

Potential Use of *Jatropha Curcas* Stem for Ethanol Production

Fayemiwo Kehinde A.*[‡], Awojide Shola H.*, Beckley Comfort A*.

*Department of Chemical Sciences, Osun State University, PMB 4494, Osogbo, Nigeria

kehindefayemiwo@yahoo.com, olusholaawojide@yahoo.co.uk, beckleycomfort@yahoo.com

[‡]Corresponding Author; Fayemiwo, Kehinde A., Department of Chemical Sciences, Osun State University, PMB 4494, Osogbo, Nigeria, +2348067726800, kehindefayemiwo@yahoo.com

Received: 17.10.2012 Accepted: 13.11.2012

Abstract- Energy has a major impact on every aspect of our socio-economic in every country. However, the limited reserve of fossil fuel which constitutes the major energy sources has drawn the attention of many researchers to search for alternative fuels. In this study, the potential use of *Jatropha curcas* stem to produce ethanol was investigated. *J. curcas* stem is a lignocellulosic biomass which primarily consists of lignin, cellulose and hemicellulose. The materials were hydrolysed into fermentable monomeric sugars from hemicellulose and cellulose content of lignocellulosic biomass, in the medium of dilute tetraoxosulphate (VI) acid (1.5% H₂SO₄) at 100 °C for 15 minutes; followed by fermentation using a broth containing *Saccharomyces cerevisiae* supplemented with 22% (w/v) sugar, 1% (w/v) of each of ammonium sulfate and potassium dihydrogen phosphate, at pH 5.0 and 30°C for 4 days. During this process, both pentose and hexose sugars are fermented to ethanol under aerobic conditions; and ethanol was distilled from the fermented broth solution. The production of renewable fuels, especially ethanol from lignocellulosic biomass, holds remarkable potential to meet the current energy demand.

Keywords- *Jatropha curcas* stem, lignocellulosic, fermentation, biofuel, ethanol.

1. Introduction

There has been a global interest in developing a renewable energy source since the period of oil crisis which occurred in the mid 70's [1]. One possible solution to this was found in the use of lignocellulosic materials to produce ethanol; which is of a renewable energy source, with no net carbon dioxide added to the atmosphere, thus making it an environmentally beneficial energy source [2-3]. Ethanol as oxygenate usually has a higher oxygen content that implies a less amount of required additive [4]. Ethanol has greater octane booster properties, it is not toxic, and does not contaminate water sources [4]. The production of these biofuels can improve rural employment and diversify rural economics; and the widespread use of this fuel may increase energy security [5-6].

Extensive research has been carried out on the conversion of lignocellulosic materials to ethanol [7-12], but the complexity of the production depends on the feedstock [4]. To attain an economically feasible process, the production cost must be reduced so as to approach the

corresponding cost for fossil fuel [1]. The most common feedstock for the production of ethanol is raw sugar from sugarcane or sugar beet, or starch found in the grain of cereals [6]. These raw materials are competing with food supply to human or livestock and the production cost is higher. Demand for food will thus act as a constraint upon industry expansion, an issue which is exacerbated by the ongoing food-vs.-fuel debate [6].

In order to achieve a lower production cost and the issue of ongoing food-vs.-fuel debate, the supply of cheap, non-competing and readily available raw materials is thus a necessity to make fuel ethanol commercially viable compared to fossil fuel. Lignocellulosic materials such as agricultural waste (e.g. wheat straw, sugarcane bagasse, corn stover), forest products (hardwood and softwood), and dedicated crops (switch grass, salix) have been identified as a source for low-cost ethanol production [12-14]. Hence, the technology development focus for the production of ethanol has shifted towards the utilization of residual lignocellulosic materials to lower the production costs [15].

