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Effect of Catalyst (Aluminum Oxide) on Bio-oil Yield from Pyrolysis of Pakistani Cotton Stalk

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Abstract

Catalytic fast pyrolysis, thermo-chemically converts lignocellulosic biomass into valuable chemicals and fuels. Aluminum oxide anhydrous catalyst was used during experimentation of pyrolysis in fixed bed reactor and found very effective and progressive resulting in higher yield of bio-oil. The bio-oil yield of 57 % was obtained at pyrolysis temperature of 500 °C with non catalytic sample of cotton stalk whereas it was increased upto 61 % with catalytic sample. The net increase of around 4 % of bio-oil yield was attained in the catalytic pyrolysis. The heating values of bio-oil at 500C were 26.05 MJ/kg for non-catalytic sample whereas 27.52 MJ/kg for catalytic sample. Higher quality fuels with lower oxygen content and greater calorific value were obtained by the application of alumina catalyst in pyrolysis. GC-MS analysis of obtained bio-oil identified the chemical compounds such as dodecanoic acid, n-penta decyclic acid, palmitic acid, 1,2-benzenedicarboxylic acid, phenols, aromatics, carboxylic acids and esters.

Keywords: Biomass, pyrolysis, catalyst, anhydrous aluminum oxide, fixed bed reactor, GC-MS analysis, bio-oil

1. Introduction:

Biomass is an abundant, renewable source of energy. Fast pyrolysis of biomass can be employed to convert lignocellulosic biomass into bio-oil, char and gas. Hydrocarbons derived from biomass are most attractive because of their high energy density and compatibility with the existing infrastructure. Thus, converting lignocellulose into transportation fuels via catalytic fast pyrolysis has attracted much attention. The main challenge of this process is the development of active and stable catalysts that can

deal with a large variety of decomposition intermediates from lignocellulose.

Organic matter that is biologically produced and comprising carbon, oxygen and hydrogen is termed as biomass [1]. Biomass and biofuel sources are classified mainly into two major classes. First type sources of biomass and biofuel consist of corn starch and sugarcane [2]. Second type of biofuel sources are municipal and agriculture wastes etc. Lignocellulosic biomass is basic constituent of biomass. A great deal regarding research, involved

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algal biomass which may be produced as by-product of nutrient [3, 4]. Biomass is also used for electricity generation which is known as green energy.

Pyrolysis is decomposition of the organic matter at higher temperatures in the absence of oxygen. It involves the change of chemical composition processes such as charring of wood, starting at 250-350 °C. The use of pyrolysis can be called by various names i.e. destructive distillation, dry distillation and cracking. Pyrolysis is different from the other processes of high temperatures like combustion and gasification. Usually it is not possible to attain a completely inert or oxygen free atmosphere because some oxygen is possibly present in any type of pyrolysis system, small amount of oxidation occur [5].

Biomass pyrolysis mechanisms are very necessary for the engineering of the continuous processes of the fast pyrolysis. The work is focused on the fast pyrolysis in this area because of the acquired products are nearer to fossil fuels in nature and chemical behavior. Dynamic studies were conducted on cellulose pyrolysis for the knowledge of pyrolysis mechanism. However, the obtained results seem to be reliable with the those attained in processes involving in different biomasses [8]. When the pyrolysis process continues, the biomass is clearly affected with respect to color and other physical properties. The color of biomass for example, changed from white to brown color and then black color. Effect on weight and size is also observed while mechanical strength and flexibility are lost. At 350°C, about 80% weight loss observed and residual biomass is converted into char. Continuous heating and exposure of temperature at about 600°C decreased char fraction to almost 10% weight of the original biomass. The major pyrolysis reactions are fragmentation and dehydration. After that several products obtained because of these reactions. The primary reaction during slow pyrolysis is dehydration, which is prominent at low temperature. Below 300°C during these reactions, molecular weight reduction of biomass results in water evolution, CO₂, char and CO and above 300°C temperature, and fragmentation dominates [9, 10]. In the process of fragmentation, the

depolymerization of biomass into compounds such as anhydro-glucose and other combustible volatiles take place. Fast pyrolysis and flash pyrolysis processes are most likely of greater interest in fragmentation due to its temperature range [11, 12].

