

Acetic acid Fermentation

Vinegar is produced by this process. This is a two-step process; the **first step** is the formation of ethanol from sugar anaerobically using yeast. In the **second step**, ethanol is further oxidized to form acetic acid aerobically by acetic acid bacteria. *Acetobacter* species are better acid producers and are common in commercial vinegar production.

Strains of acetic acid bacteria to be used in industrial production should:

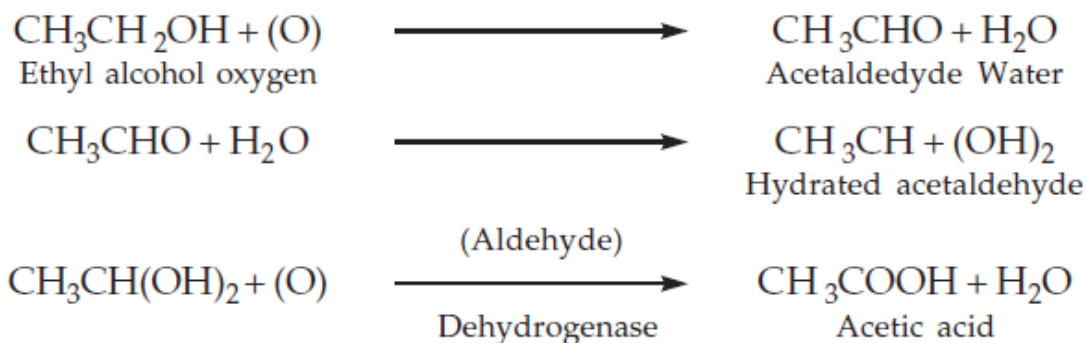
(a) tolerate high concentrations of acetic acid; (b) require small amounts of nutrients; (c) not overoxidized* the acetic acid formed; and (d) be high yielding of the acetic acid.

*The ability to oxidize acetic acid to $\text{CO}_2 + \text{H}_2\text{O}$ (called **overoxidation**), it is undesirable. It occurs when there is a lack or low level of alcohol.

TYPES OF VINEGAR

Vinegar may be classified on the basis of raw material from which it has been prepared. In fact, anything that contains enough sugar or alcohol may be used to make vinegar. As a result, vinegar can be: cider vinegar, whey vinegar, malt vinegar, grain vinegar, spirit vinegar. The largest percentage of vinegar is the spirit vinegar. It is more commonly called distilled vinegar or white vinegar.

The **biochemical processes** are simple and are shown below:



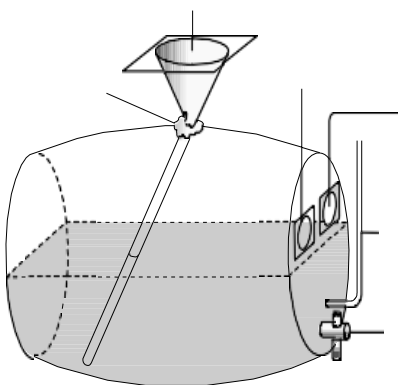
MANUFACTURE OF VINEGAR

There are three methods by which alcohol may be converted to acetic acid in the manufacture of vinegar.

- Orleans method

The first and oldest method. This is the traditional **surface method**, where the alcoholic precursor solution is placed in partially filled barrels or open vats and allowed to naturally oxidize, utilizing acetic acid bacteria occurring naturally in the air. The large surface area of the alcoholic fermentation and holes above the level of the liquid in the vat allow for the necessary oxygen exchange.

A film consisting of *Acetobacter* spp. bacterial cells and their cellulose slime (the “mother of vinegar”). This mother of vinegar builds up on the casks and aids in speeding up the acidification. Or a small amount of vinegar or mother of vinegar may be added to facilitate the conversion by lowering the pH and adding desirable acetic acid bacteria. This method is slow, requiring one to three months, but produces a good quality product with flavors and aromas because of the action of several additional bacteria that may be active in the production of other acids and esters.



