International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 12, Issue 2 (February 2016), PP.60-66

Ethanol Production by Simultaneous Saccharification and Fermentation using Co-culture and Maximising Efficiency by Channelizing the By-Products and Its Subsequent Application as an Alternative Fuel.

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Abstract:- Our aim is to design a bio-waste to ethanol converter which is a portable ethanol-micro refinery system that is suitable for the present scenario that is cost effective, safe and easy to operate. The intension is to develop a consumer friendly product that can produce an environment friendly alternative fuel form cellulosic waste thus serve the purpose of recycling as well.

The way ethanol converter works is simple. The user gives the waste (cellulosic waste) to the fermentation tank. The sensors determine the amount of water needed for fermentation and temperature is maintained by heating and cooling devices. After the fermentation is done, distillation is followed to separate alcohol and then this alcohol is sent to the storage units.

Keywords:- portable ethanol-micro refinery system, cost effective, consumer friendly, environment friendly, cellulosic waste, alcohol (ethyl alcohol)

I. INTRODUCTION

The present world is facing an energy crisis with constant and rampant depletion of the fossil fuel resources. The increased dependency on gasoline and diesel as the only available energy resources has led to many hazardous and life-challenging situations such as global warming, fuel degradation, environmental pollution etc. This calls for an urgent and effective solution to the catastrophic problems faced by the world today. Another critical problem is waste generation and its decomposition. Organic waste amounts to 48% of the overall waste generated. It accounts to about 450 million tons of the overall waste pile up of the whole world. Now, this waste can act as a resource if put through proper chemical processes.

Fig. 2: Wastes generated shown in the form of pie chart.

II. ETHANOL AS A FUEL

Ethanol is a clean fuel that has the chemical formula C_2H_5OH. Ethanol acts as a good fuel because it has a higher calorific value and also has a high octane number which makes it a viable option for usage as a fuel in accordance with other sources of energy. . It has a calorific value of **29700KJ/Kg** as compared to **41800 KJ/Kg** of diesel. It is also non-corrosive. It is a superior fuel as compared to gasoline. It doesn't has a harmful impact on the environment. So, Ethanol can be considered as the future fuel that can be efficiently produced and consumed in a large scale.

III. INNOVATION

The present technologies and plants available are large-scale and have no-scope for in-home production and its latter consumption. The plants are also sophisticated and take up a large surface area for its production. The efficiency of the plants is very low and average efficiency lies from 25-30%.The innovation required are small-scale production of ethanol with higher efficiency and less slurry deposit, a process that consumes less area and also is economically viable. . The plant we have designed incorporates all these requirements and also has provision for greater control of parameters and wide usage of the produced fuel. All the above can be achieved by the proper channelling of the waste resources and its proper conversion to viable energy resources. It is achieved by the fermentation with hybrid distillation to produce Ethanol and the subsequent channelling of the waste sources to produce electricity and consumption in automobiles. It also utilizes the waste carbon dioxide to produce greater ethanol output.

IV. BIO-DEGRADABLE WASTES FOR ETHANOL PRODUCTION

The substances used for production of Ethanol are commonly available waste materials. Generally products rich in residual sugar, alcohol, fermentable substances i.e., dairy products, distressed fruit, candies, etc. as well as cellulosic materials and even algae can be used for the production. The use of sugarcane waste increases the output by 6 times. All kinds of vegetable waste, grass trimmings and cellulosic waste can be used as raw products for the production of ethanol.

