH + O_2 +$ *Acetobacter aceti* $= CH_3COOH + H_2O$
Alcohol + Oxygen + Vinegar bacteria = Acetic acid + Water

In the conversion of alcohol into acetic acid 100 parts of alcohol should yield theoretically 130 parts of acetic acid, but the bacteria use some of the alcohol for other purposes and other bacteria and yeasts which may be present also use some so that the actual yield is only about 120 parts or less. Consequently if 7 per cent alcohol results from the first fermentation we should expect better than 8 per cent acetic acid. That vinegar of this strength can be produced from a 15 per cent honey solution has been demonstrated many times by this Station.

The length of time necessary to complete the acetic fermentation is six months to a year. This depends upon several things, the chief of which is the temperature at which the solution is kept and the amount of air in the barrel. These will be discussed later.

The vinegar bacteria form a smooth, more or less glistening film on the surface of the honey solution. This film is commonly known as "mother of vinegar" *and should never be disturbed under any circumstances.* It is customary to float the film on clean beech shavings to prevent it from sinking. If the bung is large enough, a wooden raft may be constructed to float the film. No nails should be used in constructing the raft. Floating the bacteria is done because the film becomes so heavy as time progresses that the least jar causes it to sink or its own weight may sink it. Once the film has sunken it takes several weeks for a new film to form. This greatly increases the time to make vinegar. Furthermore when the film sinks other bacteria are likely to decompose it and to produce substances of disagreeable tastes and odors which render the vinegar unfit for use.

PREPARATION OF STARTERS

Yeast Starter

The best results are secured in both the alcoholic and acetic fermentations if starters are prepared and added to the main solution in the barrel.

To prepare the yeast starter make a gallon of the honey solution about a week previous to making the main honey solution. Heat the solution to boiling and add to it the culture of pure yeast. Use great care not to get the starter contaminated with molds, other yeasts or bacteria. Detailed instructions are sent with every pure culture from the laboratory for the preparation of the starter. When foaming becomes very active add the starter to the main solution. There are many millions of yeast in this starter and they will multiply and grow very rapidly in the barrel if the proper food is present and the right temperature is maintained.

Bacteria Starter

The vinegar bacteria starter is prepared in a slightly different way. Draw off a quart of the fermented honey solution and place in a two-quart glass-top Mason jar. Fasten the top on to prevent evaporation of alcohol. Instead of heating it to boiling, as in the case of the yeast starter, pasteurize in a suitable container at a temperature of 140° F. for 30 minutes. Cool and inoculate with vinegar bacteria. Replace the top of the jar with clean boiled muslin. Do not disturb this jar. "Mother of vinegar" should appear in the course of a week. If there is no mold present, the starter may be added to the fermented honey solution after the "mother of vinegar" has formed a film 1/16 to 1/8 inch thick. Great care should be exercised in the preparation of these starters so that no contamination is introduced into the main barrel to spoil them. The starter should be floated on a raft as previously described.

OTHER CONSIDERATIONS IN VINEGAR MAKING

Temperature

The temperature at which the honey solution is kept is very important; it should be between 65° and 75° F. If it is very high, the yeasts do not grow well and the alcohol is evaporated too rapidly. If it is very low, the yeast grows very slowly and a long time is required for completion of the alcoholic fermentation and a still longer time for the acetic fermentation. At the ideal temperature it is possible to make good vinegar in nine months to a year. With low temperatures it may take as long as three years, and in

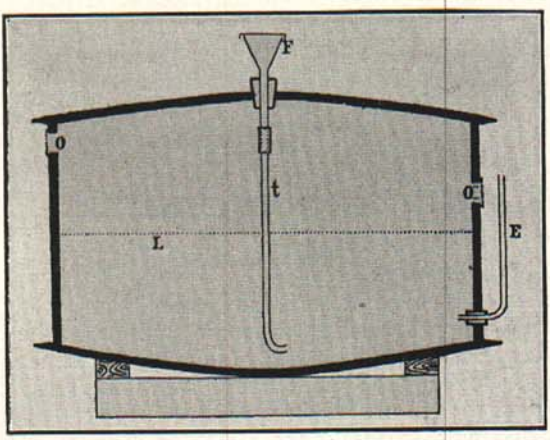

Fig. 1. Vinegar Barrel. L. surface of liquid; O, O, opens for circulation of air; F, funnel inserted through stopper in bung-hole, and t, glass tube fastened to funnel with rubber tubing, for introducing new supplies of fermented honey without disturbing the surface film; E, glass tube to show level of liquid and for drawing off vinegar. Keep this plugged with cotton to prevent the entrance of insects. (Fig. 142 from Marshall's Microbiology, 1917.)

many cases vinegar is never formed. During these long fermentations micro-organisms causing off-fermentations and vinegar disease enter and spoil the product.

