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Estimation of Bio-Oil Production By Using Affecting Parameters of Biomass Waste Through Stastitical Method

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Abstract

Biomass can be converted into useful bio-fuel by using thermo-chemical methods namely combustion, gasification, pyrolysis and liquefaction but the pyrolysis process is providing promising solution in all of the thermo-chemical methods. This study presents the bio-oil production by experimental method by using pyrolysis reactor and theoretical basis by using various affecting parameters of the biomass wastes namely proximate analysis, ultimate analysis , alkali contents and biological contents of the biomass wastes cellulose, hemicelluloses and lignin content. This study highly useful and it can predict theoretically bio-oil potential in any kind of selected biomass (agricultural waste, forestry waste, organic, polymers and plastics etc.) without any experiment and it is also helpful for the designing of the pyrolysis reactor.

Keywords: Biomass wastes, Proximate Analysis, Ultimate Analysis , Bio-oil, Pyrolysis

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1. Introduction

Recently crisis of petro-chemicals increased day by day due to the depletion of the natural fuel sources and it increased the environmental pollution problems due to the emissions of the Sox and Nox and green house gases[1]. Biomass attracted attention to use due to the eco-friendly and non-toxic nature and it has higher volatile matter and high hydro-carbon contents so it has high calorific value approximately 3000-4500 Kcal/Kg which is the just half of the petrochemicals it can be produced clean and eco-friendly energy[2]. Combustion, gasification, liquefaction and pyrolysis all of these are thermo-chemical conversion method's but pyrolysis which is the heart of all of the thermo-chemical conversion methods because it can give the promising solutions for the energy production[3]. Pyrolysis is the destructive distillation of organic contents at high temperature in the absence of O_2 for the production of bio-oil[4]. Bio-oil production and quality depends on cellulose, hemicellulose and lignin contents which can be degraded at different temperature ranges and releases the volatile contents. Cellulose degraded at 315-400 ^oC temperature and hemicelluloses can be degraded at 220-315 ^oC temperature and lignin content degraded at 150-900 ^oC temperature. All the chemical compositions of the bio-oil depend on the selected biomass wastes and operating temperature [5].

This study reported that effects of the operating parameters of the pyrolysis reactor, these are temperature, heating rate and retention time and input parameters of (proximate, ultimate and lignocellulosic) of the selected biomass were correlated by using multiple regression method by using SPSS software and after the analysis it was found that experimental and theoretical estimation of bio-oil were very similar. This method is simple, but the validation of this method is more accurate.

2. Material and Methods

2.1 Alkali test

Sodium and potassium alkali metals tested by using the method which was suggested by Apha Manual (ISI, standard).

2.2 Proximate analysis and Lignocellulosic analysis

Proximate analysis of selected biomass (soya husk, rice husk, cotton stalk, bagasse and wood saw dust) tested by using standard ASTM methods, moisture analyzed by ASTM D3173, volatile matter by ASTMD3175, ash content by ASTM D3174 and lignocelluosic contents analyzed by standard methods[6-7].

2.3 Ultimate analysis

Ultimate contents tested by using standard method by using CHNS analyzer. CHNS anayzer used its model Flash EA 1112, made by Thermo Fennigan Italy company. It is working on the principle of Dumas method which includes the instantaneous oxidation of the sample by "flash combustion. In this system combusted materials separated by chromatographic column and CHNS detected by thermal conductivity detector.

2.4 Estimation of Bio-oil production

Efforts were made to correlate the production of bio-oil by using input parameters of biomass namely proximate analysis (moisture, volatile matter, fixed carbon, ash), ultimate analysis (C,H,N,O) and biological contents (cellulose, hemicelluloses, lignin) and reactor operating

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parameters (temperature, heating rate, residence time) on the basis of the multiple regression method by using Microsoft excel. It was found that all most all parameters played major role for bio-oil production. The theoretical model was also developed and was found complex to predict estimation of bio oil production accurately from input values of proximate and elemental analysis of different biomass materials[8]. A simple multiple correlation was established to estimate the bio oil from the combination of parameters such as cellulose, hemicelluloses, lignin, carbon, hydrogen, oxygen, nitrogen, moisture, volatile matter, fixed carbon and ash as well as operating parameters of reactor (T, H/R, RT). The correlation was developed for pyrolysis process using untreated biomass materials. The data used in this correlation had summarized in Table 1 to Table 4.
The Equation established with appropriate parameters to fit the best correlation was as follows.

$$\mathbf{EOP = Intercept + A \times T + B \times H/R + C \times RT + D \times C + E \times H + F \times N + G \times O + H \times M + I \times VM + J \times FC + K \times AS + L \times Cell. + M \times Hemi. + N \times lig.}$$

Where, EOP = Estimated oil production in percentage and A to N are variables. T is the pyrolysis temperature for biomass degradation , H/R is the heating rate of reactor (^{o}C/min.), RT is the reactor residence time (min.), C is the elemental carbon of biomass in percentage H, is the elemental hydrogen of biomass in percentage, VM is the volatile matter of biomass in percentage, FC is the fixed carbon of biomass in percentage, M is the moisture of biomass in percentage AS, ash content of biomass in percentage Cellu. , Cellulose in percentage Hemi., hemicelluloses of biomass in percentage.

