

4. Distillation

After fermentation, the mixture contains ethanol along with water and other byproducts. The next step is distillation to separate ethanol from the rest of the liquid. Since ethanol and water have different boiling points, distillation allows ethanol to be concentrated.

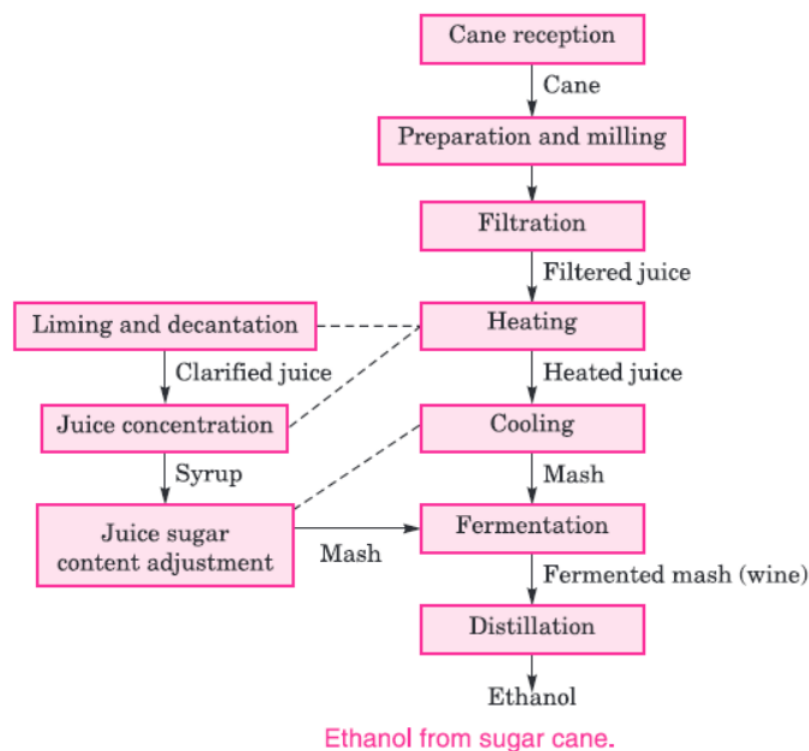
Distillation usually results in a concentration of ethanol (usually around 95-96% ethanol by volume), which can then be dehydrated to produce anhydrous ethanol (nearly 100% pure ethanol) if required.

5. Byproduct Treatment

During the production of ethanol from wood, there are various byproducts, including leftover lignin and spent solids from the hydrolysis process. These can be used as:

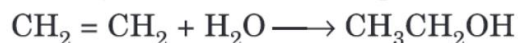
- **Biofuels:** Lignin can be burned to produce heat or electricity, making the process more energy-efficient.
- **Animal feed:** The remaining solids, known as "stillage," can be processed into animal feed.

Alcohol ethanol production from sugarcane



Fermentation ethanol may have the best future as a substrate for single-cell protein production. Its advantage in this use include: purity, acceptability; ease of storage and handling; non-toxicity; versatility as a substrate or CO substrate; miscibility with water; relatively low oxygen demand; relatively low temperature fermentation; and high cell yields.

(1) Ethanol production. Ethanol production is based on two major techniques—*chemical synthesis* and *fermentation*. The primary synthetic route is the catalytic hydrolysis of ethylene derived from petroleum:



For the fermentation sources, there are four categories of feedstocks: sugar-containing materials, carbohydrates, lignocellulosics, and urban and industrial wastes.

Raw materials. Materials containing sugar require the least costly preparation, as the sugars are already available in degradable form. Sucrose occurs in free form in sugarcane, and clarified can juice may be used directly for ethanol production. However, molasses is used rather than the corresponding juices for various reasons. This class of raw materials is relatively the most expensive to obtain since it has other markets. Sugar beets and sweet sorghum also have potential for ethanol production

Pretreatment. The fibre component of cellulosic biomass, hemi cellulose and cellulose, can be hydrolyse, but the structural features of cellulose, such as the degree of crystallinity, the degree of polymerization, the degree of water swelling and surface area, make it less amendable to hydrolysis. Some form of pretreatment is, therefore, necessary to obtain high yields of monosaccharides. Pretreatment methods, which disrupt the highly ordered cellulose structure and the lignin carbohydrate complex, remove lignin and increase the surface area available to enzymes (or acids), not only promote hydrolysis, but also enhance the rate and extent of cellulose sachharification.

The physical pretreatment involves particle reduction to very small mesh sizes. The shearing and compressive forces involved in milling cause a reduction in crystallinity, a decrease in the mean degree of polymerization and an increase in bulk density. The milled material also allows for a high slurry concentration, thereby reducing the reactor volume and hence, capital cost.

Conversion Processes

Acid hydrolysis can be carried out with dilute or concentrated acids. The important advantage of concentrated acid hydrolysis is that, since it is carried out at low temperatures, the sugars formed are not degraded. However, the large quantity of acid needed to wet the feedstock can not be discarded. Acid recovery is thus necessary, and this is a every expensive operation. As a result, virtually all recent development work has been with dilute acids.