Air

The circulation of air may be increased by boring 1/2 inch holes in each end of the barrel and covering them with several layers of cheese cloth. The barrel should be placed on its side and never be filled much more than two-thirds full during the alcoholic and acetic fermentations. (See Fig. 1.) The first reason for filling the barrel only two-thirds full is that during the active alcoholic fermentation gas is produced so rapidly that if the barrel is full a considerable amount of solution is lost in the overflow and contamination is likely. Furthermore a large volume of air is not only desirable but absolutely necessary for the second or acetic fermentation. If larger volumes of air in the form of increased surface were practicable, acetic fermentation could be hastened materially. In fact the small amount of surface exposed by this process, known as the Orleans, is one of the factors making fermentation slow. In the quick vinegar process a very large surface is exposed and as a result the time required to make vinegar is reduced in proportion. As a matter of fact, only about two days are necessary for the making of a 4 to 6 per cent vinegar by the quick process. Therefore, it is absolutely necessary to have as much surface exposed as practicable in the barrel.

Vinegar "Diseases"

The honey solution is more likely to become contaminated with undesirable microorganisms than are solutions of natural fruit juices like cider, grape juice, etc. This is due to the presence of the natural fruit juices of natural acids which protect them from these undesirable microorganisms. Cider usually contains 0.5 per cent or more acid—mostly malic acid—while grape juice has an average acidity of 0.6 per cent due mostly to tartaric acid. This is sufficient to inhibit the growth of most of the undesirable microorganisms.

Since the honey solution such as used for honey vinegar contains practically no acid, great care should be exercised in keeping it free from contamination. This can be done best by having the barrel thoroughly clean and by sterilizing the solution before putting it into the barrel.

Mycoderma, one of the most common of vinegar "diseases," is caused by a yeast known as *Mycoderma.* It forms a white heavily wrinkled scum and is easily recognized. Two species are most common, *Mycoderma vini* and *Mycoderma cucumerina.* These are false or pseudo-yeasts that gain entrance to the honey solution when proper care has not been exercised in preparing the solution and barrel. They destroy both the alcohol and acid and thus make vinegar formation impossible. About the only way to get rid of them is to heat the honey vinegar to 140° F. for 30 minutes after first skimming off the film. The barrel should be thoroughly recleaned as in the beginning and a fresh start made.

Vinegar mites sometimes become troublesome. They are tiny animals belonging to the spider family, and are easily destroyed by pouring boiling water on them. They can be prevented from entering the barrel by painting a ring with kerosene oil or turpentine around the openings.

Vinegar flies may occasionally give trouble. They breed around the openings and if numerous the maggots may get into the vinegar. The best way to prevent them is by tacking cheese cloth over all the openings.

Vinegar eels possibly cause more trouble than anything else in vinegar making. This is due to the prevalence of so much misinformation about vinegar making. Many people consider rain water essential for making good vinegar. It is absolutely unnecessary and when it is used it is generally the source of "vinegar eels." All water added to vinegar during the making or afterwards should be boiled. Vinegar eels destroy the mother of vinegar and cause it to sink. If they are very numerous, they fall to the bottom of the barrel where they putrefy and completely spoil the vinegar. The best way to get rid of them is to filter the vinegar and then pasteurize it. Clean out the barrel thoroughly as previously described and start again. Potassium metabisulfite may be added to kill them if they are very numerous, the vinegar should then be filtered to get rid of the dead eels.

Blackening—This may be due to several causes. In fruit vinegar oxidase may cause blackening. However, in honey vinegar tannin in new casks or barrels which have not been properly cleaned is one of the more common causes. It also may be produced by the acetic acid coming in contact with iron and forming a compound, iron acetate, which, when exposed to air forms dark colored salts which blacken the vinegar. *Vinegar should never come in contact with any metals.*

The best way to get rid of substances causing blackening is by fining. If the blackening is due to iron salts, the vinegar should be well aerated before fining so as to oxidize all the salts.

