Vinegar (Acetic acid fermentation):

- The word 'vinegar' is derived from the French term 'vinaigre' (vin = wine + aigre = sour), meaning "sour wine". It contains about 40% acetic acid by weight and small quantities of alcohol, glycerol, easters, sugars, and salts. Vinegar is the product obtained as a result of impartial oxidation of alcohol in a fermenting sugar containing fruit or cane juice, molasses, fermented mash of malted grain, honey, maple skimming, syrups, etc.. Vinegar is an alcoholic liquid that has been allowed to sour. It is primarily used to flavor and preserve foods and as an ingredient in salad dressings and marinades. Vinegar is also used as a cleaning agent.

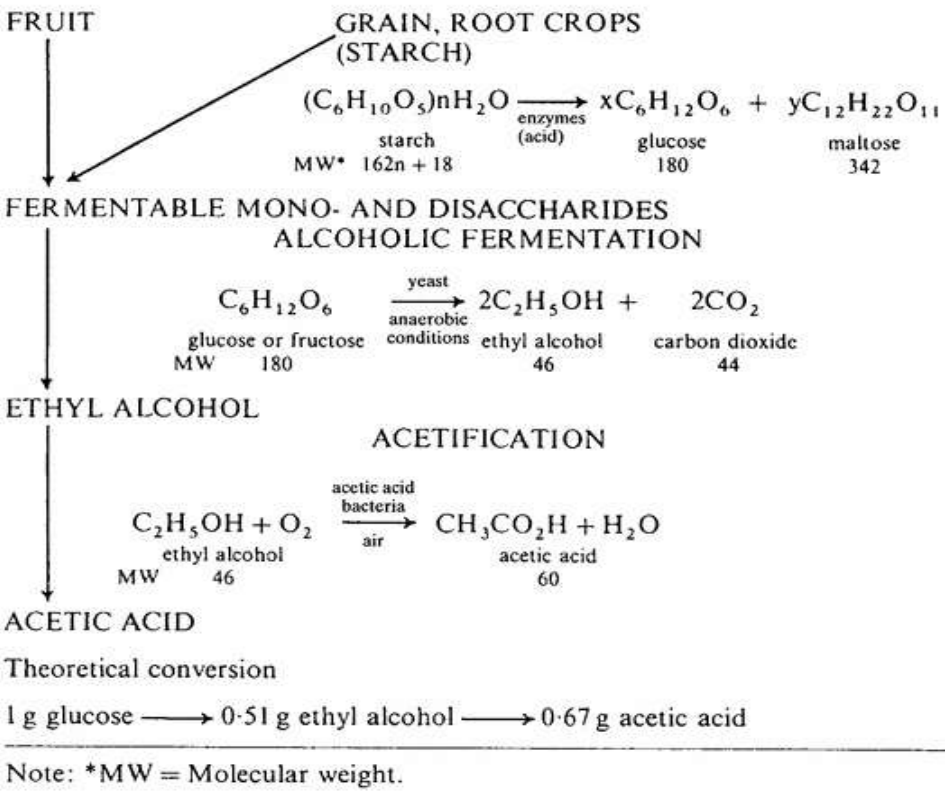


Figure (1): Scheme of vinegar production.

Acetic acid as an industrial chemical is currently produced from fossil fuels and chemicals by three processes: **acetaldehyde oxidation, hydrocarbon oxidation, and methanol carbonylation.** It can also be produced by biological routes using either an aerobic or an anaerobic route.

1- **Aerobic Process**

A- First step in vinegar production is the preparation of the raw materials which are fermentable sugar and juice solution to be acetified. In general, fruits require less preparation than seeds; Fruits are highly perishable, rich in water, and need to be processed very quickly to prevent the growth of pathogenic microorganisms that could alter the quality of the final product or even produce dangerous toxins, such as aflatoxin; however, seeds are more easily stored and preserved after harvest.

B- Alcoholic fermentation, is a fermentation step common to all vinegars. This is a biological process in which sugars, such as glucose, fructose, and sucrose, are converted into cellular energy, ethanol and carbon dioxide (CO2). This is carried out at 30–32 °C

$$C_6H_{12}O_6 \longrightarrow 2CO_2 + 2CH_3CH_2OH + \text{energy}$$

This process is mainly carried out by yeast, *Saccharomyces cerevisiae* is the most widespread species. Lactic acid bacteria can also play a role in obtaining ethanol from heterofermentative metabolic pathways.

C- Acetification is commonly known as the oxidation of the ethanol to acetic acid. It is carried out by acetic acid bacteria. Although a variety of bacteria can produce acetic acid, only members of *Acetobacter* are used commercially, typically the aerobic bacterium *Acetobacter aceti* at 27–37 °C, and it is highly dependent on the availability of oxygen. This process can be carried out spontaneously, due to wine replacement and racking at the final stages of the alcohol fermentation may stimulate the growth of acetic acid bacteria, which could start Acetification.

