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STUDY THE KINETICS & PRODUCT YIELD OF BIO MASS MATERIAL THROUGH PYROLYSIS ROUTE

Abstract

Biomass is the renewable source of Energy. In this report we have emphasized on the characterization of Biomass. Various biomass materials are selected for analyzing the properties and characteristics as an energy source. According to the literature available we have selected sewage sludge, saw dust and rice husk as our biomass material. The primary analysis was done and finally we select sawdust for the pyrolysis process. By changing the parameters like time and temperature of our process to find optimize conditions for getting maximum yield. We have also compared reaction kinetics for our biomass materials to find the energy required to start Pyrolysis process. And in the end we have compared our final product with alternative sources and then by doing the cost estimation calculations we found that our process is quite feasible.

Keywords: Biomass,Characterization, Pyrolysis, Kinetics

1. Introduction:

Biomass covers a whole global amount of energy forms. Other fuel terms which also have biomass as their basis are bio fuel, vegetable oil, bio energy, bio ethanol, biogas & etc. The great advantage of bio-fuels is that they are considered to be 'carbon neutral' that is that they use up as much carbon dioxide during growth, as they expand as a fuel.

Biomass is a little-used term by the public generally, but when you think of wood fires and wood burning stoves it is easy to see that biomass fuel has been in use for centuries. In fact, in 2003, biomass heat and electricity generation accounted for 87% of renewable energy sources in UK and about 1.55% of the total electricity supply [1]. Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. It is the fundamental chemical reaction that is the precursor of both the combustion and gasification processes and occurs naturally in the first two seconds. The products of biomass Pyrolysis include bio char, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide. Depending on the thermal environment and the final temperature, Pyrolysis will yield mainly bio-char at low temperatures, less than 450 ^{0}C, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 800 ^{0}C, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is bio-oil.

Pyrolysis can be performed at relatively small scale and at remote locations which enhance energy density of the biomass resource and reduce transport and handling costs. Pyrolysis offers a flexible and attractive way of converting solid biomass into an easily stored and transported liquid, which can be successfully used for the production of heat, power and chemicals.

A wide range of biomass feedstock can be used in Pyrolysis processes. The Pyrolysis process is very dependent on the moisture content of the feedstock, which should be around 10%. At higher moisture contents, high levels of water are produced and at lower levels there is a risk that the process only produces dust instead of oil. High-moisture waste streams, such as sludge and meat, process wastes require drying before pyrolysis.

We have used pyrolysis process for converting the bio mass into useful energy sources such as bio gas or bio diesel as the replacement of the other conventional fuel sources. Also the bio gas / bio diesel from Pyrolysis contains very less Sulphur so it does not harm the environment and we can directly use it as a fuel or power generation.Pyrolysis is one the most profitable technique to recover the energy from a particular type of biomass and most important step towards a profitable investment. It gives more product yield [2].

2. Material and Methods:

We have selected mainly three bio-mass waste materials as sawdust, rice husk and sewage sludge. From the literature, the comparisons of these materials on the basis of different chemical and physical data are mention below.

A: Chemical composition by Proximate analysis, Ultimate analysis [1,2].

B: Physical properties

Bulk density, Outer surface area, Porosity, Angle of repose, Equilibrium moisture content, thermal conductivity, pressure drop, terminal velocity[3].

For the removal of oxygen we have to do nitrogen purging. In the pyrolysis process we have used muffle furnace for heating the reactor. We also designed the reactor of height 17 cm and diameter 9.5 cm which has a capacity of 1 lit volume and the two glass condenser for condensing the gas into liquid and then the product formed in liquid state in condenser, which is having chilled water (ice) as a condensing media.

By using the PID controller which is attached to muffle furnace we have changed the process temp (450, 550 & 650) ˚C and the proposed time period as 1, 1.5 & 2 hour. For collection of gas (at around temp of 450, 500 & 650˚C) we have attached a gas collector at the end of the condenser tube.

After collecting liquid and gas, We have calculate the material balance of it, as some part of burned material will be laid there. For analysis of gas, we used GC, Hewlett Packard HP available at SVNIT, Surat.

3. Results and Discussion

3.1 Chemical composition

Proximate analysis

Table No:1 % composition of rice husk, sewage sludge , saw dust, rice straw ,wood

Property	Saw dust	Sewage Sludge	Rice husk	Rice Straw	Wood
Volatile matter	63	32	64.7	69.7	85
Fixed carbon	6	45	15.7	11.1	13
Ash	20	15	19.6	19.2	2

Ultimate analysis

Table No: 2 % composition of rice husk, sewage sludge , saw dust, rice straw ,wood

Property	Saw dust	Sewage Sludge	Rice husk	Rice straw	Wood
Carbon	45.78	26.0	38.45	37.7	48
Hydrogen	5.32	3.5	4.96	5	6.5
Oxygen	48.83	23.9	55.59	37.5	43
Nitrogen	0	2.8	0.82	0.6	0.5
Sulfur	0.07	1.1	0.18	0.21	-

Based on the literature and on the basis of calorific values, we finally select saw-dust for our pyrolysis process.

