Chapter

Bioethanol Production

Chakali Ayyanna, Kuppusamy Sujatha, Sujit Kumar Mohanthy, Jayaraman Rajangam, B. Naga Sudha and H.G. Raghavendra

Abstract

In recent decades, usage of biofuels as fossil fuel substitutes has increased. One method for lowering both crude oil use and environmental pollution is the production of ethanol (bioethanol) from biomass. This report offers an examination of the existing state of affairs and future prospects for biomass-to-ethanol. We examine different conversion routes from a technological, economic, and environmental standpoint. The main focus of this study is on the yield of ethanol from molasses in relation to the dilution ratio and the quantity of yeast used for fermentation while maintaining a constant fermentation temperature and time. In this investigation, the feedstock is sugarcane molasses. A thick by-product of turning sugar cane into sugar is sugarcane molasses. Consequently, sugarcane molasses and other agricultural byproducts are desirable feedstock for the manufacture of bioethanol. Agricultural wastes are cheap, abundant, and renewable. The least expensive strain for the conversion of biomass substrate is *Saccharomyces cerevisiae*. As a conclusion, it was found that the ethanol yield increased with an increase in yeast quantity, reaching an optimal yeast quantity before ethanol yield started to drop. The ideal ratio of molasses to water was found to be 1:2. The amount of fermentable sugars contained in the biomass has a significant impact on the output of ethanol.

Keywords: bioethanol, fermentation, feedstock, *saccharomyces cerevisiae*, sugarcane molasses

1. Introduction

The research for alternative energy sources is stimulated by the growth in the nation's renewable sources and the gradual depletion of oil resources [1]. Particularly, biomass is a renewable resource that is currently researched for the utilization of bioethanol as an additive or replacement with gasoline has been driven by concerns about global warming and the need to lower greenhouse gas emissions [2]. Bioethanol can also be used as a raw material in the manufacture of various chemicals, resulting in fully renewable chemical industry. Bioethanol is created by fermenting sugars derived from biomass. Sucrose (e.g., sugarcane, sugar beet) or starch (e.g., corn, wheat), or lignocellulosic material can be used as bioethanol feedstock (e.g., sugarcane bagasse, wood, and straw). The main ethanol producers in the world, the US and Brazil, employ corn and sugarcane as their respective feedstocks. The use of fossil fuels during the processing of sugarcane is far lower than that of corn, making it the most effective raw material for the manufacturing of bioethanol to date [3]. Additionally, there is still room for improvement in the sugarcane-based bioethanol manufacturing process, and large energy savings are conceivable.

Brazil, one of the world's top ethanol producers, has been using sugarcane as a primary input for the production of huge amounts of bioethanol for more than 30 years [4]. Large amounts of sugarcane bagasse are often created during the sugarcane processing (about 240 kg of bagasse with 50% humidity per ton of sugarcane), and this bagasse are presently burned in boilers to produce steam and power. It is now possible to have a surplus of bagasse thanks to improved cogeneration and optimization techniques for the bioethanol production process [5], which can be used as a fuel source for power production or as a raw material for making bioethanol and other biobased products [6]. Although sugarcane bagasse and other lignocellulosic materials have been the subject of intense research over the past few decades, it is still not economically feasible to produce bioethanol on an industrial scale [2]. To make hydrolysis a competitive technique, more research that takes into account process integration, increased fermentation yields, and integration of unit operations is still required [7, 8]. Hemicellulose, a mixture of polysaccharides primarily made of glucose, mannose, xylose, arabinose, lignin, and cellulose makes up the majority of lignocellulosic materials [1]. Sugarcane bagasse needs to be treated to produce fermentable sugars in order to be used as a raw material for bioethanol production [9]. To improve cellulose hydrolysis, lignin and hemicellulose must be separated from cellulose, cellulose crystallinity must be reduced, and the bagasse's porosity must be increased [10]. The Organogold procedure with diluted acid hydrolysis is one approach that might be used to accomplish that [11].