4.0 Result and Discussion

4.1 Experimental

Pyrolysis performed in a batch type pyrolysis reactor at 600 ^{o}C temperature with using 20 ^{o}C/min. heating rate and sweep gas flow rate maintained at 20 ml/min. Pyrolysis reactor is a tubular type reactor.

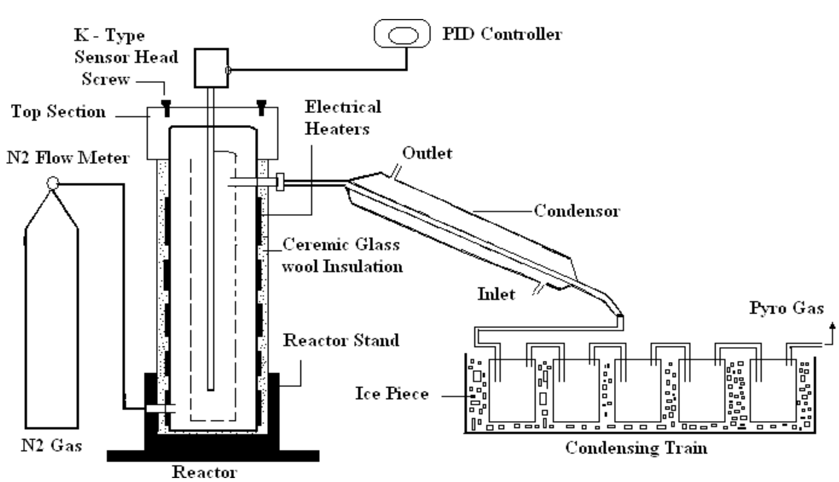

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Fig. 1 Schematic diagram of pyrolysis reactor

it was heated electrically by using electrical heaters and temperature measured and controlled by using digital PID controller. Schematic diagram of pyrolysis reactor illustrated below in Fig. 1 and test results given in Table 1.

Table 1: Pyrolysis reactor operating parameters

Biomass	T	H/R	RT	Bio-oil Exp.
Soya husk	600 ^{0}C	20	30	19.51
Rice husk	600 ^{0}C	20	30	23.52
Bagasse	600 ^{0}C	20	30	12.19
Cotton stalk	600 ^{0}C	20	30	17.14
Wood sawdust	600 ^{0}C	20	30	22.41

Bio-oil production depends on lingo-celluloses contents (cellulose, hemicelluloses, lignin), ultimate analysis (carbon, hydrogen, oxygen, nitrogen, sulfur), proximate analysis (moisture, volatile matter, fixed carbon and ash) as well as operating parameters such as temperature, heating rate and residence time. Emission of high volatiles into the biomass due to the hellocellulose content it can be increased the bio-oil production, however high ash decreased the production of bio-oil due to the inorganic carbon crates problem during the combustion[8].

Table: 2 Proximate and ultimate analysis of biomass wastes

Biomass	C	H	N	O	M	VM	FC	AS
Soya husk	42.05	6.37	3.56	48.02	10.2	77.3	15.5	7.2
Rice husk	48.91	5.85	0.58	44.66	12.4	66.7	11.3	22
Bagasse	41.21	4.92	1.98	51.89	20.2	75.7	21.2	3.1
Cotton stalk	42.39	6.15	0	51.46	9.7	67	16.2	16.8
Wood sawdust	54.96	6.16	0	38.89	11.6	80.2	17.8	2

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By the close look of Table 2 that volatile matter of soya husk, bagasse and wood saw dust are very high and ash content of the cotton stak was very higher.

Table: 3 Lignocellulosic and alkali test analysis of biomass wastes

Biomass	Cell.	Hem..	Lig.	Na	K	Bio-oil Expe.
Soya husk	30	12	16	18.4	27.3	19.51
Rice husk	36	26	23	12.7	41.3	23.52
Bagasse	38	32	20.88	30	38	12.19
Cotton stalk	44	30	19	17.8	21.8	17.14
Wood sawdust	34.4	28	23.3	13.7	11.7	22.41

Close look of Table 2 reveals that in general, bio-oil production increases with increasing percentage of volatile matter. Highest bio-oil recovery was obtained in wood saw dust (22.41%) followed by soya husk against the percent volatile matter of 80.2 (wood saw dust) and 77.3 (soya husk) respectively. Carbon content of biomass also has strong relation with bio-oil production. Higher the carbon content of biomass, higher would be bio-oil production (Table 2). For example among the selected biomass materials wood saw dust has highest carbon content (54.96%) and hence production of bio-oil was highest (22.41%), however it is not following uniform trends. It may be due to poor quality of biomass.

Table 3, reported the detected sodium metal (Na) in the tested biomass varied from 13.7 to 30 mg/L with maximum in bagasse (30 mg/L) followed by soya husk. Similarly potassium metal (K) varied from 11.7 to 41.3 mg/L with maximum in rice husk (41.3 mg/L) followed by wood saw dust (11.7 mg/L). These alkali metals creates difficulties during the thermal decomposition of biomass and hence responsible of higher ash. It was reported that presence of some alkali metals (K, Zn, Mg, Ca) while working with coir pith, corn cob, ground nut shell, rice husk and wood[9].

