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A Case Study of Bio-char Production from Biomass using Microwave Assisted Pyrolysis and its Utilization

Muhammad Zeshan Afzal, Huiyan Zhang, Muhammad Aurangzeb, Wang Bing, Yaping Zhang

***Abstract*—**Microwave pyrolysis is a modern technology to produce a good quality biochar. Gives best products, utilization and most important, process is environment friendly. In Microwave, radiation use for pyrolysis and process is: fast, specific heat area. But in conventional pyrolysis heat cannot be controlled for specific area. Microwave pyrolysis depends on the parameters: temperature, reaction time, feedstock type and Microwave Absorbers (MWAs). Production depends on the types of pyrolysis (slow, fast and flash). In the previous work focused on bio-oil and gases. But the biochar is storing source of energy and utilization. This review paper provides information about biochar obtained from microwave-assisted pyrolysis in all aspects and its utilization. It is concluded that microwave-assisted technology is an efficient technique to decrease the reaction time and increases the quality of products. In calculation, this method can overcome the requirements of feedstock destroying and improves the quality of heating.

***Keywords*—**Biomass; Biochar; Pyrolysis Parameters; Microwave assisted pyrolysis.

I. Introduction

Rise of energy utilization, restricted resources of petroleum, climate problems and global challenges needs more advance methods for the use of biomass in most better ways[1]. Recently most of energy demand is fulfilled by non-renewable energy resources containing nuclear technology and fossil fuel that's also the reason of environment pollution. Now global energy relies on fossil fuels seriously. In 2014 more than 80% of primary energy is provided by fossil fuels[2]. On the other hand, main environmental worries are changing in global environment due to emissions of greenhouse gases. For that reason, renewable energy technologies, such as wind power, bioenergy and solar photovoltaic gained growing interest. In all these bioenergy is the best option because of its lavish, safe, clean. Moreover, biomass is the only way to produce renewable solid, liquid, and gas fuels. Lignocellulosic biomass, such as wood, crops, and agricultural and forestry residues, is primarily composed of hemicellulose, cellulose, and lignin[3]. Biomass transformation provides three products, biofuel (liquid), biochar (Solid), biogas (Gas). Recently, there has been rising anxieties about the thermochemical exchange of sludge into bio-fuels for energy recovery through pyrolysis and gasification techniques.

As compared to the heat recovery from burning and combustion, through pyrolysis and gasification, specific conditions sludge can be converted into high-quality bio-syngas, flammable tar and char products. Pyrolysis/gasification is an effective technology for a clean conversion[4]. Now biomass is the hot research topic by the researcher because it's not only fulfil the energy demand but also overcome the greenhouse gas emissions[5]. The global prime energy comes from non-renewable fossil fuel resources. Biochar is solid material has pores and generally it looks like charcoal and it is produced by the pyrolysis of biomass under limited oxygen condition. Biochar has high carbon content and also has good surface area[8]. It is thermally stable product and it is the best form of biomass to store for a long time[9]. Biochar can be well-kept for hundreds of years [10]. Biomass is commonly composed of three main groups of natural polymeric materials: cellulose (around 50% on dry basis), hemicellulose (10-30% in woods and 20-40% in herbaceous biomass on dry basis) and lignin (20-40% in woods and 10-40% in herbaceous biomass on dry basis)[11]. Biochar is solid that's mean it is environment friendly that store the CO_2 in it and when it is use for soil abonnement then it gives CO_2 to the plant and that's they need. The production yield depends on the types of process (slow, fast, flash) and pyrolysis conditions (temperature, time, pressure, heating time). Besides fast pyrolysis, microwave pyrolysis (MWP) provides distinct heating method to process diversity of feedstocks and is also right for making liquid, gas and biochar products from coal and biomass. Biochar is basically transparent to microwave (MW) due to its properly low MW absorption capacity. low MW absorption of coal indicates the major uncertain during MWP, although some moisture and mineral contents within coal matrix respond more readily to MW energy. Moreover, the coal sample cannot be paralyzed or achieve sufficient temperature without Microwave Absorber (MWA) even in the presence of high MW power source[6].