A. Pre-treatment Process

The bio-degradable waste has to be pre-treated to decrease the particle size to enhance its compatibility with the system and also to spruce up the overall output of the process. The reduction in particle size is required for the efficient removal of hemi-cellulose, a deterrent of the reaction which has fibrous and meshed structure that prevents the process from reaching its maximum possible efficiency. This pre-treatment process can be achieved by mechanical treatment and acid treatment. In mechanical treatment the wastes are reduced in size by using grinders by pounding them into smaller and smaller size through a combination of simple shear and compression forces. .Increases the surface area of the material and therefore the area of contact with microbes for efficient conversion to end products. The reduction in particular size increases the surface contact of the cellulose material. The second method is acid treatment. The grounded waste is treated with Acid pre-treatment involves the use of concentrated and diluted acids to break the rigid structure of the lignocellulose material. The most commonly used acid is dilute sulphuric acid (H2SO4), which has been commercially used to pre-treat a wide variety of biomass types—switch grass , corn Stover , Due to its ability to remove hemicellulose, acid pre-treatments have been used as parts of overall processes in fractionating the components of lignocellulose biomass . This chemical pre-treatment usually consists of the addition of concentrated or diluted acids (usually between 0.2% to 2.5% w/w) to the biomass, followed by constant mixing at temperatures between 130°C and 210°C. Depending on the conditions of the pre-treatment, the hydrolysis of the sugars could take from a few minutes to hours .This is followed by neutralization of the sulphuric acid using sodium hydroxide solution. The process ensures the complete breakdown of the cellulosic material.

Fig. 2: Figures showing the grounding and acid treatment of the wastes.

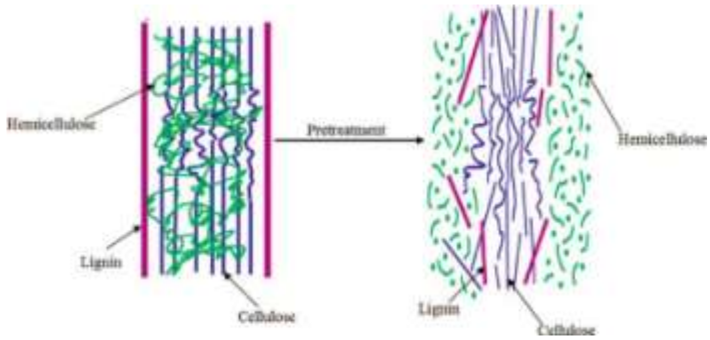

Fig. 3: Figure showing the structure of the cellulose after acid treatment.

V. SIMULTANEOUS SCARIFICATION AND FERMENTATION

A. Saccharification

Aspergillus Niger is used for production of celluloses in optimum quantities in about 96 h. The fungi as enzyme sources have many advantages that, the enzymes produced are normally extracellular, making easier for downstream process. The development of economically feasible technologies for cellulose production and for the enzymatic hydrolysis of cellulosic materials will enable to utilize the large quantities of biomass such as the residues of both food industries and agriculture. Cellulose is any of several enzymes produced chiefly by fungi, bacteria, and protozoans that catalyse cellulolysis, the decomposition of cellulose and of some related polysaccharides; specifically, the hydrolysis of the 1, 4-beta-D-glycosidic linkages in cellulose, hemicellulose, lichenin, and cereal beta-D-glucans. Celluloses break down the cellulose molecule into monosaccharaides ("simple sugars") such as beta-glucose, or shorter polysaccharides and oligosaccharides.