The overall theoretical yield is 0.67 g acetic acid per gram glucose.

2-Anaerobic Process

In the 1980s, another process for production of acetic acid emerged based on anaerobic fermentation using *Clostridia*. These organisms can convert glucose, xylose, and some other hexoses and pentoses almost quantitatively into acetate according to the following reaction:

$$C_6H_{12}O_6 \longrightarrow 3CH_3COOH$$

Clostridium thermoaceticum is also able to utilize five-carbon sugars:

$$2C_5H_{10}O_5 \longrightarrow 5CH_3COOH$$

Method of Commercial Production

There are three ways to produce vinegars:

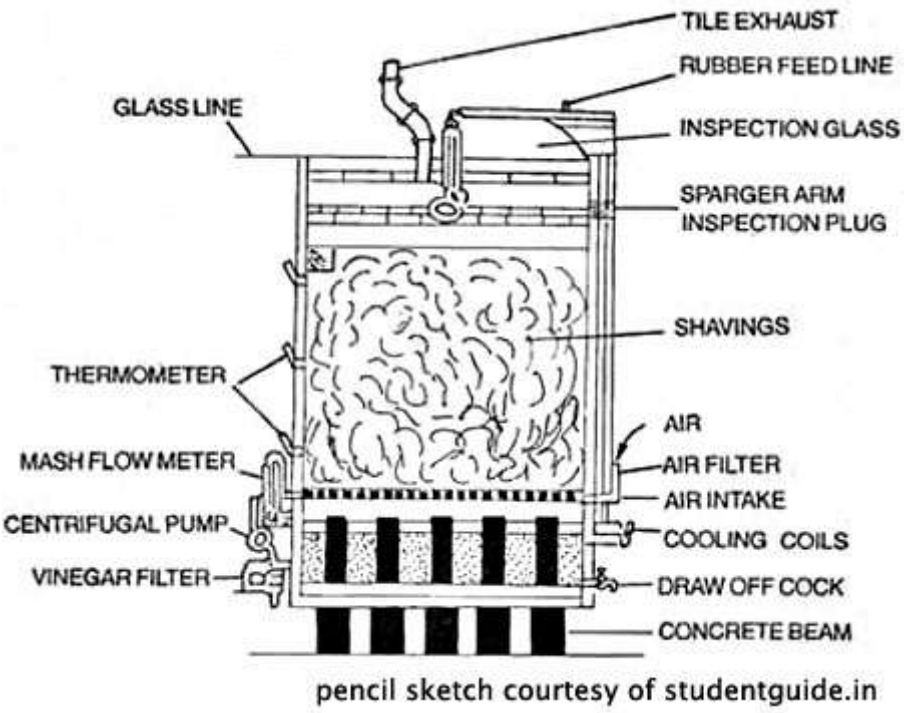
The Orleans method:

Is the old most famous French technique, a slow continuous process of vinegar production. High grade vinegar is used as a **starter culture**, to which wine is added at weekly intervals. The vinegar is fermented in large (200 liters) capacity barrels. Approximately 65 to 70 liters of high grade vinegar is added to the barrel along with 15 liters of wine. After one week, a further 10 to 15 liters of wine are added and this is repeated at weekly intervals. After about four weeks, vinegar can be withdrawn from the barrel (10 to 15 liters \ week) as more wine is added to replace the vinegar.

One of the problems encountered with this method is that of how to add more liquid to the barrel without disturbing the floating bacterial mat. This can be overcome by using a glass tube which reaches to the bottom of the barrel. Additional liquid is poured in through the tube and therefore does not disturb the bacteria. Wood shavings are sometimes added to the fermenting barrel to help support the bacterial mat.

Quick vinegar method:

Because the Orleans process is slow, other methods have been adapted to try and speed up the process. The German method is one such method. It uses a generator, which is an upright tank filled with beech-wood shavings and fitted with devices which allow the alcoholic solution to trickle down through the shavings in which the acetic acid bacteria are living. The tank is not allowed to fill as that would exclude oxygen which is necessary for the fermentation. Near the bottom of the generator are holes which allow air to be drawn in, the air rises through the generator and is used by the acetic acid bacteria to oxidize the alcohol. This oxidization also releases considerable amounts of heat which must be controlled to avoid causing damage to the bacteria.



Natural Fermentation:

It can be made easily by fermenting fresh sap into plastic or earthen jar until it becomes sour. Then pack into plastic bottles and place under the heat of sun for few days. The very common package is a used 1.5 liters Coke bottle. Sugar palm and coconut sap are common examples.