Muhammad Zeshan Afzal: National ASIC System Engineering Center, Southeast University, Nanjing, 210096, 3349596259@qq.com
Huiyan Zhang: National ASIC System Engineering Center, Southeast University, Nanjing, 210096, hyzhang@seu.edu.cn
Muhammad Aurangzeb: College of Energy and Electrical Engineering, Hohai University, Nanjing, 210096, maurangzaib42@gmail.com
Wang Bing: National ASIC System Engineering Center, Southeast University, Nanjing, 210096, 767278796@qq.com
Yaping Zhang: National ASIC System Engineering Center, Southeast University, Nanjing, 210096, amflora@seu.edu.cn

Pyrolysis is done by two techniques one is conventional pyrolysis and the second is microwave pyrolysis. The first one is an old method and not well suffices. Nowadays MW pyrolysis is very popular heating method because of its fast heating rate, selective heating, volumetric and uniform heating and that's why its accuracy and efficiency is better. These advantages of MW are attributed to dielectric heating and generated "hot spots"[12, 13]. Many researchers have reported significant reductions in processing times of microwave over conventional sintering[14]. One of other good benefit of MW is that it is easily control by switch buttons and very safe to operate. When it operate, reaction is done in reactor and the emission bad gasses do not come out that's why this technique is environment friendly [15-17]. Hence, MW is an extremely most capable means to accelerate chemical transformations, such as in the pyrolysis of biomass compared to convention pyrolysis (CP), microwave assisted pyrolysis (MAP) is conducive to obtain organic volatiles, chemicals and bio-gas at relatively low temperature with less energy consumption[18]. In microwave a cooling gas is use for immediate quenching of pyrolysis products, which is not possible in conventional pyrolysis systems. Therefore, more benefits arise from the absence of hot gas treatment and energy recovery systems[19]. Recently NASA investigated that the microwave pyrolysis is a practical method for waste recovery of craft in space. Due to this method is a major energy reduction in total energy requirement that is (~70%) compared to conventional heating system[20].

This review paper provides information about biochar obtained from microwave-assisted pyrolysis in all aspects and its utilization. It is concluded that microwave-assisted technology is an efficient technique to decrease the reaction time and increases the quality of products. In calculation, this method can overcome the requirements of feedstock destroying and improves the quality of heating.

II. MICROWAVE PYROLYSIS

It's a single mode microwave device works at very high frequency 2450 MHz. The magnetron inside the microwave generator can change over electrical power to microwave power which can be balanced from 0 to 2000 W, and after that the microwave vitality can be guided to reaction chamber, as shown in Fig 1 [21]. But all the material cannot absorb the radiation, so the raw material with a high transparency of heat is mixed with that material i.e. carbon is high heat absorber so because of that the material in a microwave reactor get temperature more than 1000°C in a few minutes. If the water exists in the feedstock that will drop the heat rate of CP due to heat absorbed by water and that's why the final pyrolysis temperature will be decreased. But in MW the water in feedstock increase the heart rate, cause to the large MW absorption capacity of water in comparison with dry biomass itself .

The biomass is placed in a glass cubic box and then placed in a reactor and to measure the temperature inside the box a thermocouple is used and N2 or Ar gas is passed to maintain the temperature and after experiments is cools down. Fig 2 shows microwave pyrolysis process flow diagram[19]. Many researchers worked to know the yield of biochar by changing the different parameter like temperature, heating rate and feedstock in both MWP and CP. Elsa Antunes et al. [22] studied the effect of pyrolysis temperature between 300 °C and 800 °C on the chemical and physical properties of biochar obtained from bio-solids through MWP. Bio-solids were pull out from soil resolving ponds at a sewage treatment facility (Euroa Wastewater Treatment facility in Victoria, Australia), and stored for one month for use in laboratory experiments. To reduce irregularities, a 10 kg lot of bio-solids were mixed to obtain a similar sample. The similar lot was stored in a sealed container in a freezer at 4 °C to reduce bacteriological action. By means of the cone and quarter method, three random samples were taken for categorization. Modified single-mode microwave chamber is used that has power 1.2 kW.