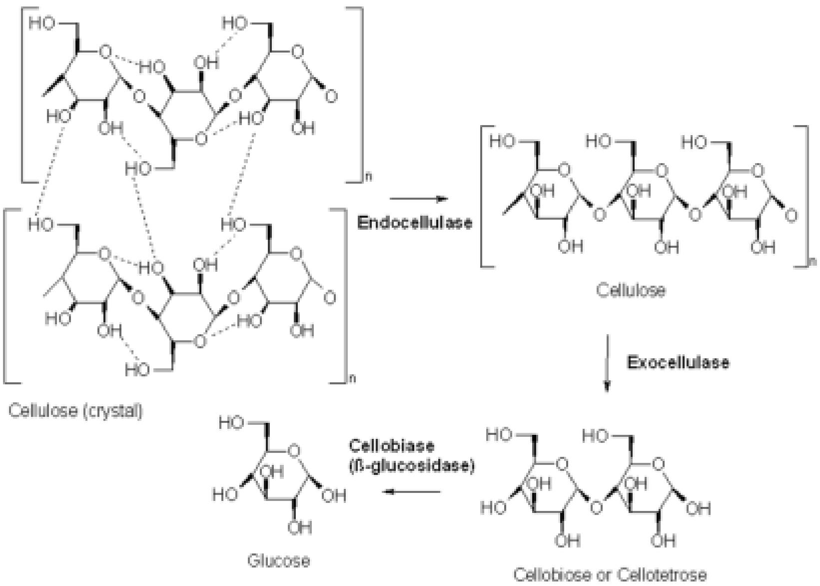

Fig. 4: Figure showing the after effect of the saccharification on the cellulosic wastes.

B. Fermentation

Yeast –Saccharomyces cerevisiae acts as a catalyst as well as a degenerating agent of the monosaccharaides prevalent after the saccharification process. This process in an exothermic reaction and results in the expulsion of a huge amount of heat. Alcoholic fermentation, also referred to as ethanol fermentation, is a biological process in which sugars such as glucose and sucrose are converted into cellular energy and thereby produce ethanol and carbon dioxide as metabolic waste products. Because yeasts perform this conversion in the absence of oxygen, alcoholic fermentation is considered an anaerobic process. Fermentation becomes the primary source of ATP energy production. Ethanol fermentation produces harvested by-products such as heat, carbon dioxide, food for livestock, and water.

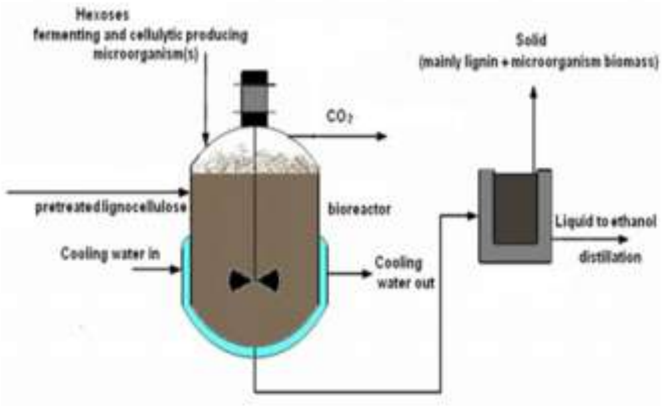

Fig. 4: A flow process of fermentation followed by ethanol production is shown.

C. Hybrid Distillation

After fermentation the liquid solution is filtered out, heated and passed through hybrid distillation apparatus. Obtained Ethanol mixture heated and vaporized and passed through a distillation column. After distillation in distillation column it is membrane distilled to produce concentrated ethanol and the separated ethanol is then stored in storage tank after condensation or cooling.

D. Fractional Distillation

Fractional distillation is the separation of a mixture into its component parts, or fractions, such as in separating chemical compounds by their boiling point by heating them to a temperature at which one or more fractions of the compound will vaporize. It is a special type of distillation. Generally the component parts boil at less than 25 °C from each other under a pressure of one atmosphere. As an example consider the distillation of a mixture of water and ethanol. Ethanol boils at 78.4 °C while water boils at 100 °C. So, by heating the mixture, the most volatile component (ethanol) will concentrate to a greater degree in the vapour leaving the liquid. Some mixtures form azeotrope, where the mixture boils at a lower temperature than either component. In this example, a mixture of 96% ethanol and 4% water boils at 78.2 °C; the mixture is more volatile than pure ethanol. For this reason, ethanol cannot be completely purified by direct fractional distillation of ethanol-water mixtures.

E. Membrane Distillation

Membrane distillation is a thermally driven separation process in which separation is enabled due to phase change. A hydrophobic membrane displays a barrier for the liquid phase, letting the vapour phase (e.g. water vapour) pass through the membrane's pores. The driving force of the process is given by a partial vapour pressure difference commonly triggered by a temperature difference. These membranes are made of hydrophobic synthetic material (e.g. PTFE, PVDF or PP) and offer pores with a standard diameter between 0.1 to 0.5 µm. As water has strong dipole characteristics, whilst the membrane fabric is non-polar, the membrane material is not wetted by the liquid. Even though the pores are considerably larger than the molecules, the liquid phase does not enter the pores because of the high water surface tension.