2. Bioethanol production

A gasoline substitute known as bioethanol (grain alcohol; C2H5OH (EtOH)) was used for transportation [12]. Globally, the amount of bioethanol produced has drastically increased [13]. Worldwide production of bioethanol climbed to 51,3 billion liters in 2006 from 45,98 billion liters in 2005 [2, 12]. Biomass-derived ethanol has been shown to be competitive with other liquid fuels on a large scale. The production method was refined and made practical by cellulose's enzymatic hydrolysis [9]. The creation of bioethanol from biomass was one method for lowering oil consumption and environmental contamination [12].

The production use of bioethanol is relevant to major national concerns like permanence, global climate change, biodegradability, municipal contamination, coal sequestration, national security, and the farm economy. It was obvious that production should be assessed in terms of economic factors, including farm-gate prices for biomass, logistic costs (transport and storage of biomass), the direct economic value of feedstocks taking into account byproducts, employment creation or maintenance, water requirements, and water availability [2, 12].

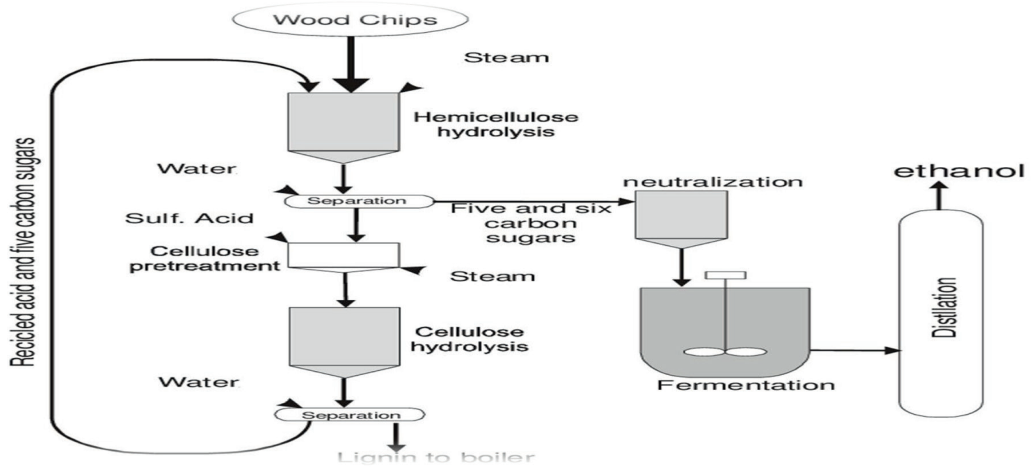
The comparison of the feedstocks for a given production line took into account a number of factors, including the chemical makeup of the biomass, cultivation methods, land availability and land use practices, resource use, energy balance, emission of greenhouse gases, acidifying gases, and ozone-depleting gases, mineral absorption into water and soil, pesticide injection, soil erosion, contribution to biodiversity, and landscape value losses [12]. Agricultural leftovers (such as corn stover and wheat straw), wood, and energy crops were all desirable raw materials for the synthesis of bioethanol [12]. The total amount of bioethanol that might be produced from such biomass was nearly 16 times greater than what is currently produced globally [14].

Arable agricultural starch and sugars were mostly used to make ethanol. Because it was pricey, the quest for other materials that would work for this purpose started [15]. Different processes were utilized depending on the type of biomass used to produce the bioethanol. It was difficult to bio-convert lignocellulosic biomass into fermentable sugars. The bioconversion of starch to sugars for the creation of bioethanol was more efficient and popular [16].