Final products are divided into three major categories. The low molecular weighted volatile products, such as acetol, CO₂, CO, H₂O, unsaturated aldehydes, furfural and tars, chars of higher molecular weight [13]. Some Products of the pyrolysis process react with the free radicals depends upon temperatures, the pressure and time of the process. The re-combination of primary products formed is more stable and reliable secondary tars. On these types of conditions, primary molecules of the products are observed in the condensed phase. Frequently collision of the molecules occurs during the vapor phases. It was observed that the formation of charcoal, H₂O, CO₂ and CO from the secondary tars and the long residence times at low temperature resulted. While at high temperature, Cracking of the secondary tars converted it into hydrocarbons, hydrogen, CO₂, CO and carbon black [14, 15].

Formation of volatile products, char and gaseous production of pyrolysis were done by two distinctive routes. Olefin production done by pyrolytic route and formed at low vapor pressure, high temperature by first vaporized the Tar on the biomass surface, and then cracking it to get olefins. In pyrolytic reactions the devolatilization of biomass to get the solid residues in the form of char yields. It does not interact or react with the pure carbons or the biomass [16].

The affecting variables of biomass pyrolysis include composition of the substrates, the temperature and different pressures of the beds, the heating rates of the furnaces, the ambient atmospheres present and most important is the applications of the catalysts etc. The application of catalyst effectively act on biomass as compared to the other factors. These conditions could be control by minimizing the unwanted and unnatural side reactions and one should promoted the formation of some important desired products [18]. Thermochemical

manufactured reactors that are specifically for estimation of the biomass pyrolysis reactions. [19, 20].

Fluidized bed has numerous advantages included good gases and that of the solids interactions, outstanding transfer of the heat characters, best temperature controlling systems, better yields typically 65-80% and larger heat storing capacity [21]. This Fluidized bed pyrolyzing system consist of the following major equipment, first of all is hopper that is used as feeding system, some pyrolysis reactor involved in pyrolysis of biomass, cyclone for the collection of charcoal and unburnt biomass etc, the bio-oil collection quenching systems, the electrostatic precipitator for the removal of moistures and at last bio-oil tanks for the collection [23].

Lignin, cellulose and hemicelluloses are the major constituents of the biomass which have different types of the reaction kinetics. The rate of reactions, the products and other thermally occurring behaviors during the biomass pyrolysis are also considered of mixture of activities of the main reactions. . The three major problems regarding biomass pyrolysis are phase separation, corrosion of the container and bio-oil instability [24].

Adjaye & Bakhshi (1995) used Catalysts, namely HZSM-5, H-mordenite H-Y, silicalite and silica-alumina which were used for the upgrading of pyrolysis bio-oil in part I of this study which were examined for their relative performance in the production of organic distillate fraction (ODF), hydrocarbon formation and minimization of char, coke and tar formation. A catalyst effectiveness criterion based on yield and selectivity for each product was defined and correlated with the performance of each catalyst. Amongst the five catalysts studied, HZSM-5 was the most effective catalyst for the production of ODF, overall hydrocarbons and aromatic hydrocarbons. Also, it provided the least coke formation. Silica-alumina catalyst was most effective for well as maximizing the production of aliphatic hydrocarbon [25].

The ethanol steam reforming on Ni/Al₂O₃ catalyst at temperatures between 573 and 773 K was studied

and an overall reaction scheme as a function of temperature was proposed by Comas and his coworkers (2004). It can be concluded that higher water/ethanol ratio (6:1) and higher temperature (773 K) promote hydrogen production (91% selectivity) [26]. Xu et. al (2010), the hydro-treatment of bio-oil, obtained from fast pyrolysis of pine sawdust was investigated over MoNi/Al₂O₃ catalyst under mild conditions (373 K, 3MPa hydrogen pressure). Acetic acid was taken as a model compound to investigate the effects of Mo promoter contents and reducing temperatures of catalysts on the catalysts activity under the condition of 473 K and 3MPa hydrogen pressure [27].