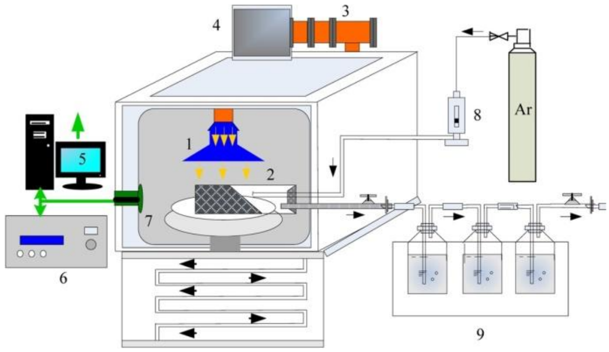


Figure 1. A schematic of the microwave preparation reactor assembly [21]: (1) microwave cavity; (2) quartz reactor; (3) waveguide; (4) magnetron; (5) PC with fuzzy logic algorithm; (6) power governor; (7) infrared radiation thermometer; (8) gas flowmeter; (9) tar products collection unit.

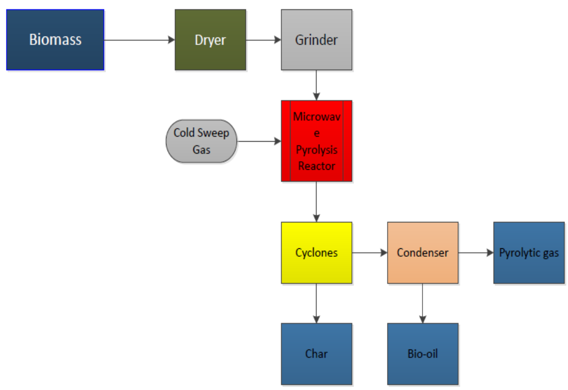


Figure 2. Fig ure 2. Microwave pyrolysis process flow diagram [19]

The bio-solid was mixed with the activated carbon and then ground after that put into a quartz beaker (volume: 150 ml) inside the MWP chamber. The compartment was eliminated with 11 L/min of nitrogen (99.9% purity) for 40 s before the pointer valve was opened and the pressure lowered to 15 kPa gauge pressure. A nitrogen flow rate of

11 L/min matches at a mean residence time of 6.38 s for the nitrogen in the pyrolysis compartment, so a purge time of 40 s was sufficient. At the start of the pyrolysis, the magneto output power was set to 600 W to allow for rapid, but controlled heating of the sample and eventual removal of sample moisture. Once the target temperature was reached, the output power of the magnetron was manually adjusted to keep the sample temperature as close as possible to set point (±15 °C). The control valve was manually adjusted to maintain the pressure within the chamber around 15 kPa gauge pressure.

Bio-solids samples were paralyzed at different temperatures between 300 °C and 800 °C for approximately 10 min. In testing, a thermocouple was placed in the middle of the sample, in the single-mode chamber, to note the reading of sample temperature. Pyrolysis temperature was checked by a shielded type K thermocouple coupled to an Arduino board, and recorded every 500 ms. The pressure in the microwave chamber was physically measured by an inline needle valve between the cold water tap and the vacuum pump.

A. The mechanism of MW for biomass pyrolysis

The mechanism is very simple because everything can be control for example how much heat is required for how long time and which specific area need heat. Microwave furnace is easily operated device. Pyrolysis of biomass such as plants, hardwood raw material, rice straw and forest residue by microwave heating system is a significant biomass learning resource ecological feedstock for the creation of bioenergy and renewable materials. Microwave heating system is better than conventional heating system due of advantages. Hot areas that form by MW radiation could have significance.

It has two steps first one is that energy is absorbed then through conduction process transferred to the biomass. In another step, as the pyrolysis continues, more carbon is created from the raw materials and the microwaves begin to pervade inside the materials, giving surge to reactions unfamiliar in conventional heating system. In the Fig 3 it is explained the nature of microwave heating[23].

Effect on the produce and characteristics of MW handlings products. Use of microwave pyrolysis, almost 50 % of lignocellulosic biomass can be changed into gas product, which is principally made up of H_2, CH_4, CO_2, and CO, with an increase of bioenergy due to its high H_2 and CO produces[24]. It was discovered that if just the natural wet sludge is heat in the microwave just only drying out of the testis occurs. However, if the sludge is blended with a tiny amount of the right microwave absorber like the char stated in the pyrolysis itself temperature ranges as high as 900°C so that pyrolysis occurs than drying out the wet biomass[25].