Through the hydrolysis and fermentation of sugars, biomass can be transformed into ethanol. Biomass wastes contain a complex mixture of cellulose, hemicellulose, and lignin, three carbohydrate polymers found in plant cell walls. In order to get sugars from the biomass, the biomass is first pre-treated with acids or enzymes to reduce the size of the feedstock and to open up the plant structure. Enzymes or weak acids hydrolyze the cellulose and hemicellulose components to produce sucrose sugar, which is subsequently fermented to produce ethanol. The biomass, which also contains lignin, is typically burned in the boilers of ethanol manufacturing facilities. The three main techniques for extracting sugars from biomass are as follows.

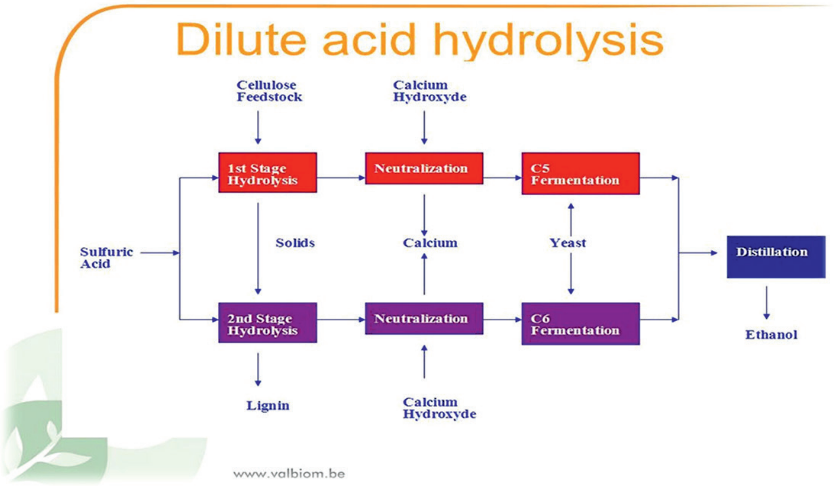
3. Method of intense acid treatment

The biomass needs to first be dried to a moisture level of 10% before the Alkanol process can begin, which involves adding 70–77% sulfuric acid. The temperature is kept at 50°C and the acid is added at a ratio of 1.25 acid to 1 biomass. The mixture is then heated to 100°C for another hour after the water is added to dilute the acid to 20–30%. The gel that results from this combination is then compressed to produce an acid-sugar mixture, which is purified to use a chromatographic column.



3.1 Acid hydrolysis in dilutes

One of the earliest, simplest, and most effective processes for generating ethanol from biomass is dilute acid hydrolysis. The biomass is hydrolyzed to produce sugar using diluted acid. The hemicellulose included in the biomass is hydrolyzed in the first step using 0.7% sulfuric acid at 190°C. An improved second stage results in a more robust cellulose fraction. By utilizing 0.4% sulfuric acid at 215°C, this is accomplished. Following neutralization, the liquid hydrolases are recovered from the process.

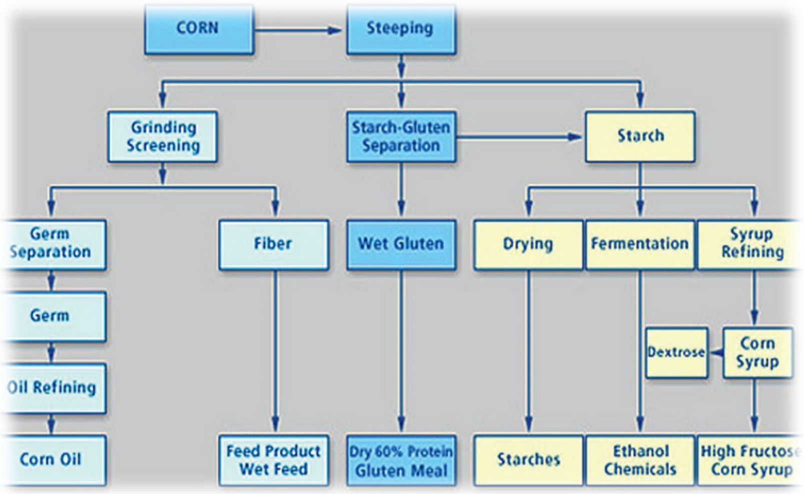


3.2 Enzymatic Hydrolysis

We can similarly break down the biomass using enzymes as opposed to utilizing acid to hydrolyze it into sugar. However, this procedure is still being developed and is highly expensive.

