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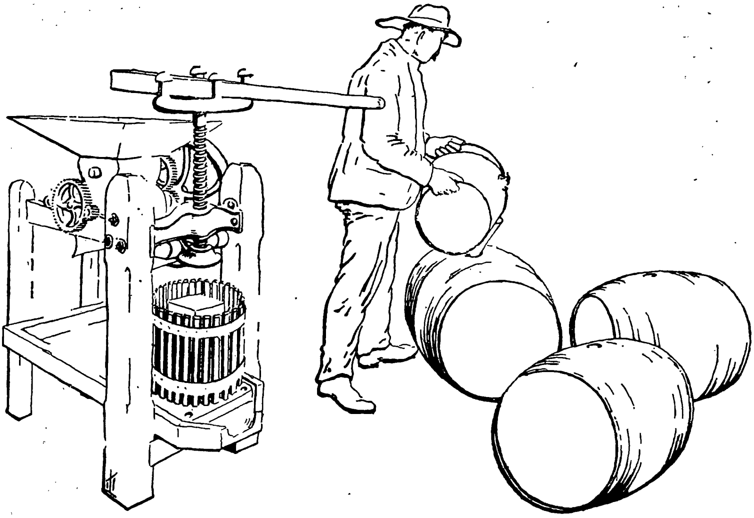

MAKING CIDER VINEGAR AT HOME.

F. H. HALL AND L. L. VAN SLYKE.

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‡ In Second Judicial Department.

POPULAR EDITION*

OF

BULLETIN No. 258.

MAKING CIDER VINEGAR AT HOME.

F. H. HALL.

Why study was needed. The making of cider vinegar is a familiar operation in almost every farm home. The final product is a necessity on every table, the small apples from which it is usually made are of practically no value for other purposes, the labor and expense of picking them up and pressing them are slight, and from the time the cider is in the barrel Nature does the work. Thus the process appears a simple one, easy to start, and self-operated to its termination in a salable commodity; so that the work-burdened farmer, with several barrels of cider in his cellar, may, in his few moments of leisure, think with pleasure of this farm operation which will bring him profit without further outlay of strength or money.

Yet vinegar is a food product and, as such, has come under the eye of State law; which says that to be legally salable the finished goods must meet certain requirements. Cider vinegar must contain 4.5 per ct. of acetic acid and 2 per ct. of cider vinegar solids before it can be lawfully sold, and frequently farmers who have made vinegar from pure apple juice only, and who have stored this under what they believe to be proper conditions for the proper length of time, find that their product falls short in

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* This is a brief review of Bulletin No. 258 of this Station, on A Study of the Chemistry of Home-Made Cider Vinegar, by L. L. Van Slyke. Any one specially interested in the detailed account of the investigations will be furnished, on application, with a copy of the complete bulletin. The names of those who so request will be placed on the Station mailing list to receive future bulletins, popular or complete, as desired. Bulletins are issued at irregular intervals, as investigations are completed, not monthly.

one requirement or the other. Thus, without fraudulent intent or attempt at adulteration or dilution, the home-made vinegar falls under suspicion. Complaints of this condition reached the Station in considerable number some years ago and in an effort to find the cause or causes of the difficulty an extensive investigation of the subject has been made. Cider has been pressed during different years and from different varieties of apples, and has been stored under varied conditions, with and without additions of yeast, "mother" or additional malic (apple) acid. In all, 36 experiments have been carried through periods of time varying from 44 months to 7 years. Each sample of cider was analyzed monthly for 10 months and at 2-month or 3-month intervals after that time, attention being paid to seven constituents in most of the analyses; so that a great amount of data has been collected, of much chemical interest and practical value.

Simple yet complex.

