Ethanol Production From Agricultural Waste :- Corn

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Abstract

As per as daily life concerned whole universe requires energy, but most of the sources of energy we have used are non-renewable sources, particularly at today's condition we need renewable sources of energy to fulfill our requirements. So that agricultural waste is one of the most effective source of energy because ethanol plays an important role in satisfying the need of energy.

Ethanol is best alternative over non-renewable petroleum products while corn stalk is suitable agricultural waste for ethanol production.

Corn stalks are initially pretreated to make it more suitable and productive for saccharification and fermentation to yield of ethanol. α-amylase enzyme and Saccharomyces Cerevisiae are used for saccharification and fermentation respectively. Then finally through separation and purification pure ethanol is obtain to fulfill our requirements of energy.

Keywords - Saccharomyces Cerevisiae, α-amylase, Agricultural waste, Corn stalks, Ethanol, Renewable

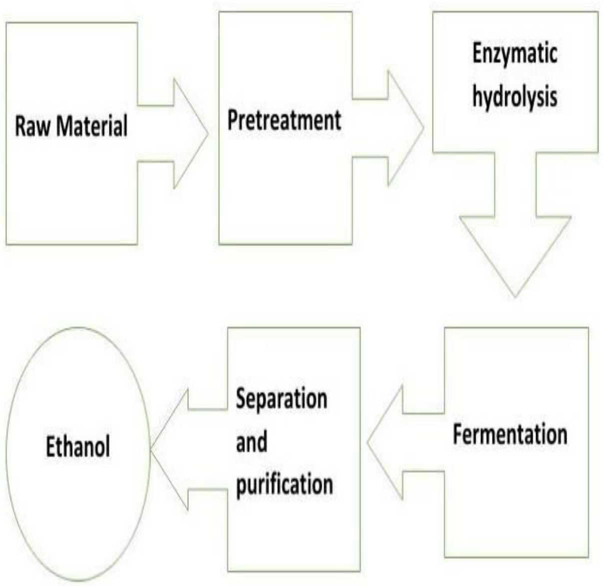
Introduction

Now days energy is the most important factor for the successful growth of the world. If we just view towards petroleum costs, it's abundance, it's effect on environment and our dependence on it. Then we can clearly say that, petroleum products are very costly, their abundance falls expeditiously and our dependence on its increase rapidly. So from above situation it is clear that, we need to find new and renewable source of energy to fulfill our requirements and this source of energy is "Bio-fuel". Biofuel is the way through which we can successively tackle our energy problems.[1]

Ethanol is most important Bio-fuel in today's generation as it causes less pollution, it is renewable, cheaper in cost and it has high octane number (99) than petrol (80-100) because of this preignition doesn't occurs. Today ethanol is widely use as competitive additive with gasoline/petroleum products and rarely in pure form. [2][3]

Ethanol can be produced from any agricultural waste like sugarcane baggage, corn stalks, cotton stalks, corn stoves, rice husk, rice straws, wheat straws etc.

[4]. Agricultural waste contains lignocellulosic biomass, 'lignocellulosic biomass' is a combination of cellulose, hemicellulose and lignin [5]. Cellulose and hemicellulose togetherly known as 'Holocellulose'. These holocellulose are complex carbohydrates further converted into ethanol, and lignin is a hard covering over the holocellulose [6]. Lignin act as a barrier in the conversion of holocellulose to ethanol. By using pretreatment method, it will easily remove and then holocellulose are converted into ethanol through enzymatic hydrolysis and saccharification and fermentation.[7] This is a review paper based on corn stalk base ethanol production using alpha-amylase enzyme and saccharomyces cerevisiae micro-organism for fermentation. This paper also gives valuable and proper information about various pretreatment methods saccharification and fermentation methods previously used.