Lignocellulosic materials are composed of mainly cellulose, hemicellulose, and lignin [11]. There is various way of producing ethanol from lignocellulosic materials; the main components are: hydrolysis of the hemicellulose and the cellulose to monomer sugars, fermentation and product recovery and concentration by distillation. The main difference between the process alternatives is the hydrolysis steps, which can be performed by dilute acid, concentrated acid or enzymatically [1].

J. curcas plant has added advantages as rapid growth, suitable for tropical and subtropical regions of the world and it does not compete with arable land that would have otherwise being planted with food crops [16-18]. Though, previous research showed that the *J. curcas* stem contains high alpha-cellulose (42.99%) [19], there is no record in the use of *J. curcas* stem for bioethanol production in literature. It is against this background that the present work was carried out to investigate the potential use of *J. curcas* stem for ethanol production.

2. Materials and Method

2.1. Raw Materials Collection and Preparation

The *J. curcas* stems were obtained from matured and healthy trees of *J. curcas* L. at Oke Baale Area, Osogbo (7030'N, 4030'E), Osun State in South Western Nigeria. The stem was chipped to a size of 2 - 4 mm, and divided into two equal parts. The first part of the sample was dried in an oven at 100 oC for 5 hours while other part was used fresh.

2.2. Sample Pretreatment and Hydrolysis

Some of the important reasons for the pretreatment step are to (i) break the lignin-hemicellulose-pectin complex, (ii) disrupt/loosen-up the crystalline structure of cellulose and (iii) increase the porosity of the biomass. These changes in lignocellulosic materials make it easier for enzymatic saccharification (hydrolysis), results in higher fermentable sugars levels and will have a significant impact on the overall process [20-21].

About 1000 g of the samples (fresh and dried stem) were incubated in the medium of 5000 ml of water and 100 ml of dilute tetraoxosulphate (VI) acid (1.5% H₂SO₄) at 100 °C for 15 minutes [23]. This process hydrolyzed the hemicellulose into sugar monomers and this are recovered in the liquid fraction (filtrate) after filtration. The residuals solid (filtrand) contained cellulose and lignin.

The acid hydrolysis process is applied to lignocellulosic biomass in a two-step (stage) process after pretreatment, because the pentose sugars degrade more rapidly than hexose sugars [4]. In the first stage, hemicellulose is hydrolyzed with dilute acid under ambient conditions and the more resistant cellulose is hydrolyzed (0.4% H₂SO₄) at higher temperatures (213°C) in the second stage and incubated for 30 minutes. The goal of this process is to generate fermentable monomeric sugars from hemicellulose and

cellulose content of lignocellulosic biomass. The sample is filtered again to obtain the filtrate and filtrand. These steps were carried out for both dry and wet *J. curcas* stem (Figure 1).

2.3. Fermentation and Distillation

The filtrate (for both dried and fresh *J. curcas* stem) from the pretreatment and hydrolysis stage respectively were mixed together and was fermented using 100 ml broth containing *Saccharomyces cerevisiae* supplemented with 22% (w/v) sugar, 1% (w/v) of each of ammonium sulfate and potassium dihydrogen phosphate, at pH 5.0 and 30 °C for 4 days. During this process, both pentose and hexose sugars are fermented to ethanol under aerobic conditions. Ethanol was distilled from the fermented broth solution and the percentage of ethanol in the distillate was determined. Collected fractions were analyzed for ethanol percentage by optical density method using a colorimeter. The physico-chemical analysis of the ethanol obtained was then carried out for both dry and wet *J. curcas* stem respectively, and the results were statistically analyzed using SPSS 17.

3. Results and Discussion

The results revealed that ethanol from the fresh and dried stem have the flash point of 71.6 OF and 68 OF respectively (Table 1). The water by distillation was 0.003 % for fresh stem ethanol and 0.006 % for dried stem ethanol which is significantly not different. The sediment by extraction was 0.012 % and 0.004 % for fresh stem and dried stem ethanol respectively, thus, higher sediment is observed in the fresh stem ethanol, these values are not significantly different. Pour point was -4°C for fresh stem ethanol and -5°C for dried stem ethanol which is the minimum temperature at which the sample will flow. Fresh stem and dried stem ethanol both had cetane number of 5 showing the measure of ignition quality of the samples. Cloud point for fresh stem ethanol was 5 while dried stem ethanol was 6 which showed the temperature below which wax in sample form a cloudy appearance. The values of cetane number and cloud point for ethanol obtained from both fresh and dried stem are not significantly different.