Seyedejn-Azad et. Al. (2011) Production of hydrogen (H₂) from catalytic steam reforming of bio-oil was investigated in a fixed bed tubular flow reactor over nickel/alumina (Ni//Al₂O₃) supported catalysts at different conditions. The features of the steam reforming of bio-oil, including the effects of metal content, reaction temperature, the mass flow rate of bio-oil per mass of catalyst) and S/C ratio (the molar ratio of steam to carbon fed) on the hydrogen yield were investigated. Carbon conversion (moles of carbon in the outlet gases to moles of the carbon feed) was also studied, and the outlet gas distributions were obtained [28].

Catalytic steam reforming of bio-oil was investigated by Salehi, Azad, Thomas and Jalal (2011) in a fixed bed tubular reactor for production of hydrogen. Two series of nickel/alumina (Ni//Al₂O₃) supported catalysts promoted with ruthenium (Ru) and magnesium (Mg) were prepared. Each catalyst of the first series (RuNi//Al₂O₃) was prepared by co-impregnation of nickel and ruthenium on alumina. They were examined to investigate the effect of adding ruthenium on the performance of the catalysts for hydrogen production. The effect of the temperature, the most effective parameter in the steam reforming of bio-oil, on the activity of the catalysts was also investigated. Each catalyst of the second series (NiMgO/Al₂O₃) was prepared by consecutive impregnation using various preparation procedures

[29].

Izhar et. Al. (2012) Sulfided, phosphorus-added NiMo/Al₂O₃ catalyst was used for hydrodenitrogenation (HDN) of bio-oil derived from sewage sludge. The received bio-oil samples contained approximately 6% nitrogen. The bio-oil was dissolved in various solvents prior to hydro-treatment and the removal of nitrogen compounds was evaluated. The HDN of bio-oil dissolved in xylene at 350°C over phosphorus added NiMo//Al₂O₃ resulted in a complete denitrogenation of bio-oil and high yield of aliphatic hydrocarbon containing product with moderate heating value [30]. Effect of operating parameters on the bio-Oil production from fast pyrolysis (without catalyst) of cotton stalk has been published elsewhere by the authors [31]. In this research work, catalyst anhydrous aluminum oxide (Al₂O₃) has been utilized to increase the yield and quality of bio oil produced from the locally available cotton stalk and good yield have been obtained.

2 Experimental Work

2.1 Material & Methods

Catalyst used in this experiment was alumina (aluminium oxide anhydrous). Alumina was made by UNI-Chem chemical reagent Germany (batch # GD8113712) having molecular weight of 101.96.

For the activation of alumina catalyst, the catalyst was calcinated at 400°C in a muffle furnace (Thermolyne, Model: 4800) for 4 hours. Then leave it overnight in the furnace for better cooling of catalyst. On next day, catalyst was shifted in a glass sample bottle, it was sealed and kept in a desiccator during the experiments.

For pH measurement, Jenco USA pH meter was used (Model # 6173). It was calibrated by buffers of pH 7 and 4 (made by Merck Germany). Then, individually every sample of bio-oil was checked on calibrated pH meter. Results of pH determination are reported in Table 1. In the calorific value test of bio-oil, we take 2 gram sample of bio-oil. This sample was placed in the bomb calorimeter sample holder. This sample holder was placed in a cylinder.

The cylinder in the bomb calorimeter was filled with oxygen. Then started the bomb calorimeter and noted the initial temperature. The change in temperature continues for 5-7 minutes. When temperature became constant then noted the reading of final temperature and calculated the heating value of the bio-oil. First of all noted the initial weight of the crucible and then placed it in muffle furnace for 1 hour at 510°C, when all the volatiles removed and its weight became constant then noted the crucible weight again. Then weighted the sample of char (1gram) in crucible and placed it into the muffle furnace for 5 hour at 760°C. Noted the weight and again placed it into furnace for 15 minutes and again observed the weight. When their weights became constant, noted the actual weight of char by calculations. For functional group analysis, FTIR spectrometer was used (model # CARY 630, made of Agilent USA). Attenuated transformed radiation (ATR), Diamond ATR, was used during estimation of bio-oil samples. For the characterization of bio-oil samples GC-MS (Model QP2010, Shimadzu Japan) was used.

Bio-mass used in experiments was cotton stalk. It was collected from Pakpatan cotton fields, dried in sunshine, crushed and grinded in Grinder and sieved. The particle size of cotton stalk sample used was 0.5 mm.