3.2 Reactions Involved in Pyrolysis Process

The biomass is directly and visibly affected as the Pyrolysis process proceeds. For example, the color of the biomass changes from white to brown to black. Size and weight are reduced while flexibility and mechanical strength are lost. At temperatures around 350^{o}C, weight loss reaches about 80% and the remaining biomass is converted to char. Prolonged heating or exposure to temperatures of about 600^{o}C reduces char fraction to about 9% of the original biomass weight. The primary Pyrolysis reactions are either dehydration or fragmentation reactions. Thereafter, several products will be produced [4].

Dehydration

Dehydration, which is dominant at low temperatures, is the primary of the two reactions during slow Pyrolysis. These reactions take place below 300^{o}C and result in the reduction of the biomass molecular weight, the evolution of water, CO, CO_2 and, char.

Fragmentation

Fragmentation dominates at temperatures above 300°C. It involves the depolymerization of the biomass to anhydro-glucose compounds and other light combustible volatiles. Because of the temperature range involved, fragmentation is of greater interest in flash and fast Pyrolysis processes [4].The Products which we get in terms of bio-oil ,bio gas and bio char are tabulated below only for our optimum condition (650°C, 90 min.) .Interpretation for the kinetics of our bio mass material forms the basis of the data which is used to find the rate equations that satisfactorily for analyzing the data[5].

Table:3 Optimum result of pyrolysis

Temp(°C)	Time(hr)	Bio-crude or bio-oil(ml)	Biogas(cc)	Solid char(gm)
650	1.5	40	35	24

Table:4 Composition of gas by GC

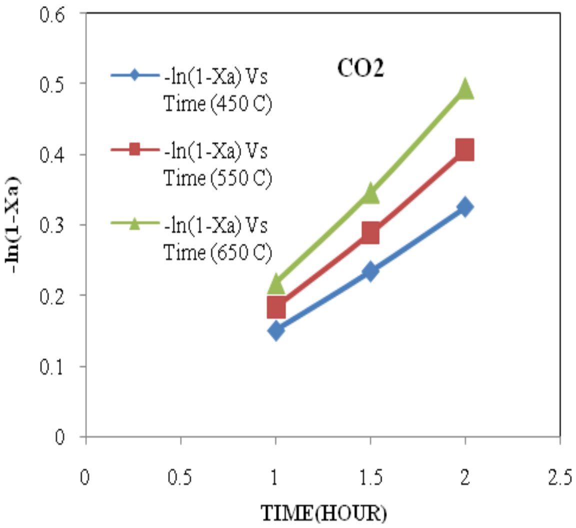
Temp(°C)	Time(hr)	CH_4	CO_2	N_2	H_2S	Others
450	1.5	36.05	22.86	13.12	5.01	22.96
550	1.5	40.25	25.09	14.08	3.73	16.85
650	1.5	48.8	29.26	15.3	1.43	5.21

For our process we assume that it is a first order reaction and so that we chose the integral method of analysis for find out the rate constant and with the help of Arrhenius equation we find the total activation energy required to start-up our reaction [5].The Activation Energy Graphs of bio gas are given below[fig.4]:

Table:5 Activation Energy and Frequency Factor

Components	**Activation Energy(Cal/kmol) E**	**Frequency Factor**
CH_4	1217.03	1.1829
CO_2	1373.41	0.7254
H_2S	-1038.00	0.00411
N_2	494.36	0.1628

Total Activation Energy= $\sum E$ = 2046.8056 Cal/kmol



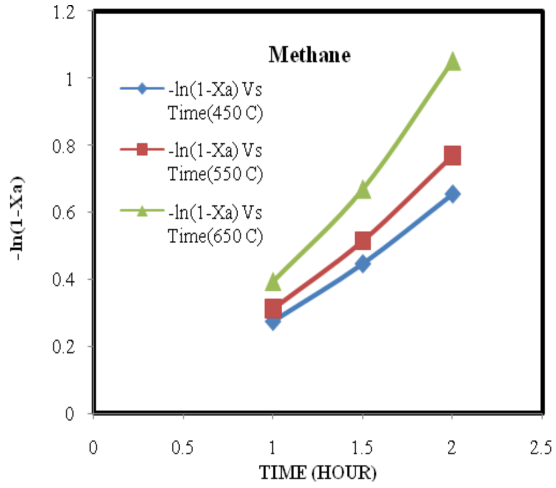
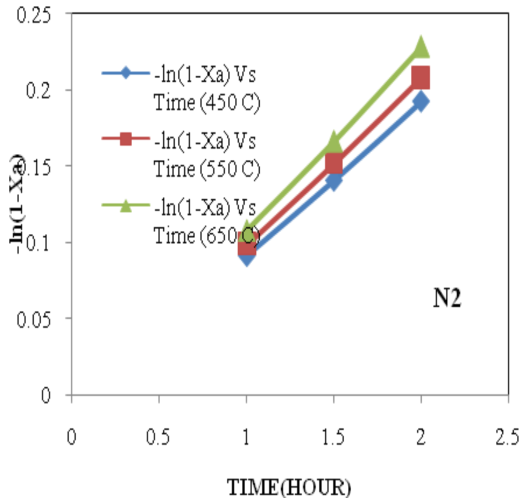