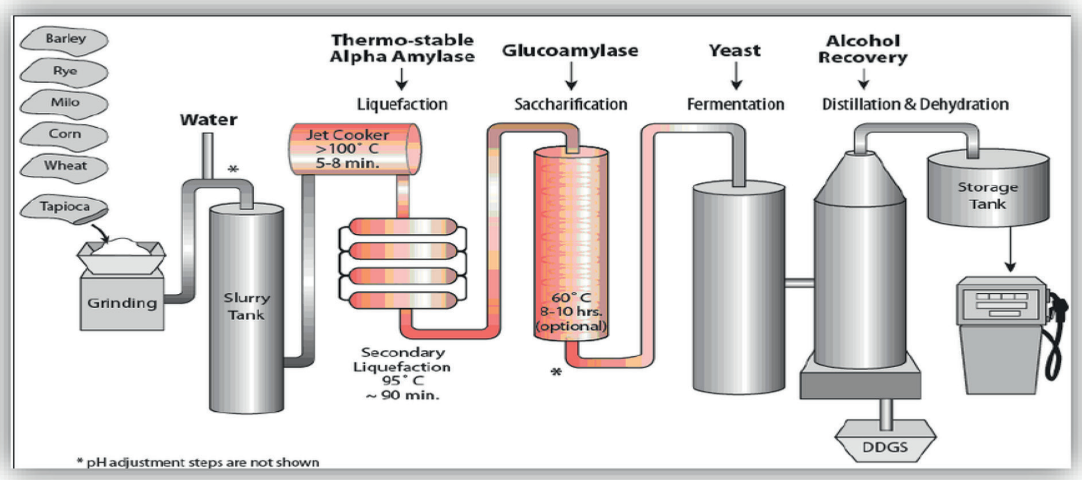
3.3 Wet milling processes

Corn can be processed into ethanol using either the dry milling or the wet milling method. The wet milling procedure involves soaking the maize kernel in warm water. This aids in the breakdown of the corn's proteins, the release of its starch, and softening of the kernel in preparation for milling. Then, the ground maize is used to make products with starch, fiber, and germ. A gluten-wet cake is made from the starch fraction after it has been centrifuged and saccharified; maize oil is then made by removing the germ. The next step is to extract the ethanol using the distillation process. The wet milling method is commonly applied in businesses that generate several hundred million gallons of ethanol annually.



3.4 Dry milling process

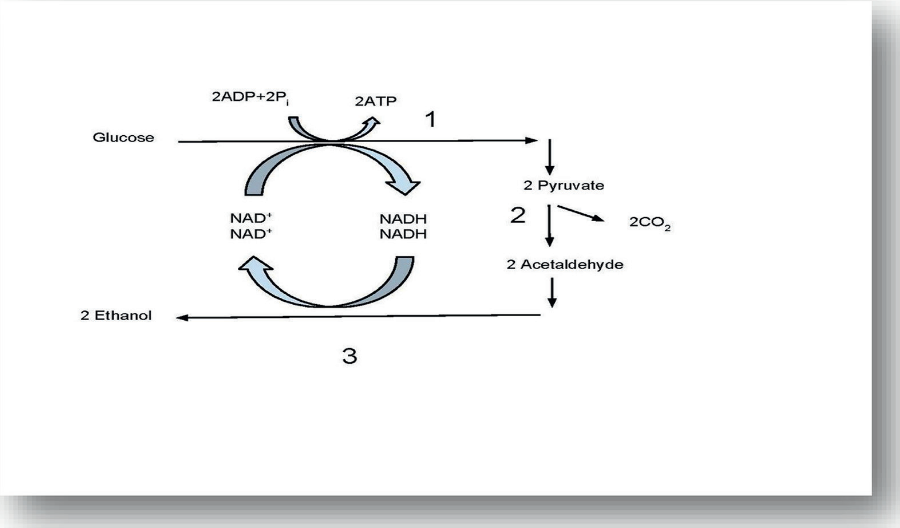
Using a hammer mill, the maize kernel is cleaned and reduced to tiny pieces for dry milling. This results in a powder with a consistency similar to a coarse flour. Maize germ, starch, and fiber make up the powder. The combination is hydrolyzed, or changed into sucrose sugars, using enzymes or a moderate acid to create a sugar solution. After cooling, adding yeast causes the mixture to ferment into ethanol. In facilities that annually produce fewer than 50 million gallons of ethanol, dry milling is frequently employed.