Flow Diagram of Ethanol Production

Raw Material

There are several types of raw materials available because of the presence of different types of agricultural waste like, sugarcane bagasse, corn stalks, cotton stalks, corn stoves, rice husk, rice straws, wheat straws etc. [4] Selection of raw material is completely depending upon the composition of cellulose, hemicellulose and lignin. Inside the lignocellulosic biomass, as cellulose and hemicellulose are further converted into ethanol so their composition must be higher while lignin offer resistance so its composition must be lower in our selected raw material. Corn stalks is one of the best and widely available raw material, which contains 40-62% cellulose, 19.3-30% of hemicellulose, 6.9-21% lignin 10.8-24.9% ash, and 1.5-1.8 % of proteins.[8]

Pretreatment

There are two major problems related to the lignocellulosic material these are, it contains lignin which is hard covering offers resistance to the conversion process require to generate fermentable sugar and second major problem is the degree of crystallinity of cellulose.

A suitable pretreatment is essential to get success in subsequent steps of saccharification and fermentation. The main goal of pretreatment process is to break the lignin seal and disrupt the crystalline structure of cellulose [9]. Pretreatment is responsible to separate the component of lignocellulosic biomass, reducing the crystallinity of material, making the cellulose accessible and removing the lignin [10].

Types of Pretreatments: -

- Physical pretreatment
  a) Drying
  b) Grinding
  c) Granulometric separation [11]

- Thermo-Chemical pretreatment

a) Steam explosion
b) Alkaline pretreatment
c) Acid hydrolysis
d) Ammonia fiber expansion
e) Liquid hot water [11]

Physical Pretreatment: -

Drying: -

Drying is the removal of volatile substance usually water from solid material through thermal evaporation. The moisture content of material is related to its water. Drying reduces water activity, thus preventing determination, microbial growth, chemical redox processes and reducing enzymatic activity [12]. The corn stalks contain 47% to 66% of moisture as compared to whole plant which can be removed using different kinds of dryers.[13]

Grinding: -

It is the unit operation of size reduction in which the size of solid material reduced by impact, compression or by shear. The advantages of grinding are A) the

ratio of surface. B) standardizing the particle size C) improving the homogeneity [14][15]. By increasing size surface/volume ratio the substrate or raw material becomes easy to digest for micro-organisms. Large size of particle of biomass are crushed first using crusher and then grinded or milled to produce smaller size partials [15].

Granulometric separation: -

In granulometric separation, previously grinded biomass particles are separated from each other and on the basis of their size using series of sieves with mesh progressively smaller under vibration. Best production reached with particle size between 1.2-1.6 mm [16].

Thermo-Chemical Pretreatment: -

Steam Explosion: -

It is widely used method for pretreatment of lignocellulosic biomass using vapor and in some cases catalyst is used [17]. The grinded biomass is subjected to the high-pressure saturated steam at temperature varying from 160 to 260ºc and pressure from 0.69 to 4.3mpa. Then after 2-30 minutes the reactor is suddenly decompressed which makes the material undergoes an explosion. It disrupts material structure and make degradation of hemicellulose, cellulose and lignin. Thus biomass is ready for hydrolysis to achieve ethanol [18].

Alkaline pretreatment: -

Dilute NaOH is used for this method. Dilute NaOH pretreatment of lignocellulosic material causes swelling, leading to the increase of material internal surface area, decrease in degree of polymerization, decrease the cellulose crystallinity degree, separation of structural linkage between lignin and carbohydrates and disruption of lignin structure.[17][19].

Acid hydrolysis: -

Dilute acid hydrolysis is an effective Thermo-Chemical pretreatment process to improve lignin separation and it is an efficient method to produce reducing sugar from holocellulose. Sulfuric acid is most commonly used in this pretreatment method [20]. Other reagents such as hydrochloric, nitric and phosphoric acids are also used [21].