The two samples had the same research octane number (RON) as 107 (a rating used to measure a fuels knocking resistance in spark-ignition internal combustion engines) which is not significant from that of standard ethanol (108). The Reid vapor pressure (RVP) for fresh stem was 2.46 psi while for dried stem ethanol was 2.17 psi, which is not significantly different; also not significantly different from that of standard ethanol (2.3). RVP is a measure of evaporative properties to help control fuel handling and emissions. The specific gravity was 0.998 and 0.982 for fresh and dried stem ethanol respectively. The two samples have good solubility in gasoline, this is important in case when a blend is needed. The flash point of ethanol obtained from both fresh and dried stem are 71.6 °F and 68°F, which is within the range of flammable substances (0°F to 100°F). The flash point is an indication of how easy a chemical may burn.

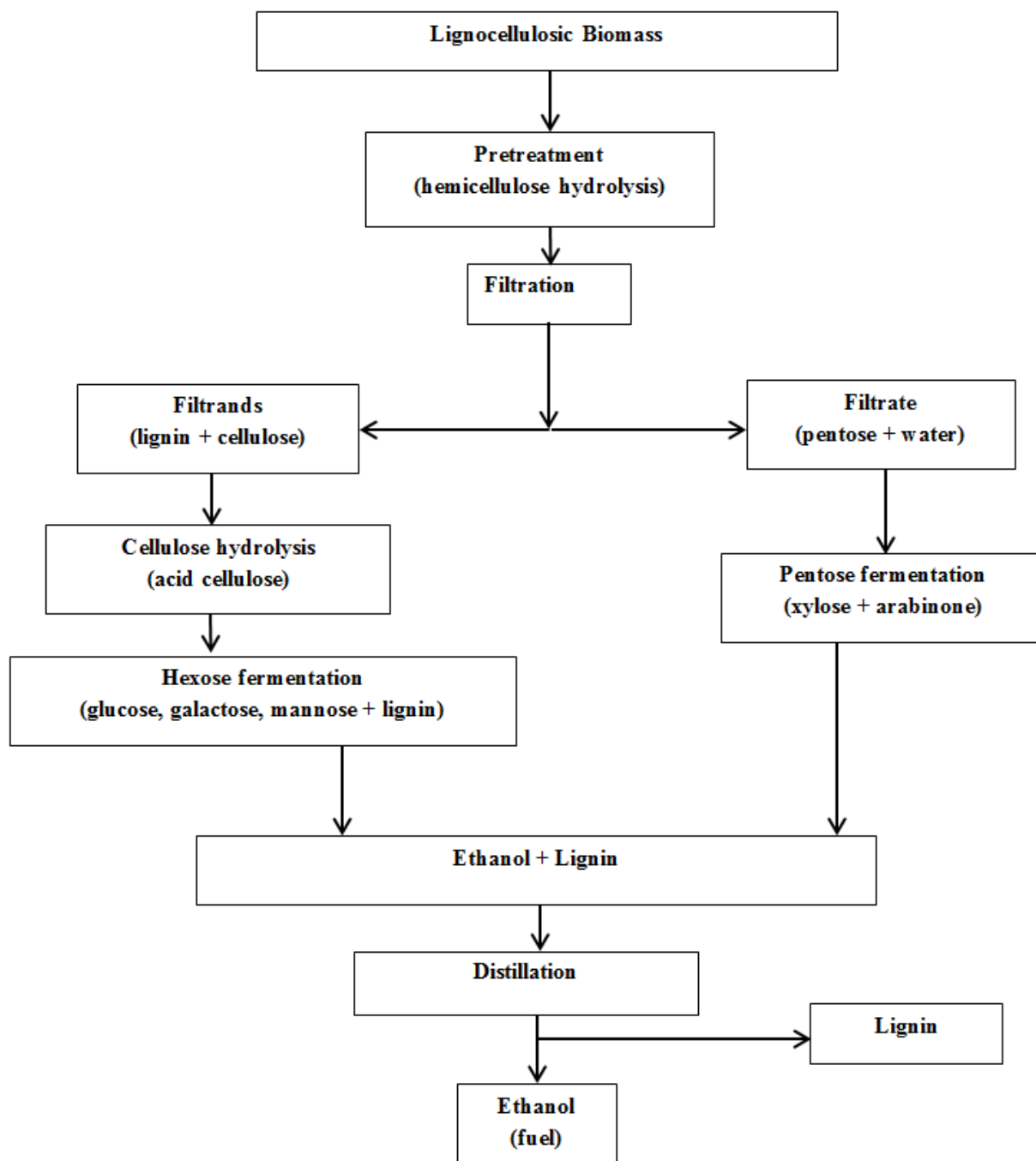


Fig. 1. Overview of the process of the ethanol production from lignocellulosic biomass (Joshi et al., 2011).

The percentage yield for ethanol from both fresh and dried stem is 16.667, out of 100 ml of fermented broth; we have 16.667 ml of ethanol. The heating value (caloric value) of ethanol obtained from both fresh (18.67) and dried stem (19.1) were relatively closed to that of standard ethanol (21.1).

The infrared spectrum graph for fresh stem (Figure 2) and dried stem (Figure 3) revealed the presence of alcohol at the band of 3395 cm^{-1} and 3365 cm^{-1} respectively. This is due