Orleans for vinegar production

- Trickling Generator

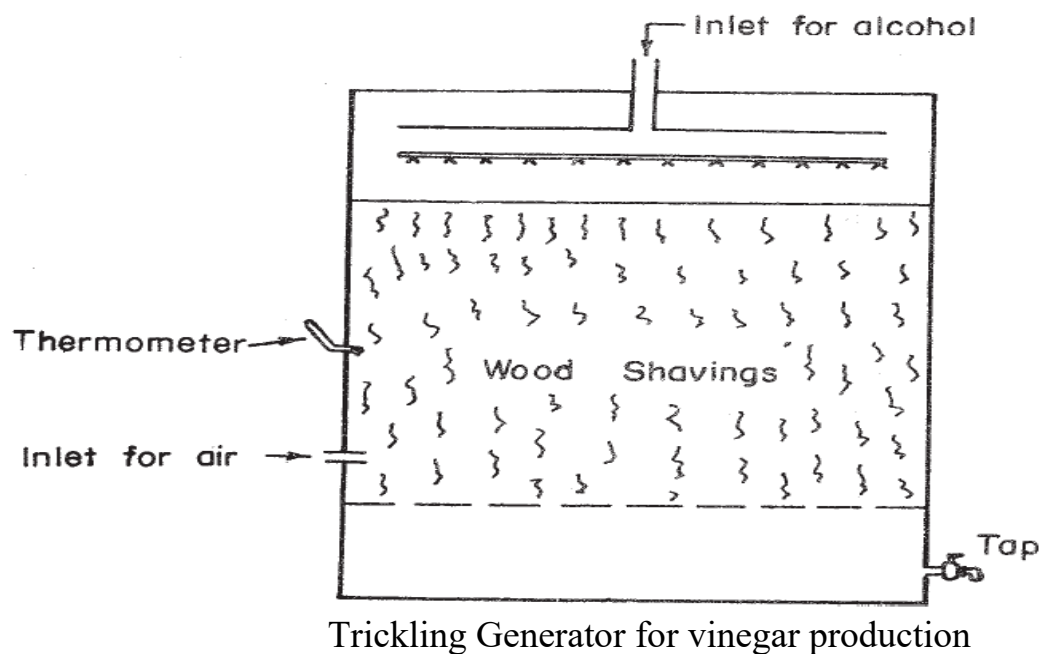
Trickling Generator, a new method for vinegar production, was developed. The alcoholic precursor was circulated through a tank packed with woody debris (colonized with *Acetobacter* spp.) repeatedly until the proper concentration of acetic acid was reached. The heat produced in the manufacture caused a draft to be created, which aerated the system and allowed the aerobic reactions to take place. This new method took days instead of weeks to produce vinegar.

This evolved into the modern vinegar generator – a tank packed with wood shavings or other inert materials that provide a large surface area on which acetic acid bacteria can adhere and a pump to recirculate the alcohol/acetic acid mixture, with provisions

for aeration and cooling. The cooling water in the heat exchanger is used to regulate the temperature in the generator to control the temperature at 26°C - 28°C; this is determined with thermometers placed at different levels of the generator. Also, care must be taken to not allow the alcohol concentration to fall below 0.3–0.5%, as the bacteria on the shavings die quickly in the absence of ethanol.

Three parameters should be controlled: (a) the circulation of the mash, (b) the flow of cooling water through the heat exchange, and (c) the amount of air delivered through the system. If the air flow rate is too high alcohol and vinegar are lost in effluent air.

This operation is semicontinuous. Addition of stock is carried out in 2-3 steps over a period of several days. The total time is between 4 and 10 days. The yield is between 85-90% and 5-liter vinegar/m³ of shaving can be obtained per day.



- Submerged Method

Submerged method of vinegar production, the method most used today. This takes place in a large, highly aerated, temperature-controlled stainless-steel tank known as an **acetator**. Specially selected strains of acetic acid bacteria grow in a suspension of very fine air bubbles continuously flowing through the alcoholic medium, oxidizing the ethanol to acetic acid. When the ethanol concentration falls to less than 0.3%, 50% of the medium is removed and replaced with fresh alcoholic medium. The bacteria are very sensitive and die quickly under low oxygen or ethanol conditions.

The common feature in all submerged vinegar production is that the aeration must be very vigorous as shortage of oxygen because of the highly acid conditions of submerged production, would result in the death of the bacteria within 30 seconds. Furthermore, because a lot of heat is released (over 30,000 calories are released per gallon of ethanol) an efficient cooling system must be provided.

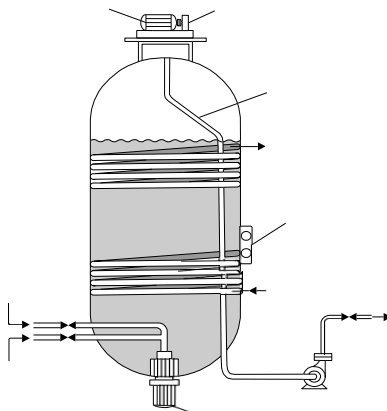
All submerged vinegar is turbid because of the high bacterial content and have to be filtered and/or treated with fining agents to clarify. Finally, the vinegar is pasteurized by heating at 60°C -70°C for a few seconds before bottling.

Advantages

- (a) The efficiency of the acetator is much higher than that of the trickling generator; the production rate of the acetator may be 10-fold higher than a trickling unit.
- (b) Producing uniform high-quality acetic acid in 24–48 hours.
- (c) A much smaller space is occupied in comparison with the trickling generator.
- (d) It is easy and cheap to change from one type of vinegar to another.
- (e) Continuous production and automation can take place more easily than with trickling.

Disadvantages

- (a) A risk exists of complete stoppage following death of bacteria from power failure even for a short time. Automatic stand-by generators have helped to solve this problem.
- (b) It has a high rate of power consumption.



Acetator for vinegar production