Evaluation of the Thermolysis Process for the Production of Biofuel and Biochar from Sugarcane Bagasse

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ABSTRACT
Biochar and fuel made from sugarcane bagasse Thermal pyrolysis has the potential to take the place of energy sources originating from fossil fuels. The numerous conversion processes, such as gasification, torrefaction, and pyrolysis, have all been considered, although the latter has received more attention due to its viability when compared to the former. The conversion of the biomass by pyrolysis was carried out at a range of pyrolytic temperatures ranging from (300-500C) at a heating rate of 250C/min, and the ideal temperature was discovered at 450C, which was determined to be 53.3% of bio-oil. The liquid product, or bio-oil, was examined using a variety of characterization methods, including GC-MS, 1H-NMR, physical characteristics, and CHNS. The bio-characteristics oil's were determined to be appropriate for usage as fuel. The effect of temperature on the yield of bio-oil, bio-char, bio-gas & reaction time were studied & plotted which showed that the bio-char yield decreased with increase of the pyrolytic temperature. The potential of the bio-char produced from biomass was analyzed by proximate, ultimate, BET surface area, SEM-EDX, anion chromatography, pH, Electrical Conductivity& Zeta Potential studies. The carbon percentage was high enough to be used as a soil amendment, the surface areas were also found to be more with low surface area as 132m2/gm for 300C bio-char to 510 m2/gm for highest temperature bio-char. This high surface area attributed towards application of the bio-char in soil amendment purpose. The ion-chromatography results also showed the presence of anions that are required as nutrients for plants for their metabolic activities. It will also serve as a good source of plant nutrients since it contains less toxic elements. The bio-char had a slightly acidic surface as found from the pH study. Thus from the above studies we found that the bio-fuel and the bio-char can serve as a source of energy as well as chemical feedstock for the future todepend on.
Keywords: Sugarcane bagasse, bio-oil, bio-char, TGA, XRD, Proximate analysis, CHNS analysis, BET surface area, Electrical Conductivity.

INTRODUCTION

People have relied on biomass for their energy needs since the beginning of time. Advances in manufacturing were made possible by the discovery of crude oil. The term "biomass" refers to the biological material derived from living things, and it often refers to the ecosystem's flora, which includes plants and components mostly generated from plants. As biomass is a renewable source of energy, after being transformed into useful goods, it may be used either directly or indirectly. The primary energy sources used to meet the need for energy are coal, oil, and natural gas. As petroleum sources are getting depleted, and also there is a demand for petroleum products, so we have to develop economical and energy-efficient processes for the production of fuels. Thus, a dire need to put a control over its consumption has been felt by environmentalists and economists aswell, to examine renewable and less cost substitute to fossil fuel to meet their energy demand. In regards to this, a lot of research work is going on around the globe on various alternative sources of energy such as solar, wind, geothermal, hydrogen, nuclear, bio fuel or biomasses.The main source of biomass generally comes from the forestry products, agricultural crops and residues and biological wastes. The energy derived from the biomass generally helps reducing the carbon dioxide emission from the atmosphere thereby reducing the global warming effect. Since the carbon dioxide acts as a green house gas and increases the temperature of the atmosphere.

BIOMASS CONVERSION PROCESSPYROLYSIS

Pyrolysis is the thermal decomposition of biomass at modest temperatures in absence of oxygen. The steps in pyrolysis includes: feedstock preparation and introduction of the feed into the reactor, carrying out the reaction by absorption of heat or other addition of agents such as air, oxygen, steam, hydrogen, post combustion or processing of the gases produced during the reaction step, and proper guidance of the resulting liquids, char, and ash .Pyrolysis product basically consists of gases like CH_4, CO_2 ,and NH_3 and liquids like ethanol, bio-oils, acetone, acetic acid etc. and solid as char .The relative proportion of the output depends upon the process and process condition, characteristics of biomass, optimum temperature and residence time of material. In this process the biomass is heated to a temperature range with low residence time and rapidly cooled to collect the condensed liquid which is otherwise known as bio-oil.

Longer residence times and High temperatures increase biomass conversion to gas, and short vapor residence time and moderate temperatures are optimum for producing liquids. The most important features for pyrolysis to occur to give proper bio oil yield are:

1. A Temperature of around (400-500C) in order toproduce bio oil in maximum.
2. Finely ground biomass with about less than 3mmsize with high heatingrates.
3. Vapor residence times of about less than 2 sec tolessen the secondary reactions to occur.
4. The remaining bio-char must be removed so as toprevent the secondary cracking reactions.
5. The vapors are rapidly cooled to produce the bio oil as the intermediateproduct.