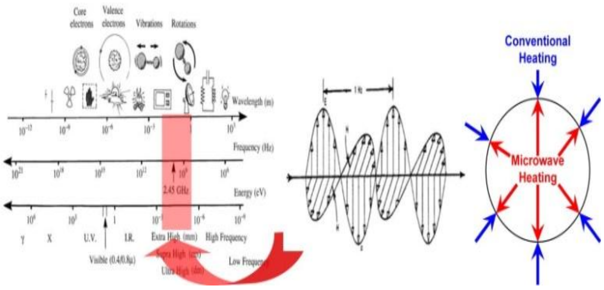
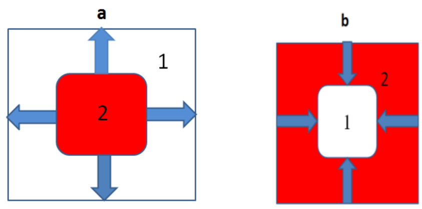


Figure 3. Electromagnetic spectra and microwave heating nature [23]

MWs heating is done my two mechanism that are dipole rotation and ionic conduction. When MWs in contact with polar molecules or iron then heat is induced quickly. In the fast oscillating electric field of the MW polar molecules try to rearrange themselves. Throughout this occurrence, loss of energy is in the form of heat through molecular resistance and dielectric loss. When a MW-absorbing material is placed in an electric field energy is absorbed permanently, because of this technique it gives a fast 'volumetric' heating. In this type of heating, the center of material has clearly been heated to a significantly higher temperature than the outer material, but the conventional pyrolysis is phenomena is opposite the material get heat from the outer side to inner side, the phenomena is shown in Fig 4. MW heating can be defined as a form of energy exchange rather than a form of heating; for example, electromagnetic energy is transformed into heat. Because of this distinctive inverse heating mechanism offers many benefits such as an increase in energy transfer efficiency and decreases in heating time for getting desired temperature for pyrolysis. It is better than conventional pyrolysis. it allows improved controlling of the heating process and removes the threat of the sample surface overheating and possibly degrading an also this technique can be used for drying the wet material.



1=cooler region, 2=hot region

Figure 4. The differences in temperature distribution and direction of heat transfer between conventional and microwave heating.

B. Microwave absorber

MWA work is to absorb Microwave heat very efficiently. In an experiment sometime, it is very hard to achieve required temperature or desired peak pyrolysis temperature. So, for that problem material is used as absorber that have high dielectric lost tangent parameter (DLTP). Because of absorber the reaction become faster so its work is like a catalyst too. MWA have been utilized in military applications; such as, antenna design shaping, radar cross reduction and electromagnetic interference (EMI) reduction

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for a few decades. Even more recently with the surge of wireless electronics at higher GHz frequency, MWA or noise suppressors are being used to reduce EMI. Magnetic absorbers are slim (0.1-3 mm) polymeric materials filled with permanent magnetic nano/micro sized particles[26-30]. To test the material for a good absorber there are some parameter to test that material. The following points are considered for a good absorber: (I) what frequency bands need to be covered? (II) Is coverage required over the entire range of frequencies or just at specific frequencies? (III) What is the order of importance in coverage? A design can be more easily being finalized if these priorities are met[31].

There is a list of absorber that are char NaOH, Na2CO3, Na2SiO3, NaCl, TiO2, HZSM-5, H3PO4, Fe2(SO4)3[23]. These absorbers are used in a microwave pyrolysis. It is calculated that all these absorbers whether they are basic, neutral or acidic, metallic or non-metallic water soluble or insoluble, have increased yield of solid products greatly and decreased yield of gaseous products more or less. Liquid yield undergoes no dramatic change. The absorbers in pyrolysis evolve the gases earlier and for that the absorbers that have sodium play an important role[32].Figure 5 shows the effect the absorbent on heating characteristics using SiC absorbant.