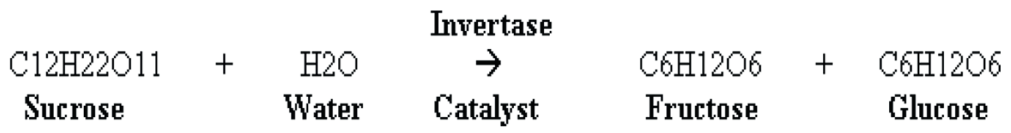
* pH adjustment steps are not shown

3.5 Sugar fermentation process

The cellulose component of biomass or corn is broken down during the hydrolysis process into sugar solutions, which can subsequently be fermented to produce ethanol. The mixture is heated after adding the yeast. Invertase, an enzyme found in yeast, serves as a catalyst and aids in the breakdown of sucrose carbohydrates into glucose and fructose (both $C_6H_{12}O_6$).



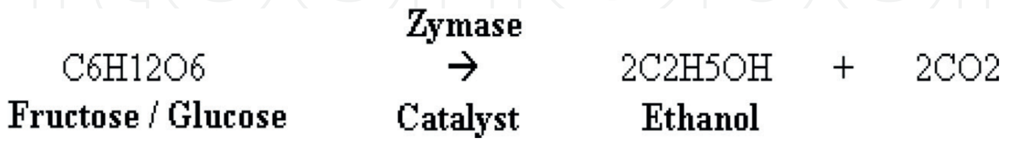
The chemical reaction is shown below



$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{Water}}{H_2O} \xrightarrow[\text{Catalyst}]{\text{Invertase}} \underset{\text{Fructose}}{C_6H_{12}O_6} + \underset{\text{Glucose}}{C_6H_{12}O_6}$$

A second enzyme called zymase, which is also present in yeast, then reacts with the fructose and glucose carbohydrates to create ethanol and carbon dioxide.

The chemical reaction is shown below:

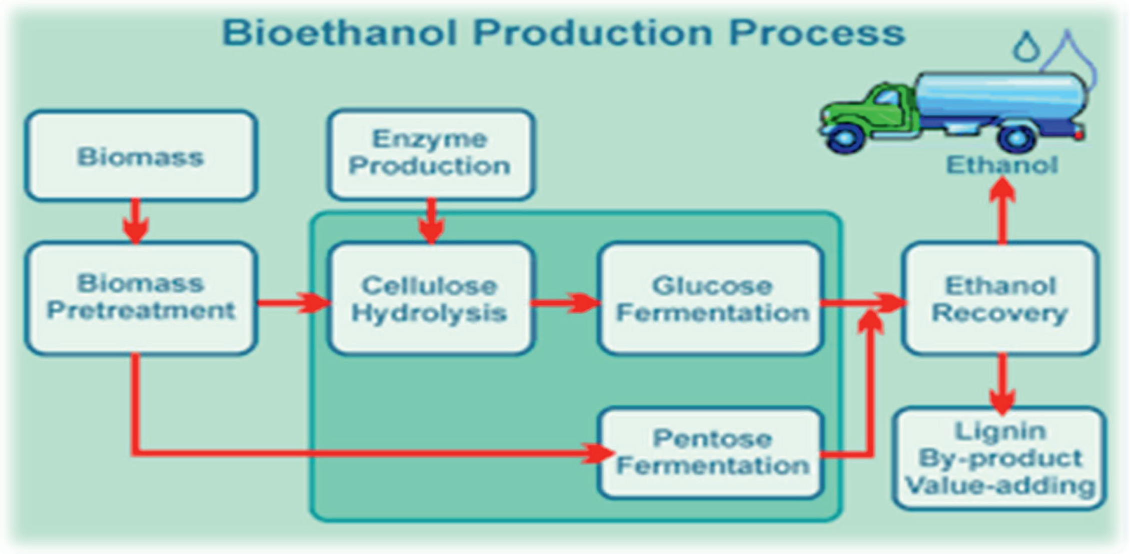


$$\underset{\text{Fructose / Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{Catalyst}]{\text{Zymase}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2$$

Between 250°C and 300°C, the fermentation process is carried out over the course of around 3 days.

3.6 Fractional distillation process

The fermentation process results in the production of ethanol, but there is still a sizable amount of water present that needs to be removed. Utilizing the fractional distillation method, this is accomplished. The mixture of water and ethanol is heated during the distillation process. The fact that ethanol has a lower boiling point than water (78.3 vs. 100°C) means that it can be separated and condensed before water does.



4. The possibility of using bioethanol

The performance of the vehicle would not be affected if bioethanol were used as a pure fuel or in a blend with other fuels in sufficient quantities to replace conventional motor fuels [17]. Without any adjustments, the mixture might be burned in a conventional combustion process. Gasohol was the most popular bioethanol-petrol mixture

(E10). 10% bioethanol and 90% gasoline were combined to create gasohol. Most contemporary automobiles with internal combustion engines (ICEs) were capable of burning E10 [12, 17]. The fuel blend E85, which is composed of 15% gasoline and 85% bioethanol, may also contain bioethanol [18]. About 5% of the ethanol created biologically was water. This blend was azeotropic. Because of this, ordinary distillation was insufficient to clean it. Gasoline and diesel fuel were not entirely blended with hydrated ethanol.

Bioethanol and diesel could be blended together by employing the right emulsifiers. Diesohol is a mixture of hydrated alcohol with diesel oil with an emulsifier. Diesel, hydrated ethanol, and a 0.5 percent emulsifier were used to make diesohol [17]. Ethanol was used as gasohol or clean fuel in Brazil (24% bioethanol and 76% gasoline) [12, 19]. The EN228 standard allows for the use of bioethanol as a 5% blend of gasoline in the European Union [12, 20]. Bioethanol was an oxygenated fuel with 35% oxygen content. Lowering the amount of nitrogen oxide (NOx) and particle pollutants produced during combustion. Utilizing a bioethanol-fuel combination allowed for the decrease in greenhouse gas (GHG) output and oil consumption [12]. It was possible to increase the fuel's oxygen content by adding bioethanol to conventional gasoline, which increased fuel combustion and reduced exhaust pollutants such CO and unburned hydrocarbons [12, 16]. Bioethanol was added to gasoline to reduce environmental pollution and the use of fossil fuels. Because 1 liter of bioethanol could substitute for 0.72 liters of gasoline, using it as a gasoline substitute proved very cost-effective [14].

5. Conclusion

Bioethanol can be employed as a fuel source. Studies are now being done to advance biofuel producing technologies. Bioethanol manufacturing could be carried out using biomass as a raw source. The investigation mainly concentrated on the usage of biomass wastes. With the help of starch and lignocellulosic biomass, bioethanol was formed. Starch was transformed into bioethanol via three sequential steps: hydrolysis, fermentation, and product purification. Hydrolysis, fermentation, pretreatment, and purification were the four steps that were followed in order to produce bioethanol from lignocellulosic biomass. Pretreatment can be done physically, physiochemically, chemically and biologically. Each of these approaches has benefits and drawbacks. It played a crucial role in choosing the best pretreatment strategy. It was crucial to focus on the creation and application of suitable pretreatment techniques in addition to other phases of the synthesis of bioethanol.