2.2 Experimental Setup

All the experiments of pyrolysis were performed in three zone tube furnace Model: 3ZF-1/12. This furnace was fabricated by Pakistan Council of Scientific and Industrial Research (PCSIR) Complex, Lahore. Length of tube was 800 mm and diameter was 63 mm. Tube was made of SS-316. Outer body was made by mild steel and powder coated. Temperature was controlled by digital controllers. Its temperature range was up to 1000°C. Nichrome alloy wire was used as heating element in furnace.



Figure 1: *Three zone Tube Furnace*

The device consists of sample holder, furnace, control system and condensers. Eight inches long stainless steel basket was made for sample insertion in tube furnace. Its bottom was covered with SS made sieve to retain sample on it and for the easy movement of nitrogen gas. Nitrogen gas was supplied from the bottom of the tube furnace to get inert atmosphere. It was also used as a carrier gas for flue gases. Nitrogen gas carried Flue gases from tube furnace to the condensers and then exit into the atmosphere.

Glass made coiled and reflux condensers were used for condensation of the flue gases. Flue gases emit from tube furnace were passed through the Coiled condenser. The liquid sample was collected in the collector and the gases were passed through the secondary reflux condenser to collect the low boiling point fractions and then emit.

These condensers were joined with a water circulating motor from one side and with an ice cooled water tank to the other side. Water circulating motor circulate ice cold water from the water tank to the condensers. Flue gases cooled in condensers and collected in the form of bio-oil in bio-oil collecting flasks. At the end of the experiment, this collected bio-oil was used for further characterization.

2.3 Experimental Procedure

2.3.1 Non-catalytic samples of cotton stalk

About 20 g of finely grinded cotton stalk was used in each experiment. Its particle size was 0.5 mm. For experiments using catalyst, 2 g of alumina catalyst was mixed in biomass sample. Sample was placed into the stainless steel basket and inserted into the tube furnace. The purging of nitrogen gas was started from the bottom of the tube furnace for inert atmosphere with flow rate of 150 ml/min. At the same time water pump was turned on to circulate ice cold water in the condensers. After that temperature of the three zones of the tube was set at 600°C For the internal reactor temperature a thermocouple also immersed into the reactor, its temperature was logged after every ten minutes at 600°C, temperature of reactor was 450°C. Experiments were continued until no further significant release of flue gases was observed. flue gases from pyrolysis were condensed in the ice cold water condenser. Flue gases condensed in the form of bio-oil, which was collected in the flask. This bio-oil then was distilled stored for further characterization. After cooling the tube furnace, sample basket was opened and residue/ biochar was collected and stored for further characterization.

3. Results and Discussion

The values of pH of bio-oil from experiments are shown in the Table 1.

Table 1: pH values of bio-oil

Experiment No.	Max Reactor Temperature (°C)	pH of non-catalytic samples	pH of catalytic samples
1	450	2.95	2.76
2	500	3.02	2.82
3	550	3.19	3.01
4	575	3.27	3.09

In the Table 1, comparison of pH values of non-catalytic and catalytic samples of bio-oil are reported. The pH of bio-oil is ranging from 2-4 pH usually. Low pH is basically related to the amount of formic acid and carboxylic acid present in bio-oil. pH values of bio-oil samples were similar to that of other researchers reported in their experiments [32]. The above table indicated that at low temperatures low acidity of the product was observed while on increasing temperatures the pH of the bio-oil increased. It was interesting to observe the effect of catalyst on pH. In the absence of catalyst the overall pH of the product was less acidic (high pH), while catalyst favor to more acidic (low pH) values of the product. The effect of yields of non-catalytic samples of bio-oil, char and gas are shown in the Figure 2.