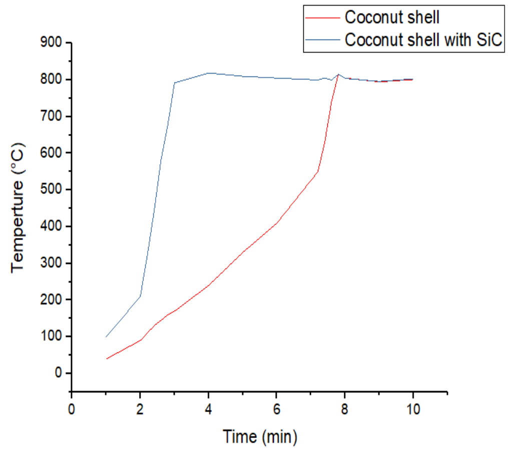

Figure 5. The temperature profiles for coconut shell with and without SiC under microwave heating

C. *Conventional pyrolysis*

Conventional heating systems include outward heating by conduction, convection or radiation. In this method a huge amount of energy is wasted and the resulted biochar is not enough capable. Because of this method a huge amount of heat damages the biochar surface and layers. In biomass pyrolysis there are many parameters under consideration like (heating rate, pyrolysis temperature, pressure, particle size). However for the large quantity of biochar to achieve by low temperature and low heating rate is the best condition[33]. It has many drawbacks in which transferring of heat, waste most of the part of heat, no proper heat to the right place, due to high temperature the damage of reactors walls etc. The other flaw is it takes more time to reach the desired temperature and because of long heating time the secondary reaction take place and because of the secondary reaction the layer of biochar are damage and it effect the overall quality of product[34]. Fig 6 is the design of the CP[35].

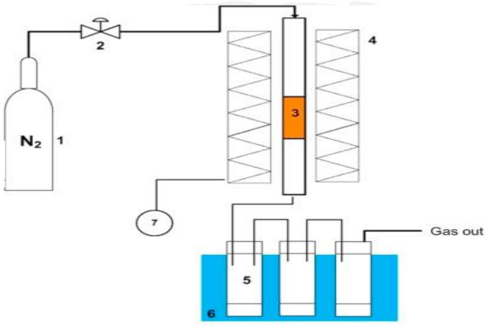

Figure 6. [35] 1 N2 gas,2 Mass Flow controller,3 Biomass sample, 4 Furnace,5 Bio-oil Condenser,6 Thermal bath, 7 Temperature controller

D. *Microwave and conventional Pyrolysis*

Microwave pyrolysis is one of the many ways of converting biomass into higher value products such as bio-oil, syngas, biochar and chemicals. Table 1 shows the advantages and disadvantages of microwave pyrolysis and conventional pyrolysis [55]. Comparing with conventional pyrolysis, there has a lot of advantages for microwave pyrolysis, such as, no size reduction, wet biomass can be used directly without drying, higher quality of products, and process contingency. All these will not only improve the energy efficiency for the process, but also reduce the capital cost, such as feed storage, size reduction, and feed dryer. Another key advantage of the microwave heating process over conventional heating method is the nature of fast internal heating by microwave irradiation. Microwave energy deposition in the dielectric loss mode of heating can cause spatially uniform heating[56].Biomass fast pyrolysis can be achieved by microwave radiation. Products obtained from MWP and CP at different temperature Table 2 [36,37]. And also the the classification of pyrolysis are listed in Table 3.

TABLE I. ADVANTAGES AND DISADVANTAGES OF MICROWAVE PYROLYSIS VS. CONVENTIONAL PYROLYSIS

	Microwave Pyrolysis		Conventional Pyrolysis	
	Advantage	Disadvantage	Advantage	Disadvantage
1	No size reduction and drying for biomass; Flexibility of feedstocks and products	Temperature measurement	Flexibility of feedstocks and products	Lower quality products (e.g. formation of PAHs)
2	Energy savings at significantly reduced processing temperatures (150-300°C)	Economics of the process scaling-up	Well developed and easy scale-up	Energy consumption due to higher temperature (>600°C)
3	Possibility of	Large scale	Possibility of	Lower quality

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	continuous processing with multiple units	inhomogeneneities/re producibility issues in products	continuous processing at large scale	products (e.g. formation of PAHs)

TABLE II. OBTAINED PRODUCT FROM MWP AND CP AT DIFFERENT TEMPERATURE [36, 37]