Cellulose, hemicelluloses and lignin of biomass also played major role for bio-oil production, cellulose and hemicelluloses contents increased the bio-oil percentage due to the emission of higher volatiles and lignin content increased the charcoal percentage due to the presence of inorganic carbon contents (Na, K etc.). The percentage of bio-oil with correlation of cellulose, hemicelluloses and lignin contents illustrated in Table 3. The wood saw dust and rice husk has high potential to production of bio-oil due to the low alkali contents in these biomass materials.

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The highest carbon percentage was found in wood saw dust and in rice husk in comparison to the three biomass materials soya husk, cotton stalk and in bagasse. The high carbon percentage also indicates high conversion of bio-oil in the wood saw dust and rice husk biomass but H2 content found similar into all of the selected biomass and it has not affected to the bio-oil.

Table:4 Correlations of experimental data for estimation of bio-oil

Biomass	Production of bio-oil from pyrolysis	Prediction of bio-oil production from theoretical model
Soya husk	19.51	19.51
Rice husk	23.52	23.52
Bagasse	12.19	12.19
Cotton stalk	17.14	17.14
Wood sawdust	22.41	22.41

Table 4 resulted, the experimental Vs theoretical prediction of bio-oil, close look of Table 4 represents the experimental and theoretical values of bio-oil production was very similar and multiple regression R^2 value calculated 1. Anova results discussed in Table 5.

Anova Test Results:

Table 5: Anova summary of estimated bio-oil by using multiple linear regression method

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	1.000	1.000	.-	-.	1.000	.	4	0	-.	2.214

a. Predictors: potassium, cellulose, lignin and Fixed carbon.

b. Dependent Variable: Bio-oil

Table 5 reported that R square value found 1, it signifies that model is more accurate and correation between reactor parameters and input parameters of the biomass were validated.

Table 6: Anova summary of estimated bio-oil by using multiple linear regression method

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Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	12.1900	23.5200	18.9540	4.53166	5
Residual	.00000	.00000	.00000	.00000	5
Std. Predicted Value	-1.493	1.008	.000	1.000	5
Std. Residual	.	.	.	.	0
a. Dependent Variable: Bio-oil					

Close-look of Table 6, represented that bio-oil estimation predicated value minimum 12.19 to maximum value 23.52, mean value 18.9540 and standard divation calculated 4.53 and standard residual calculated minimum (-1.493) to maximum (1.008) and standard deviation found 1.

5. CONCLUSIONS

It concluded that high alkali contents (Na and K) can be decreased the bio-oil percentage due to the reduced the bio-oil, but the presence of high carbon and high volatile matter increased the potential of bio-oil. This study also resulted that experimental and theoretical model of bio-oil production were similar. Experimental results carried out by using pyrolysis at 600 C temperature with 20 C/min. hating rate and 20 ml/min. heating rate and theoretical study performed by using multiple regression method by using SPSS software. The validity of this model was found satisfactory.

References

[1] S. Papari, K. Hawboldt, “A review on the pyrolysis of woody biomass to bio-oil: focus on kinetic models”, Renew. Sust. Energ. Rev. 52, pp. 1580–1595, 2019.

[2] A. Demirbas, “ Biorefineries: Current activities and future developments”. Energy Convers Manag, Vol. 50, pp.782-2801, 2009.

[3] A.V. Bridgwater, “Review of fast pyrolysis of biomass and product upgrading”, Biom. Bioen. 38 pp. 68–94,2012.

[4] A.P.Singh Chouhan, A.K.Sarma, “Critical Analysis of Process Parameters for Bio-oil Production via Pyrolysis of Biomass: A Review”. Rec. Pat. on Eng. July 2013. Rec. Pat. Eng., 2013, Vol 7, pp.000-000, 2013.

[5] H. Yang, R. Yan, H. Chen, D. H. Lee , C. Zheng, “Characteristics of hemicellulose, cellulose and lignin pyrolysis”, Fuel vol 86, pp. 1781–1788, 2007.

[6] B.Tuya, C.Abdelkar, G.P.Manuel, R. Denis, R. Christian, “Colloidal properties of bio-oils obtained by vacuum pyrolysis of softwood bark. Characterization of water-soluble and water - insoluble fractions”. Ener. Fuel, 2 vol. 18(3), pp.704–12, 2004.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

[7] P. Jacquet, A. Leonard, “Annual book of ASTM standards. American Society for Testing of Materials”, USA Intern. 1983.
[8] Raveendran K, Ganesh Anuradha, Khilart C, “Kartic. Influence of mineral matter on biomass pyrolysis characteristics”, Fuel Volume 12, pp. 1812-1822, 1995.
[9] D.Chiaramonti, A.Oasmaa, Y. Solantausta, “Power generation using fast pyrolysis liquids from biomass”. Ren. and Sust. Ener. Rev, pp.1-28, 2005.