LITERATUREREVIEW

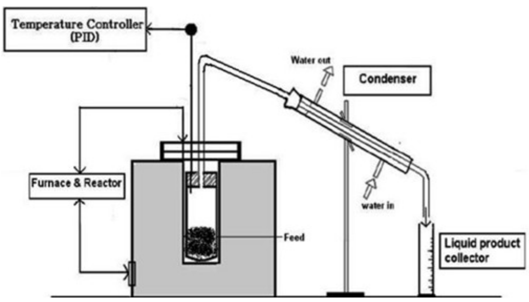
A. Lucia et al (1). The advancement in thermo chemical process use for bio fuel production has gained a lot of importance for the production of clean and efficient energy substitute. The choice of process depends upon the type of desirable product; Fast pyrolysis leads to high yield of bio-oil whereas the slow and vacuum pyrolysis process gives a good choice for production of bio-char and bio-oil furnishing high yields and simultaneously superior quality of bio-char A.V Bridgewater et al (2). It is recognized that biomass exceeds many other renewable energy sources because it is plentily available, high energy values and it is versatile, and sugarcane bagasse is the most abundant crop waste found in the world J.M Encinar et al (3) .Biomass pyrolysis products are the complex combination of the products from individual pyrolysis of cellulose, hemicelluloses and extractives each having its own kinetic characteristics. In addition to that the secondary products come from the cross reactions of primary pyrolysis products between pyrolysis products and the original feedstock molecules, Pyrolysis of each constituent is itself a complex process which is dependent on many factors Dinesh Mohan et al (4) .The pyrolysis characteristics of sugarcane bagassehemicellulose were found out using a tubular furnace, the pyrolysis experiment was conducted at various elevated temperatures starting from 550,600,650,700,750,800,850 & 900 0C in a homemade tubular furnace. The main objective of theproject was to investigate the effect of temperature on the various product yields and to characterize the products with various analytical techniques. The liquid products were analyzed by GCMS and it was found that the main gas products were (CO, CO_2, CH_4& H_2) respectively Peng et al (5) .The biomass pyrolysis was carried out using Thermo gravimetric analyzer and packed- bed pyrolyser. It inferred that there were no detectable interactions among the components during pyrolysis in either of the above two process on the other hand the ash present in the biomass had a strong influence on both pyrolysis characteristics and the product distribution.

MATERIALS AND METHODS COLLECTION OF RAWMATERIAL:

The precursor is collected from the nearest sugar industry namely (SHAKTI SUGAR INDUSTRIES) as they are used for power generation inside the sugarmill. The raw material is in the form of fibres.

PYROLYSIS PROCEDURE:

Pyrolysis of the biomass is carried out with a system which comprises of a reactor, a furnace and a condenser that is being used to condense the gas and thereby collect the bio-oil. It is carried out using a reactor which is made up of stainless steel (SS 316) material having diameter of about 4.5cm and a elevation of 18.5cm. The reactor is the one inside which the precursor is being filled and certainly inserted vertically inside the furnace. Once the reaction is started the precursor is pyrolysed and the moisture is eliminated with next volatiles and thereby remaining with ash (bio-char). The bio-oil is collected in the measuring flask which lies below the condenser. There also lies a temperature controller inside the furnace which is PID controller. The furnace has a maximum temperature reach ability of 1200C.



CHARACTERIZATION OF THEMATERIAL

PROXIMATEANALYSIS:

It is done in order to calculate the moisture content, ash content, volatile matter content and the fixed carbon content of the biomass sample. The experiment was conducted by ASTM D3173-75. The fixed carbon is calculated by difference, after the calculation of moisture content, volatile content and ash content. It is the quantitative analysis which separates all the above 3 components from any material. The ash content of the material doesn’t contribute to the calorific value of the fuel. The proximate analysis was done for the bio-mass as well as bio-charsamples.

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RESULTS ANDDISCUSSION

PROXIMATE AND ULTIMATE ANALYSISOFBIOMASS

PROXIMATE ANALYSIS	
Content	**Weight percentage (%)**
MOISTURECONTENT	1.94
VOLATILE MATTER	71.48
FIXED CARBON	15.57
ASH CONTENT	11.01
ULTIMATE ANALYSIS	
Elements	**Weight percentage (%)**
CARBON	56.160
HYDROGEN	3.512
NITROGEN	6.213
SULPHUR	2.380
OXYGEN	31.73
H/C	0.750
O/C	0.560
OIL CONTENT (%)GROSS CALORIFIC VALUE	53.3 2754.32
ELEMENTAL FORMULA	CH0.75 N0.0946 S0.015O0.560

The proximate analysis and ultimate analysis gave their result with highest volatile matter in thebiomass of about 71.48% and the lowest moisture of 1.94 whereas the ultimate analysis showed the highest presence of carbon of about 56.16 %. The elemental formula of the biomass is alsopredicted above

THERMO GRAVITRIC ANALYSIS(TGA):

The TGA curve of the biomass gave the decomposition stages of the biomass and the temperature between which the thermal pyrolysis would be done so as to get the optimum temperature. It is conducted at gas flow rate of 35 ml/min and the amount of sample taken during TGA analysis was 2.926gm and within a temperature range of (0- 600)0 C. The decomposition occurs in 3 stages the first stage shows the removal of moisture from the bio-mass , the 2nd stage gives the removal of volatile matter present in the biomass sample and in the 3rd stage the total combustion of the material takes place with the weight loss from the material giving rise to decomposition of the hydrocarbons . From the 3 stage process the rapid decomposition occurs during the volatiles are eliminated and so the stage is consideredto be important for pyrolysis. The pyrolysis is performed according to the information from TGA between 300-500 0C.