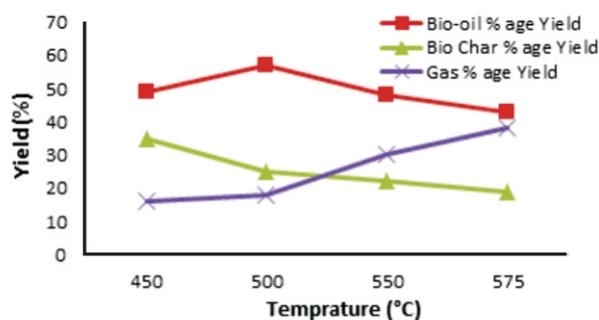


Figure 2: Effect of temperature on non-catalytic samples of pyrolysis products yield of cotton stalk

Figure 1 showed the percentages of bio-oil yield on different temperature ranges. Bio-oil yield was low at low temperature and constantly increased due to increase in temperature. An increase in pyrolysis temperature from 450 to 500°C, showed increased yield of bio-oil from 49-57% because high temperature accelerated the decomposition mechanism of biomass. When temperature increased from 500°C onward, bio-oil yield decreased and the gaseous yields increased. This trend was same as Zheng et.al [33] reported in their experiments.

In Figure 2 the temperature effect on char yield can easily be observed. At low temperature bio char yield is higher as compared to higher temperatures.

Its reason was, at low temperature decomposition mechanism never completed that's why higher bio char vales obtained. Biochar yields were decreased by increase in temperature. That means pyrolysis conversions remained at minimum level because pyrolysis process never completed on low temperature. This trend was same as other researchers [33] reported in their experiments because biochar yields all the time decreased with the increase in temperature.

Percentage of gas yields and temperature can easily understood in figure 1. Low gas yields observed at lower temperatures and then an increase observed due to increase in temperatures. This was due to thermal reaction that resulted in the production of additional gas yield due to increase in temperature. But it remains comparatively low at moderate temperatures same as reported Funda and Asli [34] in their experiments.

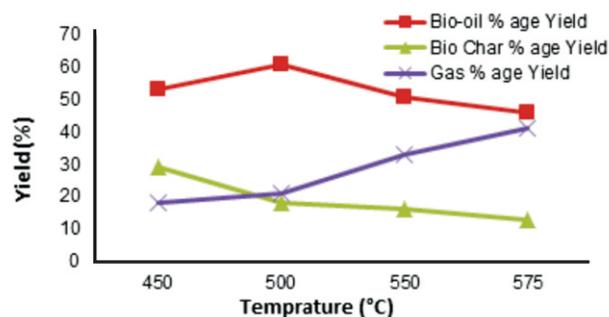


Figure 3: Effect of temperature on catalytic samples from pyrolysis products yield of cotton stalk

Figure 3 showed the catalytic effect on percentage of bio-oil yield at different temperatures. Bio-oil yield was low at low temperature and constantly increased due to increase in temperature but there was observed considerable increase in bio-oil yield after the application of catalyst in biomass. An increase in bio-oil yields from 57% to 61% was observed because high temperature and catalyst accelerated the decomposition mechanism of biomass. When temperature increased from 500°C onward, bio-oil yield decreased same as in non-catalytic samples. This trend is same as other

researchers [33] reported in their experiments.

The temperature and catalytic effect on biochar yield can easily be observed in Figure-2. At low temperature bio char yield was higher as compared to higher temperature but in catalytic samples biochar values decreased as compared to non-catalytic samples. Its reason was the catalyst enhanced decomposition mechanism that's why higher bio char vales never obtained. Biochar yields were decreased by increase in temperature. These experiments showed same trend as [34] reported during their experimentation.

The effect of catalyst on percentage of gas yields can easily understood in Figure 3. Low gas yields were observed at lower temperatures and then an increase observed due to increase in temperatures. Major increase in gas yields was observed at temperature 500-575C. Gas yield almost double time increased. By the increase in temperature, it was observed, primary pyrolysis products transformed into secondary pyrolysis products at the same time the use of catalyst synergistically affected the gas yields as compared to the non-catalytic samples. Primary cracking occur on the exterior surface that followed diffusion into the pores of the catalyst. Short chained compounds are produced by the vapors of the pyrolysis that stimulate the cracking reaction on catalyst pores that resulted increased temperature. Catalyst in fact induced reaction rate that resulted in cracking reactions, at high temperature. This development is same as other researchers [35] reported in their experiments.