Figure 1: First order reaction kinetics for CO_2. **Figure 2**: First order reaction kinetics for methane



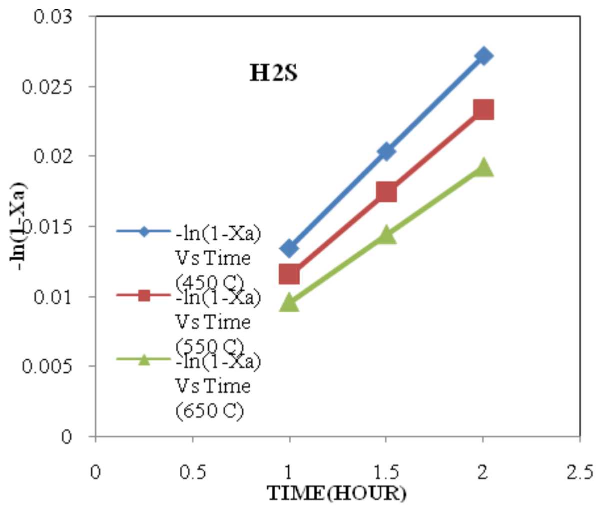


Figure 3: First order reaction kinetics for N_2. **Figure 4:** First order reaction kinetics for H_2S.

3.4 Capital (Fixed) Costs:Capital (fixed) costs;Raw material cost = 10 Rs/Kg saw dust.Electricity cost ; Muffle furnace consumes 4 KW (4 unit) per 1 hour, As cost estimation done on 1 Kg batch size and as per muffle furnace capacity and reactor design it consume 60 KW . i.e. 60 units. As per the torrent power ltd, SURAT, The cost is Rs. 5 per unit so for 60 units it takes 300 Rs. Purging cost; For one time N_2 purging it takes avg. Rs. 100.Utility cost; For condensation purpose ice is used as a condensing media and it takes Rs. 50 for each run.

Now the total cost = Raw material cost + Electricity cost + Purging cost + Utility cost +Purification cost + Transportation cost + Reactor designing & installation cost per run(approximately)

Total investment per run (Rs.) = 10+300+100+50+100+150+450=1160

Volume of one bladder is 0.001706 m^3which gives 8.2 m^3/day. Now time required to fill up one bladder is 3 min. And at our optimize condition, we get gas continuously for 18 min.

So total 6 bladders are filled with gas ; 6 × 8.2 = 49.2 m^3/day . As per the Gujarat gas standard the value of SCMD (standard cubic meter par day) is Rs. 21.44 [6].Total cost of Gas (Rs.);49.2 × 21.44 = 1055 Now for bio oil price, as per the US standard 1 barrel = 1.5899×10^5 ml.By calculations we get 6400 ml bio oil per day.The value of bio oil US 1 barrel = 100 $ = Rs. 6009.5 So for 6400 ml = Rs. 241 So total Earning = Rs 1295.84

Profit = Earning – Capital Cost

= 1295.84 – 1160 Rs.

= 135.84 Rs.

So our process is quite beneficial.

4. Conclusion:

By doing the Pyrolysis of Bio mass Material (Saw dust) we found that the final product in terms of bio gas , bio oil , bio char gives maximum product yield at our optimum condition at 650 ° C and time period of 1.5 hour. We have also studied the kinetics of our bio mass sample which shows that the activation energy required to startup our reaction is quite less. We also have estimated the production cost of our product and compared with other alternative petroleum sources which shows our process is quite feasible. As it is feasible in all aspect, still not coming 100% efficient since H_2S is produced.Due to limitation of our resources for better process design, we have tried to optimize the temperature and time which ultimately gives us our desired product with some hydrogen sulfide, so it needs to be purified further before using it domestically.

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Vaishali Umrigar[1], Saurabh Kachhia [2], Ankit Bhuva [3] , Vivek Dhimmar[4] Nilesh Patel[5]

[1]Vaishali Umrigar, Assistant Professor, Chemical Engineering Department, Sarvajanik College of Engineering & Technology,Surat-395001
[2]Saurabh K Patel, Chemical Engineering Department, Sarvajanik College of Engineering & Technology,Surat-395001

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