	T (°C)	Heating rate (°C/min)	Carrier gas (mL/min)		Product yield (Wt. %)		
			Argon	N2	Char	Liquid	Gas
CP	310	20	-		59.7	31.5	8.79
	500	-		60	29.2	13.5	57.2
MP	800	-		60	25.3	11.8	62.9
	200	8	-		43.2	47.1	9.7
	500	-		60	30.2	7.9	61.9

TABLE III. PYROLYSIS CLASSIFICATIONS

Pyrolysis Techniques	Reactio n temp./°C	Heating rate/°C s^{-1}	Particle size/mm)	Residence time	Pressure/ MPPa)	Major product Types	References
Slow pyrolysis	300-800	0.1-1.0	5-50	5-30 mi	0.1	Biochar, bio-oil and syngas; biochar is dominant	[55-58]
Intermediate pyrolysis	300-450	3-5	1-5	~10 mir	0.1	Biochar, bio-oil and syngas	[54,56,58
Fast Pyrolysis	500-550	10-100	<1	< 2 s	0.1	Bio-oil, syngas and biochar; bio-oil is i high quantity	[59]

1) Effect of parameters on MWP yield

TABLE IV. THE YIELD OF BIOCHAR OBTAINED FROM MWP ON DIFFERENT TEMPERATURE

Feedstock	Experiment parameters	MWP	ref
Aspen pellets	T 450-550 _C, MW ,catalysts: Al2O3, , MgCl2, AlCl3, CoCl2, and ZnCl2	biochar yield: 25-31 wt.% ,Bio-oil yield: 35-42 wt.% (MgCl2.6H2O: 0e8wt%, dia. 4.8 _ 4-8 mm pellets)	[60]
Pine sawdust	T =400-800 C, MW power =2k W, 4 g sawdust,MW heating tim =3 min, N2 of 30 mL/min; MWA charcoal size 1-2 mm	Char yield: 13-26 wt.%; Syngas composition: CO = 40-48v%, H2=16-31v%, CO2 = 7-30v%,	[61]
Wheat straw	T = 400-600C, MW power = 3 kW, size <90 mm,5-30 g sample, N2 of 3L/min, MW heating time = 10min	Char yield: 40-50 wt.%; Gas yield: 17.69 to 22.27 wt. %; Combustible gas ratio=67.21-77.14 vol%;	[62]
Kraft lignin	300 g char and lignin, 623-967 _C, MW power: 1.5-2.7 kW, N2 of 500 ml/min, 800s heating time	Major products in bio-oil: Guaiacols (135-184mg/g oil)	[63]

2) Graphical comparison between MWP and CP

As shown in Fig. 7 a number of researchers observed at MWP in comparison with CP and recognized significant differences between the two technologies emphasizing decomposition temperature, heating rates and requirements [38].

3) Energy distribution

The heating values of the oils are the highest, followed by those of the cars, whereas the heating values of the gases are the lowest. The Higher Heating Value (HHV) of the oils and gases are higher when MWP is used to compare to CP, while the core values are similar for both pyrolysis methods (_24 MJ/kg). The effect of temperature on the HHV

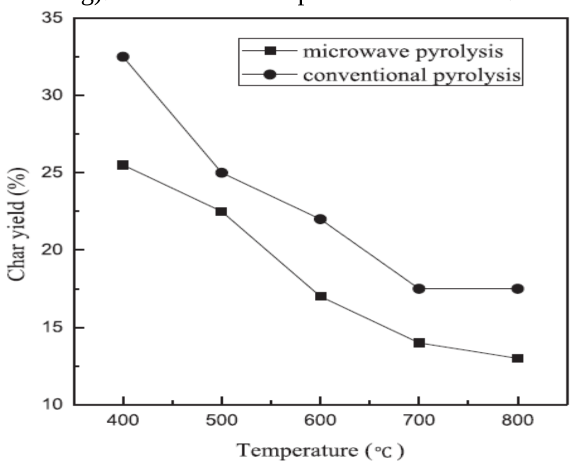

Figure 7. Variation of the char yields from MWP and CP of pine sawdust with temperature [38]

of the oils and chars is practically negligible. However, the HHV of the gases increase with the increase in pyrolysis temperature. The amount of recoverable energy from each pyrolysis product (Ei) was determined in order to compare it with the energy content of the raw material. Ei was calculated by the following expression