to the stretching of O-H bond. The bands 1637.73 cm^{-1} and 1637.96 cm^{-1} show the presence of carbon- carbon double bond respectively. Also, the bands 1393.71 cm^{-1} and 1388.23 cm^{-1} show deformation leading to the presence of aromatic rings at 567 cm^{-1} and 614.60 cm^{-1} respectively. The *J. curcas* used for this study was locally grown and sourced in Nigeria which is a tropical region as compared to other temperate region; this variation maybe a limitation which needs to be summoned for further studies.

Table 1. The physicochemical analysis of ethanol produced from *Jatropha curcas* stem (dried and fresh).

Parameters	Ethanol from Fresh Stem	Ethanol from Dried Stem	Standard ethanol*	Methods
Flash Point (PPMC)(°F)	71.6 ± 0.01 ^a	68 ± 0.05 ^b	55	ASTMD 93-10a (Pro. B)
Viscosity @ 100F (SUS)	386 ± 0.45 ^b	242 ± 0.95 ^a	-	ASTMD 2161
Water by Distillation (% Vol)	0.003 ± 0.00 ^a	0.006 ± 0.00 ^a	-	ASTMD 93-10
Sediment by Extraction (% W)	0.012 ± 0.00 ^b	0.004 ± 0.00 ^a	-	ASTMD 473-07
Cetane Index	30 ± 0.05 ^a	25 ± 0.01 ^a	-	ASTMD
Pour Point (°C)	-4 ± 0.03 ^a	-5 ± 0.01 ^a	-	ASTMD 97-11
Cetane Number	5 ± 0.01 ^a	5 ± 0.01 ^a	-	ASTMD 613
Cloud Point	5 ± 0.05 ^a	6 ± 0.02 ^a	-	ASTMD 2500 ASTMD 3117
Research Octane No.	107 ± 0.26 ^a	107 ± 0.30 ^a	108	ASTMD
Reid Vapour Pressure (psi)	2.46 ± 0.01 ^a	2.17 ± 0.00 ^a	2.3	
Specific Gravity	0.998 ± 0.00 ^a	0.982 ± 0.00 ^a	0.796	ASTMD
Percentage yield (%)	16.667	16.667	-	
Oxidation Stability 110°C, min	1hour	2 hours	-	EN14112
Solubility in Gasoline	Good	Good	Good	ASTMD