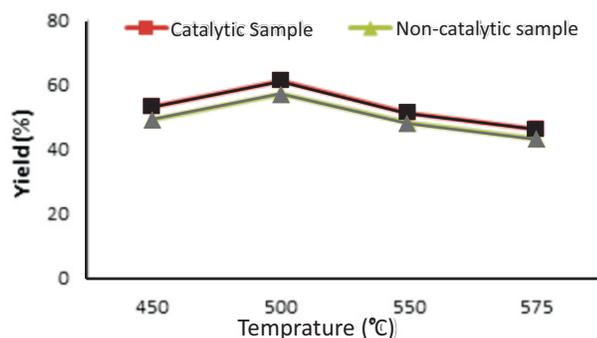


Figure 4: Comparison of bio-oil yields of catalytic and non-catalytic samples of cotton stalk at different temperatures

At 450 °C the oil yield 49% was obtained from non-catalytic sample that reached 53% by using catalyst (Figure 4), which showed an increase of 8% during experiments. Similar trend observed at optimum temperature 500 °C in which 57% of bio-oil yield increased up to 61% of highest yield obtained during all of these experiments and showed an 4% increase in bio-oil yield as compared to non-catalytic sample. At higher temperatures a sudden decrease in bio-oil yield was observed both in catalytic and non-catalytic samples. At 550°C & 575 °C bio-oil yield was 48% and 43% of non-catalytic samples and 51% and 46% of catalytic samples respectively that showed 6% increased yield of bio-oil in both samples. From the obtained results it could be concluded that the catalyst alumina used with the cotton stalk maximized the yield of some products that depends on the temperatures. These pyrolysis products are formed by the reactions took place in the in catalyst pores. At optimum and low temperature it increased the oil yields as compared to the non-catalytic samples. This influence was comparatively same as compared to Funda and Asli [34] mentioned in their experiments.

3.2 Characterization Of Bio-oil

3.2.1 Heating value of bio-oil

Heating values are always higher with lower oxygen content during the pyrolysis of bio-oils without catalyst at high temperature or with catalyst at optimum temperature. The calorific values of this experiment was lower than that of other reported results [35]. Its reason was the presence of more moisture content that was observed in our experiment. During experimentation, heating values of 26.05 MJ/kg for non-catalytic sample and 27.52 MJ/kg for catalytic sample at 500C was observed. The calorific values of our products were higher as compared to reported results [33] because fixed bed reactor was used in our experiment that can transfer more oxygen in un-condensable gases as a result bio-oil of our product has less oxygen content and more calorific value. The calorific values of the obtained product were comparable to that of the values reported in literaure which were almost half less than that of crude oil (44 MJ/kg).

3.2.2 Ash value of bio-char

Ash value of the bio-char of non-catalytic sample at 500C was 25% and catalytic sample ash value at same temperature was 18%. These lower ash values indicated that it might possible the complete combustion of biomass at this temperature occurred and readily released more volatile compounds during pyrolysis, left solid product with lesser ash content. More improved heating value and more

valuable product resulted.

3.2.3 Fourier transform infrared spectroscopy (FTIR) analysis of bio-oil

Chemical composition of bio-oil samples were also determined by FTIR technique. FTIR is latest and non-destructive technique used for the analysis of compounds that actually based on the absorption of functional group in the infra-red (IR region) of bio-oil [36]. Followings are the spectra of bio-oil samples:

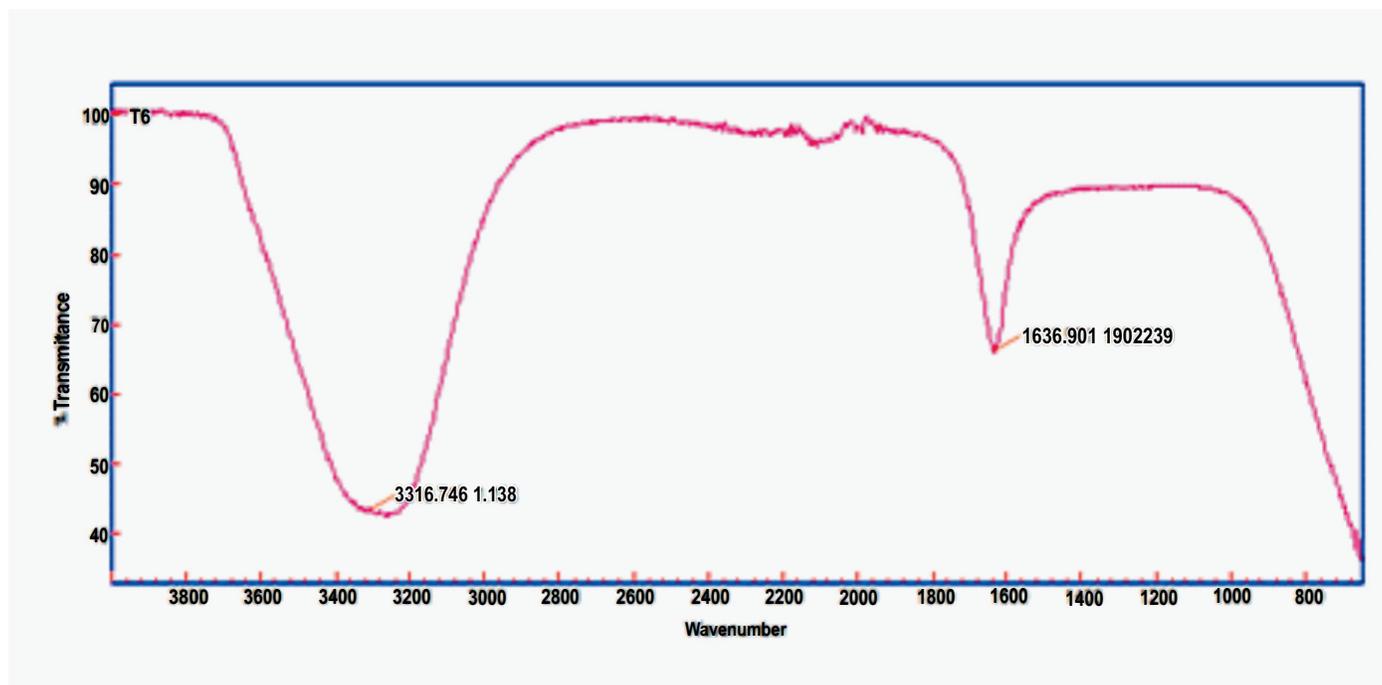


Figure 5: FTIR analysis for non-catalytic sample of bio-oil

The O-H stretching bands for different functional groups present in the experiment # 1 for non-catalytic sample, justified through FTIR analysis by the signals at 3316 cm^{-1} indicate the presence of alcoholic and phenolic compounds and also confirms the presence of water content in the aqueous product of bio-oil, because high intensity of the absorbance observed in this region. The C=C stretching vibrations in the region of 1650-1580 cm^{-1} confirm the presence of aromatic and alkenes

compounds in the sample by the signal at 1636 cm^{-1} . This trend was same as Jewel and Sergio mentioned in their experiments of corn stover pyrolysis in a pressurized batch reactor [37]. The same compounds were observed in cotton stalk samples in the reported results.