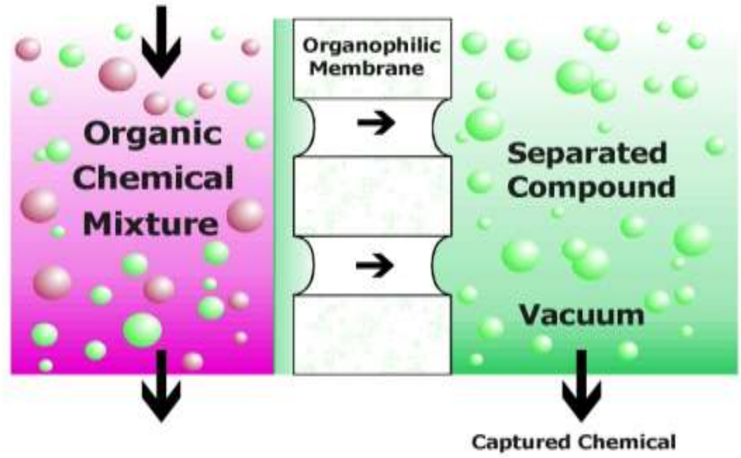

Fig. 5: A schematic representation of membrane distillation.

Photosynthesis

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

carbon dioxide + water ⟶ glucose + oxygen

Fig. 6: Equation depicting the process of photosynthesis.

VI. PLASTIC PLATE PHOTO-BIO REACTOR

Another development approach can be seen with the construction based on plastic or glass plates. Plates with different technical design are mounted to form a small layer of culture suspension, which provides an optimized light supply. In addition, the more simple construction when compared to tubular reactors allows the application of cheap plastic materials.

The microalga Porphyridium cruentum (Rhodophyta) is a potential source for several products like fatty acids, lipids, cell-wall polysaccharides and pigments. The polysaccharides of this species are sulphated and their structure gives rise to some unique properties that could lead to a broad range of industrial and pharmaceutical applications. Additionally, P. cruentum biomass contains carbohydrates of up to 57 % have been reported. Thus, the combined amount of carbohydrates in biomass and exopolysaccharides of this microalga could potentially provide the source for bio-fuel.

Light As with all plants, algae photosynthesize, i.e. they convert carbon dioxide into organic compounds, especially sugars, using the energy from light. Light may be natural or supplied by fluorescent tubes. Too high light intensity (e.g. direct sun light, small container close to artificial light) may result in photo-inhibition. Also, overheating due to both natural and artificial illumination should be avoided. The pH range for most cultured algal species is between 7 and 9, with the optimum range being 8.2-8.7.

Aeration and mixing is necessary to prevent sedimentation of the algae, to ensure that all cells of the population are equally exposed to the light and nutrients, to avoid thermal stratification (e.g. in outdoor cultures) and to improve gas exchange between the culture medium and the air. The optimal temperature for phytoplankton cultures is generally between 20 and 24°C, although this may vary with the composition of the culture medium, the species and strain cultured .Salinities of 20-24 g/L have been found to be optimal.

Thus our system consumes the co2 that it produces to grow algae. The algal biomass is then separated and sent for acid pre-treatment to break down its polysaccharides and contribute in increasing production of ethanol.

VII. MAXIMIZING EFFICIENCY BY CHANNELIZING THE FORMED CARBON DIOXIDE

The CO_2 formed can act as a viable reactant for the production of ethanol, electricity and production of algae that spruce up the saccharisation and distillation reactions to increase the efficiency of the reactions.
The CO_2 being produced can be used for the following processes:-

A. Production of ethanol

By conversion of CO2 to carbon monoxide followed by thermo pyrolysis to ethanol

B. Production of electricity

Fuel cells which utilize C02 are currently in the research phase.