Ei =HHVi _ Yi; i = char; oil or gas;

where Y is the fraction yield and HHV is the corresponding higher heating value. From these values the energy distribution in each pyrolysis Product (%) was calculated as follows:

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$$\text{Energy distribution i } (\%) = 100\left(\frac{Ei}{HHV\ raw\ material}\right)$$

Fig.8 give the detail of energy distribution (%) at different temperatures for conventional (CP) and microwave (MWP) pyrolysis. In the microwave, the energy that recovered at all temperatures is almost close to 100 %. Although, it increases with increase in temperature in conventional pyrolysis from 85% to 98% at 500 and 1000 °C, respectively. Production of gas increases by two techniques one is increasing the temperature and other is using microwave. But the error in the recovery of oil and the recoverable energy from the oil is reduced.

In CP at 1000 °C, the percentage of energy distribution in the gas portion is the maximum; contrariwise the oil and biochar portion have minimum energy distribution. Furthermore, the energy accrued by the gas increases as the pyrolysis temperature increases. Inversely, the energy accrued by the char decreases with the temperature. These effects are more prominent in MWP than in CP.

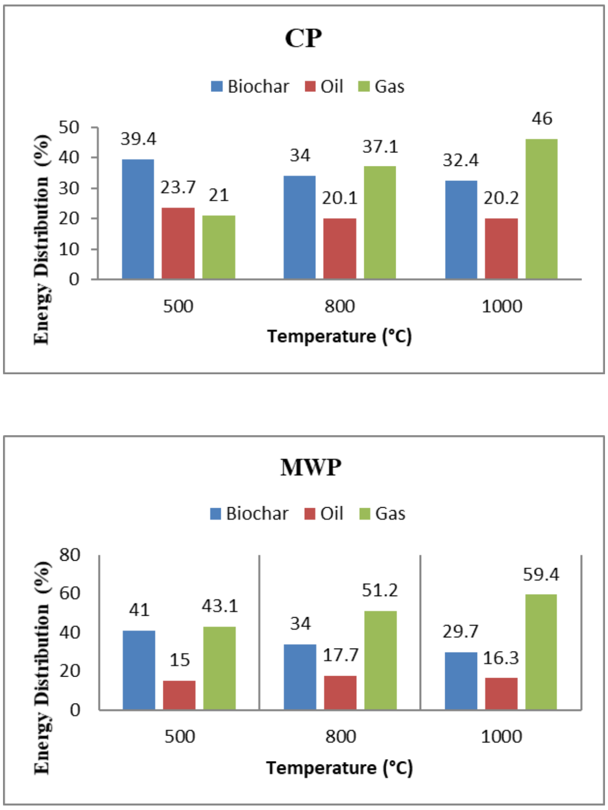

Figure 8. Energy distribution (%) in each fraction from conventional (CP) and microwave (MWP) pyrolysis [37]

III. UTILIZATION

The biochar has many benefits in environment and agricultural field, including. Decrease from claiming manufactured fertilizers, carbon sequestration, worldwide warming mitigation, water asset protection, soil. Biochar is applied to soil systems for soil improvement, mitigation of climate change, and waste management[39,40]. Furthermore, improvement in crop production. Biochar for soil is very valuable, effect its chemical and physical properties, reduces greenhouse gas (CO2, CH4 and N2O) emissions, and improves the infectious health of soil. It profits agriculture, the budget and the environment a series of benefits. Generally, biochar contains of particles with low density and thus repaying it to soils can decrease soil bulk density, growth soil softness and increase the soil terrene. By addition biochar, the soil is well able to hold moisture and the soil quality improves in terms of several carbon and energy sources as well as mineral nutrition for the development and reproduction of microorganisms[41].