Ammonia fiber expansion:

It is the process in which liquid ammonia is added to the biomass under pressure of 0.7 to 27 MPA and temperature 70-200^{o}c before rapidly releasing the pressure [22]. This process does de-crystallization cellulose, hydrolyze hemicellulose, remove lignin and increase the number and size of micropores in the cell wall. Due to which the rate of enzymatic hydrolysis increases significantly.[9]

Liquid hot water: -

It is the process in which a biomass is thermally treated using water only without any chemical. In this process lignin start solubilizing in hot water at 200^{o}c temperature but because of its high reactivity degree, it recondensed and causing rapid precipitation method facilitating lignin removal and enzymatic cellulose hydrolysis.[11]

Enzymatic hydrolysis and saccharification: -

The main aim of using enzyme is to catalyze the reaction. The enzymatic hydrolysis is essential because of highly crystalline structure of cellulose. Enzymatic hydrolysis and saccharification breakdown this crystalline structure and convert cellulose which is complex sugar into simple sugar molecule further in fermentation it will converted into ethanol.[23] Enzymatic hydrolysis and saccharification a is typically perform at pH 5 and 50^{o}c temperature for 24 -120 hours, which is then followed by addition of a fermentation organism to achieve production of

Ethanol [24]. There are several types of enzymes are available for enzymatic hydrolysis and saccharification, some common enzymes use for this process are alpha-amylase, Trichoderma reesei, term-amyl enzyme, cellulase enzyme etc.

Fermentation: -

Fermentation is the process achieve by using micro-organisms. Those convert simple sugar into ethanol using anerobic digestion. There are many organisms are available for fermentation but commonly used organisms are saccharomyces Cerevisiae. It gives more conversion of sugar into ethanol. Fermentation process takes 4-5 days for completion and temperature required for it is ranges from 30-40^{o}c [25]. There are two methods through which enzymatic hydrolysis and saccharification and fermentation are done are

a) Separate hydrolysis and fermentation.
b) Simultaneous saccharification and fermentation.

Separate hydrolysis and fermentation: -

It is the process in which hydrolysis is followed by fermentation. Here the hydrolyzed stream is passes from hydrolysis reactor to fermenter to which the yeast is added to convert the glucose into ethanol.[26]

Simultaneous saccharification and fermentation:

It is the process in which saccharification and fermentation are occur in same reactor simultaneously. Initially the biomass added to reactor then enzymes for hydrolysis and saccharification along with micro-organisms for the fermentation.[26]

Separation and purification

Distillation: -

It is the unit operation use for separation of two or more substances from each other. Simple distillation is use for separation of ethanol from ethanol and water mixture. Before distillation, filtration of biomass is done. As we increase the temperature of sample above the fermentation temperature activity of micro-organisms stops as temperature reaches at 78.3^{o}c ethanol gets evaporate from mixture and further condensed to get pure ethanol.[27]
Simple distillation can give 95% of pure ethanol concentration which is just below the azeotrope.[28]

Molecular sieve drying: -

Molecular sieve is made of zeolite having 3 A^0 pore size. This pore size is large for water molecules (2.8A^0)but it too small for ethanol molecule (4.4 A^0). Zeolite has large water adsorption capacity it can be adsorb up to 22wt% of water. In this way, water and ethanol mixture separated.[28]

Pressure swing distillation: -

In this method distillation pressure is less than atmospheric is used which causes the ethanol-water azeotropes to shift to more ethanol rich mixture. Hence distillation 1st yields an ethanol-water mixture containing more than 96% ethanol. The mixture is again distilled at atmospheric pressure to obtain pure ethanol.[28]

Discussion

In this review the biomass used for production of ethanol is cornstalk. Initially it is pretreated for the purpose of lignin removal and reducing its crystallinity. Now a days, it is a big challenge to remove significant lignin from the biomass as it can restrict the holocellulose conversion to ethanol by avoiding enzymes and micro-organisms from digestion of biomass[4].According to this paper there are two processes of ethanol production i.e. Separate hydrolysis and fermentation (SHF) and simultaneous saccharification and fermentation (SSF).In SHF the glucose yield is typically low due to end product inhibits the hydrolysis step by glucose and cellulose. Where in SSF higher ethanol yield attributed to the removal of glucose and cellulose by fermentation avoiding the hydrolysis inhibition.[26]

Conclusion: -

The main aim towards making this review paper is to show that, the ethanol is most important fuel in today's time and it can be produced from agricultural waste mainly from cornstalk. Secondary aim of making this paper is to represent the different types of pretreatments, fermentation and separation techniques. Also, to introduce with the challenge regarding ethanol production.

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