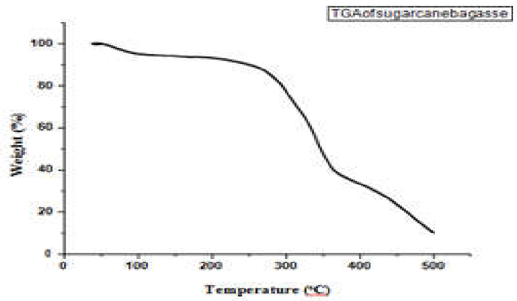

Fig.TGA of Sugarcane Bagasse

EXPERIMENTAL RESULTS

Table. Experimental result of Sugar Bagassepyrolysis

CHARACTERISTICS	SUGARCANE BAGASSE								
TEMPERATURE (°C)	300	325	350	375	400	425	450	475	500
LIQUID PRODUCT (%)	20.32	25.66	44.46	45.46	46.21	50.66	53.30	51.13	41.33
BIO-CHAR (%)	49.54	46.73	40.8	34.7	33.05	31.90	29.78	25.0	20.12
VOLATILES (%)	30.14	27.61	22.74	19.84	18.62	17.44	16.92	23.87	38.55
REACTION TIME(MIN)	48	45	38	32	29	25	22	20	17

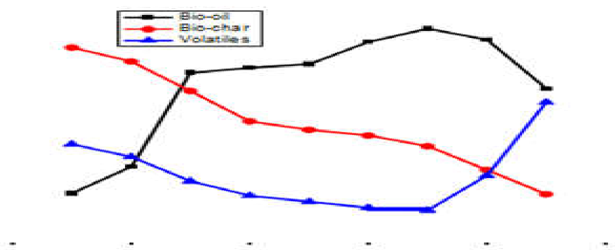

Table: proximate analysis results at various prolytictemperatures

Temperature	Volatile matter	Ash content	Fixed carbon
300	61.52	7.46	31.02
350	53.23	10.43	36.34
400	46.48	13.25	40.27
450	36.60	18.82	44.58
500	30.36	20.12	49.52

Table: Ultimate analysis results at various prolytictemperatures

Sample name	N%	C%	H%	S%	O%	H/C (MOLAR RATIO)	GCV
300	3.21	54.12	2.82	1.74	39.85	0.625	15.98
350	3.78	57.88	3.01	1.08	34.52	0.624	18.37
400	4.45	58.74	2.77	1.24	32.80	0.566	18.60
450	3.66	58.21	2.24	1.60	34.29	0.461	17.43
500	2.86	56.31	2.55	1.41	36.87	0.543	16.81

Conclusion

Since the demand for energy is growing more and more the dependency on fossil fuel need to be reduced since they will get totally exhausted, the need for more and more efficient used of biomass by converting it to an efficient and clean source of energy, therefore the biomass conversion is done by pyrolysis technique to find efficient utilization of biomass to produce the energy in form of solid, liquid&gaseousfuels. In this present work the pyrolysis of the sugarcane bagasse is conducted at various temperatures starting from 300C- 500C at 150 C rate of heating in the reactor thereby giving an yield of 53.3% which was found to be optimum at the temperature of 450C . On contrary the bio-char yield showed a decreasing trend and the volatiles in a similar manner showed increasing trend upto optimum temperature i.e, 450C, giving an yield of 53.3% bio- oil at 450C thereafter showing a decreasingtrend. The components present in the bio-oil sample were found suitable for its use as bio-fuel in turbines and other applications. Whereas on the other hand the bio-char produced by the pyrolysis of bio-char also has its applications as found by characterization of the bio-char like the nutrients present in it may help as a precursor in the soil amendment purpose. The weight loss from the TGA studies of the bio-char gave that the weight loss found was 35%. The surface area values of the bio-chars would suitably find its application in soil amendment purpose. The anion chromatography results also inferred various plant required nutrients which might find its applications. The proximate and ultimate analysis of the bio-chars produced at various pyrolytic temperatures revealed that the carbon content were upto the mark which can be used as a fuel , since the carbon composition in thebio-fuel plays a vital role. The FTIR analysis results showed negative functional groups on the surface of the bio- char like carboxyl groups and phenolic groups. Therefore with such tests conducted for the bio-oil and the bio-char were all found feasible for itsapplication as bio-fuel as well as its application as bio-char and various other applications depending upon the properties of the sample, therefore the use ofthe bio-fuel in refinery was found feasible from properties study.

FUTUREWORK:

1. Engine performance of thebio-oil.
2. Soil amendment studies of the bio-char.
3. Bio-char applications as fuel & otherapplications.
4. Study of adsorption properties of the bio-char.
5. Study the distillation range of thebio-oil.

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