Fining or Clearing Vinegar

Often vinegar is cloudy or black from the causes just stated. It is cleared and the substances causing the blackening are removed by the process known as fining. Several methods are available. Vinegar may be cleared and the tannins removed by adding gelatin. One to one-half ounces of gelatin soaked in warm water and added to the vinegar is sufficient to clear 100 gallons. The gelatin solution should be thoroughly stirred into the vinegar. When the gelatin has settled to the bottom pour off the vinegar using care not to disturb the coagulum at the bottom.

Isinglass may be used to clear vinegar according to Bioletti. Cut 1/2 to 3/4 ounces of isinglass into small pieces and soak for 12 to 24 hours in a little water containing an equal weight of acetic or tartaric acid (1/2 to 3/4 ozs.). This gelatinous solution is then rubbed through a very fine sieve, gradually adding more water until a perfect fluid is obtained. This liquid is then mixed with a little vinegar and thoroughly stirred into the barrel. With some vinegars it is necessary to add tannin, from one-half to one-seventh the amount of the isinglass used. The tannin should be added at least 24 hours before the finings.

These substances clear vinegar in the same manner that egg white clears coffee. Clear vinegar is very desirable from a market standpoint and the extra time required to clear it is really a good investment.

Pasteurization

After the vinegar has been made, further fermentation is undesirable particularly if the vinegar is to be kept for any length of time. Pasteurization is one of the best ways to prevent further fermentation. Heat the vinegar at 140° F. in a water bath for 30 minutes using care not to have it come in contact with metals. Enamelware kettles free from cracks or other defects are suitable for this purpose. After pasteurization the vinegar should be stored in bottles made air-tight or in completely filled barrels tightly bunged.

If the vinegar is to be stored in bottles, the best way is to pasteurize in the bottles loosely corked and then cork tightly after pasteurization.

Storage of Vinegar

After the vinegar has been made, it must be properly stored. Improper storage causes the loss of much good vinegar. This care is necessitated by the fact that the same bacteria that made the acetic acid will destroy it. The best way to get rid of these bacteria is by raking off the vinegar into a clean barrel and filling it completely and then bunging it tightly. This shuts out all the air so that the bacteria are unable to grow. Pasteurization previous to this still further reduces the possibility of growth of not only the vinegar bacteria but of other microorganisms as well. Vinegar properly prepared for storage in the way indicated will keep for years without deteriorating and may be kept and sold when the market is most favorable.

APPLICATION FOR PURE CULTURES OF VINEGAR YEAST AND BACTERIA

Show This To A Neighbor

Date .....

Name .....

Postoffice .....County .....

State .....R. F. D. .....

I desire to co-operate with the Bacteriological Laboratory of the Michigan State College in its attempt to produce a better vinegar and to overcome losses by off-fermentations.

I will endeavor to:

1. Carry out instructions carefully;
2. Observe all changes accurately; and
3. Report these changes and results

as soon as the fermentation is completed by filling out the "Report Blank" sent with the cultures and returning it to the Bacteriological Laboratory.

Probable date of using cultures ....., 19.....

(Yeast cultures should be ordered one to two weeks before honey solution is prepared; cultures of vinegar bacteria should be ordered at the same time and used as soon as the alcoholic fermentation is over.)

I wish ..... yeast cultures to control the alcoholic fermentation, the first stage of vinegar production, and ..... cultures of vinegar bacteria to control the acetic acid fermentation, the second and last stage of vinegar production.

One culture each of yeast and vinegar bacteria is sufficient for a barrel two-thirds full of honey solution. If the alcoholic fermentation is completed (as evidenced by the cessation of foaming) a pure culture of vinegar bacteria alone will be sufficient.

A nominal charge of 25 cents per culture is made to cover cost of material and shipping. No amount less than a single culture will be sent. Two or more cultures will be forwarded at 25 cents *each*.

A charge of 50 cents is made for the chemicals.

Enclosed find $..... Send money preferably by money order. No stamps accepted.

Address this application when filled out in a sealed envelope to the

BACTERIOLOGICAL LABORATORY,
MICHIGAN STATE COLLEGE,
East Lansing, Michigan.