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References

[1] Saxena RC, Adhikari DK, Goyal HB. Biomass-based energy fuel through biochemical routes: A review. Renewable and Sustainable Energy Reviews. 2009;**13**:167-178

[2] Balat M, Balat H, Öz C. Progress in bioethanol processing. Progress in Energy and Combustion Science. 2008;**34**(5):551-573

[3] Macedo IC, Seabra JEA, Silva JEAR. Green house gases emissions in the production and use of ethanol from sugarcane in Brazil: the 2005/2006 averages and a prediction for 2020. Biomass and Bioenergy. 2008;**32**(7):582-595

[4] Goldemberg J. Ethanol for a sustainable energy future. Science. 2007;**315**(5813):808-810

[5] Ensinas AV, Nebra SA, Lozano MA, Serra LM. Analysis of process steam demand reduction and electricity generation in sugar and ethanol production from sugarcane. Energy Conversion and Management. 2007;**48**:2978-2987

[6] Buddadee B, Wirojanagud W, Watts DJ, Pitakaso R. The development of multi-objective optimization model for excess bagasse utilization: A case study for Thailand. Environmental Impact Assessment Review. 2008;**28**:380-391

[7] Cardona CA, Sánchez ÓJ. Fuel ethanol production: Process design trends and integration opportunities. Bioresource Technology. 2007;**98**:2415-2457

[8] Zaldivar J, Nielsen J, Olsson L. Fuel ethanol production from lignocellulose: A challenge for metabolic engineering and process integration. Applied Microbiology and Biotechnology. 2001;**56**:17-34

[9] Mosier N, Wyman C, Dale B, Elander R, Lee YY, Holtzapple M, et al. Features of promising technologies for pretreatment of lignocellulosic biomass. Bio/Technology. 2005;**96**:673-686

[10] Kuo C-H, Lee C-K. Enhanced enzymatic hydrolysis of sugarcane bagasse by N-methylmorpholine-N-oxide pretreatment. Bioresource Technology. 2009;**100**:866-871

[11] Rossell CEV, Lahr Filho D, Hilst AGP, Leal MRLV. Saccharification of sugarcane bagasse for ethanol production using the Organosolv process. International Sugar Journal. 2005;**107**:192-195

[12] Balat M, Balat H. Recent trends in global production and utilization of bioethanol fuel. Applied Energy. 2009;**86**:2273-2282

[13] Koh LP, Ghazoul J. Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities. Biological Conservation. 2008;**141**:2450-2460

[14] Kim S, Dale BE. Global potential bioethanol production from wasted crops and crop residues. Biomass and Bioenergy. 2004;**26**:361-375

[15] Enguídanos M, Soria A, Kavalov B, Jensen P. Techno-economic analysis of Bio-alcohol production in the EU: A short summary for decision-makers. 2002

[16] Maria G, Chisti Y. Biotechnology-a sustainable alternative for chemical industry. Biotechnology Advances. 2005;**23**:471-499

[17] Demirbas A. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy Conversion and Management. 2008;**49**(8):2106-2116

[18] De Oliviera MED, Vaughan BE, Rykiel EJ Jr. Ethanol as fuel: Energy, carbon dioxide balances, and ecological footprint. Bioscience. 2005;**55**(7):593-602

[19] Demirbas A. Importance of biodiesel as transportation fuel. Energy Policy. 2007;**35**:4661-4670

[20] Malca J, Freire F. Renewability and life-cycle energy efficiency of bioethanol and bio-ethyl tertiary butyl ether (bioETBE): Assessing the implications of allocation. Energy. 2006;**31**:3362-3380