As seen by the farmer, vinegar making is a simple process; to the chemist, though less intricate than many other chemical transformations, it is complex; while to the biologist, the various steps in the change of sugar in the fresh apple juice to the acetic acid of vinegar are manifestations of very complex life activities of many species of organisms, divided into two great groups, yeasts and bacteria, each group performing a specific function in the change. There may also come into action, under certain unfavorable conditions, other bacteria which hinder the useful transformations, or which destroy the products desired and thus lower the quality of the vinegar. This interplay of living organisms, sometimes for good, sometimes for ill, has not been studied in all its details, and has been considered, in this investigation, only as results were produced, the chemical transformations alone being considered.

Chemistry of vinegar making.

In a general way these transformations are two: Sugar, the ordinary cane sugar and other forms known as invert sugars (dextrose and levulose), in the sweet cider, is first changed into alcohol through the fermentative action of one group of organisms; then the alcohol, by the action of a second group of organisms is changed to acetic acid.

Chemically considered, each molecule of sugar consists of six atoms of carbon, twelve atoms of hydrogen and six atoms of oxygen. When this molecule of sugar is acted upon by the proper ferments, it passes through a series of chemical changes which may be said to result, finally, in splitting it up into two molecules of alcohol, each containing two atoms of carbon, six of hydrogen and one of oxygen, and two molecules of carbon dioxide gas, each containing one atom of carbon and two of oxygen. This may be expressed in the form of an equation:

$$\underset{\text{Sugar}}{C_6H_{12}O_6} = \underset{\text{Alcohol}}{2\,C_2H_6O} + \underset{\text{Carbon Dioxide}}{2\,CO_2}$$

Theoretically, we should be able to get from 100 parts of sugar by weight, about 51 parts of alcohol and 49 parts of carbon dioxide; but because of evaporation and certain minor chemical changes we can get in practice only about 45 to 47 parts of alcohol or less.

After the alcohol is formed, the organisms which act upon it begin the transformation to acetic acid. In this process oxygen is taken from the air. The result may be similarly represented by an equation:

$$\underset{\text{Alcohol}}{C_2H_6O} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Acetic Acid}}{C_2H_4O_2} + \underset{\text{Water}}{H_2O}$$

Theoretically, again, we should obtain from 100 parts of alcohol about 130 parts of acetic acid, but we usually get less than 120 parts. So, starting with 100 parts of sugar in the apple juice, we may get under favorable conditions from 50 to 55 parts of acetic acid; therefore to have vinegar with 4.5 per ct. of acetic acid we must have juice containing not less than 8.5 per ct. of sugar.

Sugar in apples.

This percentage, however, is found in practically all ripe, sound apples, although in a record of about 100 analyses of 80 varieties of American-grown apples, made at this Station, in Washington, D. C., in Pennsylvania and in Virginia, five samples, of as many different varieties, were too low in sugar to produce vinegar of the required acidity. The sugar in apples reaches its maximum in ripe fruit, being low both in those that are green and those that are overripe. It averaged, in the apples used in the tests at this Station, 13⅓ per ct., and varied less than 2 per ct. either above or below the average. A somewhat surprising fact to those not familiar with the chemistry of the subject, is that "sweet" apples do not owe their sweetness to their large percentage of sugar but to the small amount of malic acid they contain. For example, the sample of Red Astrachan juice contained 10.16 per ct. of sugar and 1.15 per ct. of malic acid; while Tolman Sweet and Sweet Bough contain about the same amount of sugar, but only 0.10 to 0.20 per ct. of malic acid.

Alcoholic fermentation.

Starting, then, with juice containing sufficient sugar, what are the conditions which will best promote the changes to alcohol and to vinegar and prevent loss? The sugar must first be acted upon by the enzyms, or ferments, which are produced by yeast plants. The yeast germs are usually present everywhere, so that they pass from the surface of the apples into the juice as it is pressed out, or fall into the cider from the air. It has sometimes been held unwise to wash apples before pressing them, for fear of carrying away the necessary yeast germs; but the apples used in all the Station tests were washed without apparent interference with alcoholic fermentation. If apples have become dirty it is certainly best to wash them, as otherwise there is danger of introducing bacteria that interfere with proper fermentation. In ordinary cellar temperature, most of the sugar is changed into alcohol in five or six months, the change being slow during the first month, but quite rapid during the second, third, and fourth months. The process may be greatly hastened by storing in rooms warmer than cellars usually are during the fall and winter months. By placing bottles of vinegar in rooms of different temperature, running from 55° to 85° F. it was found that at 55° only 2¼ per ct. of alcohol was formed in three months; at 60° and 65° F., more than 4½ per ct.; and at 70° and 85° F. about 6½ per ct. was formed in the same time. At higher temperatures than this, evaporation of the alcohol would be liable to cause loss.