Mean values from triplicate measurements ± standard deviation. Values with different superscripts in the same row are significantly different (p < 0.05)

*Source: <http://www.afdc.energy.gov/afdc/fuels/properties.html>

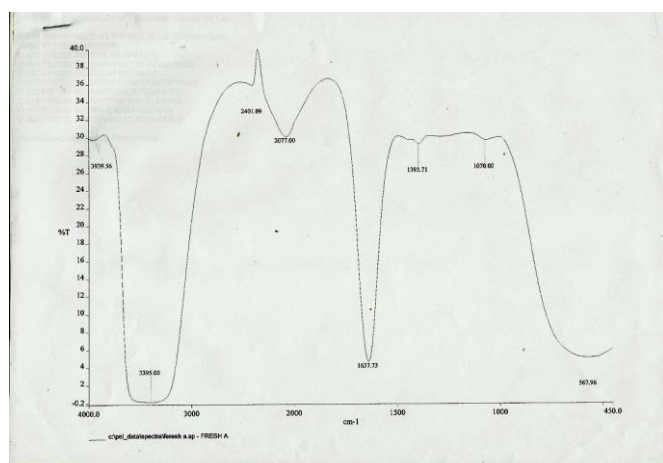


Fig. 2. IR representation of ethanol from fresh *Jatropha curcas* stem

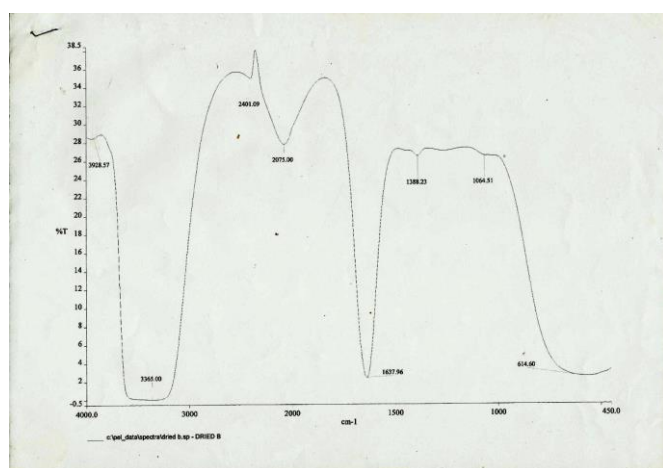


Fig. 3. IR representation of ethanol from dried *Jatropha curcas* stem

4. Conclusion

The study has shown that bioethanol can be obtained from both dried and fresh *J. curcas* stem. Some of the parameters from the bioethanol produced were comparable with that of standard bioethanol; these values obtained revealed that *Jatropha* stem (fresh and dried) is a potential source of bioethanol. There are still challenges that need further investigations; these include developing an innovative efficient process to obtain pure ethanol; and optimizing the process into economic production systems. We strongly believe that ethanol from *J. curcas* stem could serve as a cheap alternative source of energy to supplement the fuels being currently used; where Nigeria and the World could have a cleaner and environmental friendly combustion.

References

- [1] Galbe M, Zacchi G. A review of the production of ethanol from softwood. *Appl Microbiol Biotechnol* 2002;59: 618-28.
- [2] Olsson L, Hahn-Hagerdal B. Fermentation of lignocellulosic hydrolysates for ethanol production. *Enzyme Microbial Technol* 1996;18: 312-31.
- [3] Yu Z, Zhang H. Ethanol fermentation of acid-hydrolyzed cellulosic pryolysate with *Saccharomyces cerevisiae*. *Biores Technol* 2004;93: 199-204.
- [4] Sanchez OJ, Cardona CA. Trends in biotechnological production of fuel ethanol from different feedstock. *Biores technol* 2008;99: 5270-95.
- [5] Hillring B. Rural development and Bioenergy - experiences from 20 years of development in Sweden. *Biomass Bioenergy* 2002;23: 443-51.