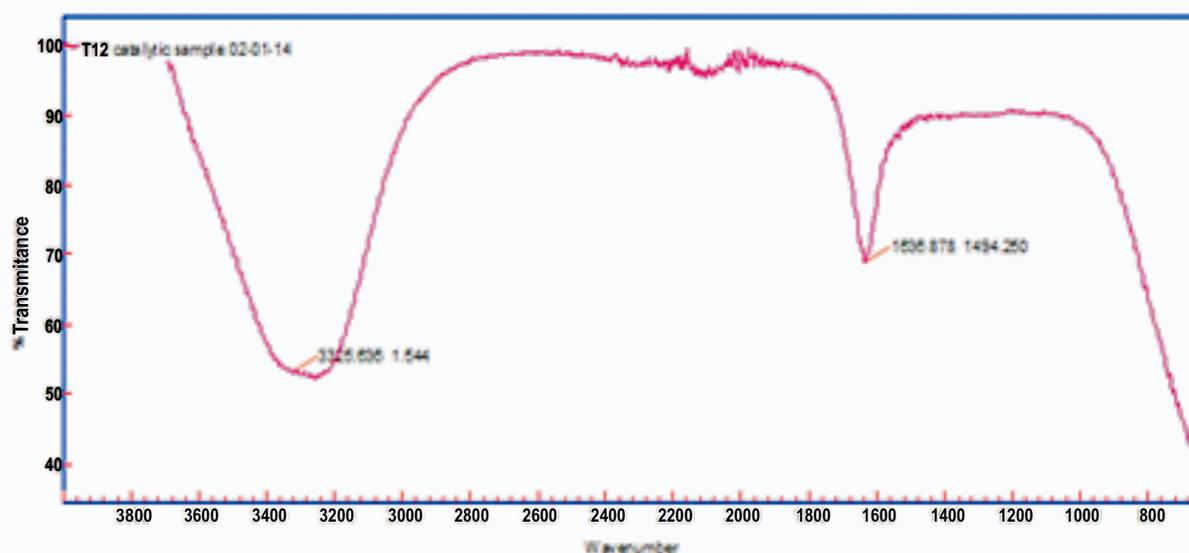


Figure 6: FTIR analysis for catalytic sample of bio-oil

The O-H stretching bands for different functional groups present in the experiment # 1 for catalytic sample, justified through FTIR analysis by the signals at 3325 cm^{-1} indicate the presence of alcoholic and phenolic compounds and also confirms the presence of water content in the aqueous product of bio-oil, because high intensity of the absorbance observed in this region. The C=C stretching vibrations in the region of $1650\text{-}1580\text{ cm}^{-1}$ confirm the presence of aromatic and alkenes compounds in the sample by the signal at 1636 cm^{-1} . This trend is same as Jewel and Sergio mentioned in their experiments of corn stover pyrolysis in a pressurized batch reactor [37]. The same compounds are observed in cotton stalk samples in the reported results.

3.2.4 Gas chromatograph-mass spectrometer (GC-MS) analysis

Gas Chromatograph mass spectrometer is very reliable, convenient and quick source for the estimation of bio-oil samples [38]. There were some compounds that found in bio-oil sample can be classified as phenols, carboxylic acids, alkylated derivatives, polycyclic aromatic hydrocarbons and some other types of hydrocarbons (alkenes, alkanes) [35]. Table 2 shows some detailed components of bio-oil samples by GC/MS. This table included compound names and retention time.

Table-2: GC-MS analysis of catalytic bio-oil

Compound	Conc (wt%)
Acetic Acid	4.7
Acetol	3.4
furfural	1.4
2-methyl-2-cylopenten-1-one	1.2
dodecanoic acid	0.8
1,2-benzenedicarboxylic acid	0.8
fufuryl alcohol	0.7
3-methyl-1,2-cyclopentandione	0.6
5-hydroxymethyl-2-furaldehyde	0.6
palmitic acid	0.5
4-ethyl phenol	0.4
n-penta decyclic acid	0.4
2(5H)-furanone	0.2
phenol	0.3
guaiacol	0.2
p-cresol	0.2

The above mentioned compounds were present in sample of bio-oil. The presence of carboxylic acids, aromatics and ester is relevant to the results of Funda and Asli [35] reported in their experiments on corncob. In the sample of bio-oil, from cotton stalk, same compounds were verified by GC-MS. Following are the libraries of GC-MS characterization.

4. Conclusions:

At low temperature, higher pH values of bio-oil were observed and at the same time, char products were also observed at higher side and showed high calorific and lower ash values. By the application of catalyst all the values of pH were decreased. Moderate temperature of 500C, was an optimum temperature for the production of bio-oil products whereas higher temperatures favored cracking the products in gas form, during non-catalytic experimentation. By the application of catalyst, gas yields were increased when temperature was high. Application of catalyst and at the same time increase in temperature synergetically influenced gas yield as compared to non-catalytic samples. The characterization of bio-oil product showed that phenols and aromatic compounds were detected in greater amount during catalytic experiments as compared to non-catalytic. Optimum temperature of 500C was ideal for these compounds. At high temperatures gaseous products were formed and aromatics with single ring and multi ring were also detected. Major improvement was the detection of carboxylic acids and esters in cotton stalk samples that were the major constituent of the bio-oil. In fast pyrolysis of biomass, use of the catalyst can be useful for better quality fuels and essential chemicals.

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