The addition of yeast also hastens alcohol formation, so that at a temperature of 55° F. cider with yeast added gave 6¼ per ct. of alcohol, and at 70° F., with yeast, 7¼ per ct., both in one month. The use of any form of commercial yeast, if sufficiently fresh, will probably be found to give good results.

Acetic fermentation.

After the yeast fermentation has been completed the acetic-acid forming bacteria begin to attack the alcohol and produce acetic acid. This process is ordinarily very slow for about three months after the sugar has all been changed to alcohol, that is during the eighth, ninth and tenth months of cellar storage ; but advances rapidly from the tenth to the fourteenth month and is practically completed in two years. This process also moves more rapidly, when once well started, at higher temperatures ; but differences of temperature appear to have little effect during the three months after the sugar has disappeared. Beginning with the tenth month of storage, however, and up to the end of 2½ years, nearly twice as great a percentage of acetic acid was produced where the temperature varied from 50° to 90° F. as where it was from 45° to 65° F. The percentage of acid formed at lower temperatures never became as great as at higher temperatures, though part of the apparent increase in the warm room was due to evaporation of the water. The best results were secured at temperatures of 65° to 70° F.

It is the ordinary practice to add vinegar, especially vinegar containing "mother," to the barrels in which vinegar is making ; and the investigation proved the practice a most excellent one, as the acetic fermentation was more rapid and more complete in every case where this form of inoculation or "seeding" was used. This addition of "mother" is comparable to the addition of a "starter" in souring milk, for the "mother" is produced by the growth of the acetic bacteria in the presence of air and contains large numbers of these bacteria.

It appears to be of advantage in some cases to draw off the clear portion of the cider after alcoholic fermentation has been completed, leaving the dregs ; and to continue the process in new clean barrels or to wash out the settlings and return the clear liquid to the barrels. This proved of considerable advantage in the case of vinegars stored at low temperatures, but of less utility when the vinegar was stored at higher temperatures where the acetic fermentation proceeded rapidly. Possibly with cider made from uncleaned apples and carelessly strained juice the results along this line would be more striking; for the liability to contamination with undesirable germs would be greater in such cases.

Loss of acetic acid.

In both alcoholic fermentation and acetic fermentation, the air should have free access, especially in the latter; for, as can be seen by the equation given to explain the process, oxygen must be added to alcohol to make the acetic acid and this must come largely from the air. On this account the barrels should not be filled more than two-thirds or three-fourths full with the apple juice, or with the "hard" cider. But when the acetic fermentation has ceased to be active and the amount of acetic acid is safely above 4½ per ct. the vinegar should be drawn from the barrels and strained, the barrels cleansed, the vinegar returned filling the barrels full, and the bung driven in tight.

Unless this is done, destructive fermentation may begin and the acetic acid decrease instead of increasing. In several experiments where the vinegar was held in loosely stoppered casks or bottles, it lost all or nearly all its acid, and in some cases actually became alkaline in reaction. This destructive fermentation may be due to new species of bacteria introduced, or even in some cases to the same acetic-acid-forming species which, when the alcohol is exhausted, attack the acetic acid itself.

As showing how complex may be the processes passing in vinegar, the case may be cited of four 1-quart bottles of the same juice stored under the same general conditions. At the end of five years bottles a and b contained 5.74 and 5.44 per ct., respectively, of acetic acid, bottle c 2.10 per ct. and bottle d gave an alkaline reaction. Bottles a and c contained nearly three times and bottle b 2½ times as much solids as bottle d.