- [6] Mabee WE, McFarlane PN, Saddler JN. Biomass availability for lignocellulosic ethanol production. *Biomass Bioenergy* 2011;35: 4519-29.
- [7] Reshamwala S, Shawky BT, Dale BE. Ethanol production from enzymatic hydrolysates of AFEX-treated coastal Bermuda grass and switch grass. *Appl Biochem Biotechnol* 1995;51/52: 43-55.
- [8] Wright JD. Ethanol from biomass by enzymatic hydrolysis. *Chem Engr Prog* 1998;84(8): 62-74.
- [9] Krishnan MS, Nghiem NP, Davison BH. Ethanol production from corn starch in a fluidized-bed bioreactor. *Appl Biochem Biotechnol* 1999; 77-79: 359-72.
- [10] Bothast RJ, Schlicher MA. Biotechnological processes for conversion of corn into ethanol. *Appl Microbiol Biotech* 2005;67: 19-25.
- [11] Pimentel D, Patzek TW. Ethanol Production Using Corn, Switch grass, and Wood; Biodiesel production using soybean and sunflower. *Natural Resou Resear* 2005;14: 65-76.
- [12] Dawson L, Boopathy R. Use of post-harvest sugarcane residue for ethanol production. *Biores Technolo* 2007;98: 1695-9.
- [13] Sun Y, Cheng J. Hydrolysis of lignocellulosic materials for ethanol production: A review. *Biores Technolo* 2002;83: 1-11.
- [14] Kumar P, Barrett DM, Delwiche MJ, Stroeve P. Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Ind Engr Chem* 2009;48(8): 3713-29.
- [15] Howard RL, Abotsi E, Jansen van Rensburg EL, Howard S. Lignocellulose biotechnology: Issues of bioconversion and enzyme production. *Afr J Biotechnolo* 2003;2: 602-19.
- [16] Achten WMJ, Verchot I, Franken YJ, Mathijs E, Singh VP, Aerts R. *Jatropha* biodiesel production and use. *Biomass Bioenergy* 2008;12: 200-16.
- [17] Carels N. *Jatropha curcas*: A review. *Adv Botan Research* 2009;50: 40-69.
- [18] Shuit SH, Lee KT, Kamaruddin AH, Yusup S. Reactive extraction of *Jatropha curcas* L. seed for production of biodiesel: process optimization study. *Environmental Sci. Technology* 2010;44(11): 4361-7.
- [19] Vaithanomsat P, Apiwatanapiwat W. Feasibility study on vanillin production from *Jatropha curcas* stem using steam explosion as a pretreatment. *Inter J Chem Biolo Engr* 2009;2(4): 211-4.
- [20] Sun FB, Cheng HZ. Evaluation of enzymatic hydrolysis of wheat straw pretreated by atmospheric glycerol autocatalysis. *J Chem Technolo Biotechnolo* 2007;82: 1039-44.
- [21] Yang B, Wyman CE. Pretreatment: The key to unlocking lowcost cellulosic ethanol. *Biofuel Bioprod Biorefin* 2008;2: 26-40.
- [22] Joshi B, Bhatt MR, Sharma D, Joshi J, Malla R, Sreerama L. Lignocellulosic ethanol production: Current practices and recent developments. *Biotechnolo Molecular Biol Review* 2011;6(8), 172-82.
- [23] Wingren A, Galbe M, Zachhi G. Techno-economic evaluation of producing ethanol from Softwood: Comparison of SSF and SHF and Identification of bottle necks. *Biotechnolo Prog* 2003;19: 1086-93.