Cellulose hydrolysis in dilute acids requires higher temperatures (at least 180°C) which cause the product sugars to decompose.

Hydrolysis and Ethanol Fermentation

Hydrolysis is the technology which converts cellulose to alcohols through fermentation. Ethyl alcohol can be produced from a variety of sugar by fermentation with yeasts. Molasses is diluted with water to a sugar content of about 20% by weight, acidified to pH 4.5 and then mixed with yeast culture (5% by volume) in a fermentor. Ammonia is used to reduce acidity. When 8-10% alcohol is accumulated, then liquid is distilled, fractionated and rectified 2.5 litres of can molasses produces about one litre of alcohol. Alcohol fermentation of a large variety of substrates has been obtained. They include: corn barley mashes, sugarcane, molasses and cheese whey, sugar beet molasses and potatoes.

If a prehydrolysis step is included the hemicellulose sugars can be recovered with little degradation, and the hexose can be fermented with the glucose produced from the cellulose. Technologies are also being developed to convert the pentose sugars to energy products; otherwise, they may be marketable in other forms, such as animal feed molasses. If there is no prehydrolysis, potentially recoverable amounts of furfural, acetic acid and other products are formed.

Acid hydrolysis is suitable for any cellulosic feedstock, although it is most often used with wood. For the batch or semi continuous hydrolysis processes, the permeability of the bulk substrate is important. Some cellulosic feedstocks tend to compact and cause plugging of in the beds. Thus feedstocks like bagasse, corn stover and municipal wastes may be difficult to hydrolyse in a batch reactor. The moisture content of the feedstock, determines the amount of acid needed to achieve the desired concentration. It is undesirable to dry the feedstock before hydrolysis, as this reduces the ability of the acid to diffuse into the substrate.

Ethanol production from sugarcane is a well-established and widely used process, particularly in countries like Brazil, where sugarcane is abundant. Sugarcane is rich in sucrose (a simple sugar), which can be easily fermented into ethanol by yeast. The process of ethanol production from sugarcane typically involves the following steps:

1. Harvesting and Crushing

- **Harvesting:** Sugarcane is harvested, usually by cutting it manually or with mechanical harvesters.
- **Crushing:** The harvested sugarcane stalks are washed and then crushed to extract the juice. This juice is primarily composed of sucrose, along with small amounts of water, minerals, and other compounds.

2. Juice Clarification

After extraction, the sugarcane juice contains impurities, including plant fibers and other solids, which need to be removed:

- The juice is clarified by adding lime (calcium hydroxide) and heating it, which helps to precipitate impurities such as suspended solids and non-sucrose sugars. This leaves a clearer liquid, which is the primary feedstock for fermentation.

3. Fermentation

- Fermentation is the process where microorganisms, primarily *Saccharomyces cerevisiae* (brewer's yeast), convert the fermentable sugars (mostly sucrose, glucose, and fructose) into ethanol and carbon dioxide.

- The clarified sugarcane juice is then inoculated with yeast in a fermentation vessel (bioreactor), typically under controlled temperature and pH conditions.
- The fermentation process usually takes between 24 to 48 hours, and the resulting mixture contains about 10–15% ethanol by volume.

4. Distillation

- After fermentation, the liquid (known as "beer") contains ethanol along with water, residual sugars, and other byproducts.
- The mixture is then subjected to distillation, a process that uses heat to separate ethanol from the other components based on their boiling points. Ethanol boils at 78.37°C, while water boils at 100°C, so distillation allows for the ethanol to be concentrated and separated from the water and other impurities.
- The result of this first distillation step is a mixture that is about 95-96% ethanol by volume.

5. Dehydration

- To obtain anhydrous ethanol (which is nearly 100% pure ethanol), the 95% ethanol from distillation undergoes a dehydration process. This is typically done using molecular sieves or by employing an azeotropic distillation process.
- Dehydration removes the remaining water, yielding anhydrous ethanol suitable for use as fuel or for industrial purposes.

6. Byproduct Treatment

Sugarcane ethanol production generates several byproducts, some of which are valuable:

- **Bagasse:** The fibrous material remaining after the juice is extracted. Bagasse is typically burned to generate heat and electricity for the ethanol production process, making the operation more energy-efficient.
- **Molasses:** The thick, dark syrup left over after most of the sucrose has been extracted from the sugarcane juice. Molasses can be used as an additional feedstock for fermentation or sold as animal feed.
- **Vinasse:** The residual liquid left after distillation, which is rich in organic matter. It is often used as a fertilizer in sugarcane fields or treated for wastewater recovery.

7. Ethanol Purification and Storage

Once the ethanol is purified, it is typically stored in large tanks for distribution. Ethanol for fuel use is generally transported to blending facilities, where it is mixed with gasoline to produce E10, E85, or other ethanol-gasoline blends.

Key Advantages of Ethanol from Sugarcane

1. **High Yields:** Sugarcane has a very high sugar content (compared to other biomass sources), making it an efficient feedstock for ethanol production. The process is highly efficient in converting sugar into ethanol.