Malic acid.

The acid of fresh apple juice is not the acid of vinegar, but a fixed acid called malic acid. This has certain chemical characteristics which make it quite easily recognizable; and so its presence in vinegar has been considered an index to determine whether the vinegar were or were not truly vinegar from apples. But these investigations have proven that this acid disappears quite rapidly from vinegar, so that in 24 months it had shrunk from an average of 0.55 per ct. to 0.02 per ct.; while in some older vinegars it had disappeared entirely. The relation of malic acid to cider vinegar is being further studied.

Legal Standard.

The legal standard of the State for acid, 4½ per ct. of acetic acid, has been upheld fully by these results; for apple juice from good ripe apples, properly managed in fermentation should and does easily give 4½ per ct. of acetic acid within two years at cellar temperatures and in less time at higher temperatures.

Concerning solids, the wisdom of the standard is not quite so clear. In several experiments made in this investigation, vinegars made from pure apple juice and well above the limit in acid contain less than two per ct. of solids.

Conditions producing poor vinegar.

Among the conditions which may produce vinegar below standard are these: (1) The juice may be poor to start with because made from varieties of apples low in sugar, from green apples or from overripe or decayed apples; or the juice may be watered either directly or by watering the pomace and pressing a second time. (2) The fermentation processes may be delayed or disturbed by using dirty fruit or unclean barrels, thus affording entrance to undesirable organisms and causing the wrong kind of fermentation; the temperature may be too low to insure the necessary activity of favorable organisms; or air may be excluded by filling the barrels too full or putting the bung in too tight so that the bacteria can not live and work. (3) The acetic acid may disappear after its formation, destructive fermentation being encouraged by leaving the bung-hole of the barrel open or the barrel only partially full.

To make good vinegar.

Briefly summarized, the method to be employed for the manufacture of good vinegar at home, without the use of generators, is this: Use sound, ripe apples, picked or picked up before they have become dirty, if possible, otherwise washed. Observe the ordinary precautions to secure cleanliness in grinding and pressing, and discard all juice from second pressings.

If possible, let the juice stand in some large receptacle for a few days to settle, then draw off the clear portion into well-cleaned barrels which have been treated with steam or boiling water, filling them only two-thirds or three-fourths full. Leave the bung out, but put in a loose plug of cotton to decrease evaporation and to prevent the entrance of dirt. If these barrels are stored in ordinary cellars, where the temperature does not go below 50° or 45° F., the alcoholic fermentation will be complete in about six months; but by having the storage room at a temperature of 65° or 70° the time can be considerably shortened, and the addition of Fleischmann's compressed yeast or its equivalent at the rate of one cake to five gallons of juice may reduce the time to three months or less. Use a little water to thoroughly disintegrate the yeast cake before adding it to the juice. The temperature should not go above 70° for any length of time, to avoid loss of the alcohol by evaporation.

After the sugar has all disappeared from the juice, that is, when the cider has entirely ceased "working" as revealed by the absence of gas bubbles, draw off the clear portion of the cider, rinse out the barrel, replace the liquid and add two to four quarts of good vinegar containing some "mother," and place at a temperature of 65° to 75° F. The acetic fermentation may be complete in three months or may take 18 months according to the conditions under which it is carried on; or if stored in cool cellars may take two years or more. If the alcoholic fermentation be carried on in the cool cellar and the barrel be then taken to a warmer place, as outdoors during the summer, the time of vinegar formation may be reduced from that given above to 15 or 18 months. Where the alcoholic fermentation is hastened by warm temperature storage and the use of yeast and the acetic fermentation favored by warmth and are good vinegar "start," it is possible to produce good merchantable vinegar in casks in 6 to 12 months.

When the acetic fermentation has gone far enough to produce 4.5 to 5 per ct. of acetic acid, the barrels should be made as full as possible and tightly corked in order to prevent destructive changes and consequent deterioration of the vinegar.