VIII. ADVANTAGES OF THE PROCESS

1) Ethanol is non-corrosive to car parts
2) A potential fuel, it can be produced from the commercial bakery, waste fruits, cellulosic waste materials and feedstock.
3) No engine modifications are required
4) It has a high shelf life.
5) Ethanol as a fuel is superior to gasoline.
6) Occupies less space and time for production is also very small.
7) Usage of sugarcane pulp or bagasse makes the process 6 times more efficient.

IX. COST REPORT

Table 1.The details and cost approximation of setting up a Ethanol Conversion Plant.

EQUIPMENT	MODEL NO. / SPECIFICATIONS	COST (IN RUPEES)
Ethanol Sensor	PS 2194	1000
Glucose Concentration Sensor	Texas Instruments	500
Thermocouple	Texas Instruments	375
Magnetic Float Sensor	Texas Instruments	695
PH Sensor	Texas Instruments	1400
Nitrogen Sensor	Texas Instruments	600
Phosphorus Sensor	Texas Instruments	800
Cost of Metal Fabrication	Aluminium Folds	6000
Cost of Various Manifolds	Aluminium Manifolds	4000
Overhead Charges	Transportation Etc.	3000
Overall Equipment Charges		18370
Superficial Cost		20000

The cost of the biodegradable waste to the Ethanol conversion Plant = RS. 20000(approx)

X. COST ESTIMATION OF PRODUCTION AND USE IN AUTOMOBILES

3KWH Of Electricity is used for producing 3.7845 litres of Ethanol
Cost of 1 Unit of Electricity – RS.6.00
Cost of 3 Units Of Electricity – RS.18.00
Cost Of 3.7845 Litres Of Ethanol - RS. 146.49
Average Mileage Using 1 Litre Of Ethanol – 33.7192 KMS
Average Mileage Using 3KWH of Electricity – 101.389 KMS
So Empirically, Using Rs 18, Average Distance Covered is 101.3 Km(approx)

Comparison With Petrol Engine
Average Cost For Running 100 kms Assuming 20 kmpl For Petrol Engine
Cost of 1 Litre Of Petrol – RS 73.47
Cost For 100 kms at 20kmpl Mileage – 73.47 X 5 = RS 367.35
So overall savings in Producing 1 Gallon of Ethanol – RS. 367.35 – 18 = RS.359.35
Assuming Overhead Charges and considering minimal Efficiency of the Plant at 20%
The overall cost would be Rs. 36 for 100 Kms of the Vehicle Run.

XI. CASE STUDY ON A FUEL EFFICIENT CAR RUNNING ON PURE ETHANOL

Mileage(Assuming)– 16.8 KMPL
Cost Analysis For Distance of 10000 Kms.
For 10000 Kms at the current Mileage -537 Litres of Petrol is Consumed.
Cost For 10000 Kms Run = 537 X 73.47 = Rs 39,453.39
Cost For Producing Ethanol at Minimal Efficiency of the plant – RS. 36 for 100 Kms of Vehicle Run
For 10000 Kms, Expenditure – Rs 3600
Overall Savings on 10000 Kms Run of the Vehicle – Rs 39453.39 – 3600 = Rs 35853.39
Savings Percentage = 90.87%
Assuming The Average Life Expectancy of the Plant as 20 Years.
Overall Savings In 20 Years – Rs 7, 17, 060

XII. CONCLUSION

1) The Ethanol Conversion Plant is Highly Efficient and provides an overall savings of 90.87%.
2) The Overall Savings Accounts to Rs.7,17, 060 and proves to be a highly cost effective and value for money model.
3) The Ethanol produced can be incorporated to produce Electricity from a generator to further spruce up the performance and make the model self-sufficient.
The process provides a viable solution to the energy crisis face by the world today. It tackles the problems of both the energy crisis and the waste generation of the organic and bio-degradable wastes. Ethanol acts as a viable solution for the future and could serve as a boon for the energy depletion scenario, faced by the world today. Also, the widespread applications associated with Ethanol makes the Ethanol production system, a striking change-maker in the energy management and waste disposal crisis faced by the world today.

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