Biochar is mainly used in agriculture where it has many positive aspects related to carbon storage, soil hydrology, soil biota, crop yield, compost improvement, or feed additives[42-45]. Biochar need an incredible possibility will absorb Ecological contaminants because of its totally accessibility of feedstocks, minimal effort Furthermore ideal physical/chemical surface characteristics, for example, an expansive. Particular surface area, microporous structure, Active functional groups, Furthermore high ph. Biochar camwood a chance to be utilized Likewise an impetus straightforwardly alternately Concerning illustration a forerunner to making impetus in the fields for syngas cleaning, change for syngas under fluid hydrocarbons[46]. Biochar produced from microwave catalytic pyrolysis is more efficient in increasing the soil WHC(Water Holding Capacity) due to its high porosity in comparison with the biochar produced from conventional pyrolysis at the same conditions. Strong positive correlations also can be found among soil WHC(Water Holding Capacity) with CEC(Cation Exchange Capacity) and biochar microspore area. Biochar from microwave-assisted catalytic pyrolysis is apparently a novel way for producing biochar with high sorption affinity and high CEC. These catalysts staying in the biochar product would provide essential nutrition for the development of bioenergy and food crops[47]. Biochar and other carbonaceous materials are widely used as treatment materials to remove a range of metals (e.g., As, Cd, Cr, Cu, Ni, Pb, Zn) and organic contaminants from aqueous solutions[48-50].

Elsa Antunes et al. [51] detached silver from an aqueous solution successfully using biochar. The increase in silver concentration and temperature influences positively on silver removal onto biochar. Biochar feedstock plays a main role in silver removal from aqueous solution. Bio-solids almost have 50% moisture content were filtered to get particle size less than 5.2 mm then mixed with activated charcoal, make sure that charcoal particles did not break during the mixing process. Mixture samples (60 g) were used for microwave pyrolysis. The pyrolysis tests were carried out in a modified single-mode microwave at 600 W Temperature was monitored by a type K thermocouple and kept at set-point by adjusting the applied net microwave power.

Huang et al.[52] reported that biochar produced from microwave pyrolysis has a better ability to absorb CO2. A

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biochar produced by a microwave that has 200W power and maximum temperature 300C can absorb CO2 with the capacity of up to 80 mg/g at 20 °C, which is higher than the biochar produced by conventional pyrolysis by 14%. The CO2 adsorption capacity is extremely linked with the specific surface area.

Mohamed et al.[53] showed that the biochar produced from microwave is more efficient than biochar produced by conventional pyrolysis in term of soil water holding capacity and to get a good biochar for soil application the catalytic microwave pyrolysis is best at low temperature 300°C. Biochar's produced from mixing switchgrass with two or more catalysts results greater performance in increasing soil WHC (Water Holding Capacity) and CEC (Cation Exchange Capacity), and improving soil fertility clearly compared with the biochar produced from one catalyst only.

CONCLUSION AND FUTURE WORK

Microwave pyrolysis is a modern technology to produce a good quality biochar. And it gives the best byproducts and their best utilization and the most important thing is this process is environment friendly. In Microwave the radiation is used for pyrolysis and this process is very fast, time saving and we can heat the specific area of biomass and also can control the volume of the radiation. And we get a biochar that has a large surface area and very good pores layers. Almost all the reviews explain the characteristics of bio oil and gasses. But in this review Paper it will give the detail about Microwave assisted pyrolysis and the source of biochar, its characteristic, chemical composition, distribution and the amount of Biochar obtained. In Microwave pyrolysis to make the reaction fast and to increase the heat absorption fast for that Microwave absorber and catalyst are use. Because of these the reaction is fast and takes a little time to get our biochar. In reactor the gases are produce so Microwave absorber also react with these gases to maintain the quality of product. Microwave pyrolysis and the obtained biochar is depending on parameters that are very important Temperature, reaction time, feedstock type and to absorb the sufficient heat we use catalyst called Microwave absorbers MWAs. And production depend upon on the types of pyrolysis (slow, fast, flash).

The Conventional and Microwave Pyrolysis are two different techniques. They both are used for different kind of products to obtained. the quality of biochar by microwave pyrolysis is good as compared to Conventional Pyrolysis but quantity is higher in CP. The work is to be done is to increase the more quality and quantity of biochar in MWP by changing the Temperature, reaction time, feedstock type, reactor type and Microwave absorber or catalyst. One more thing need attention that is after getting biochar by Microwave pyrolysis the Microwave absorber remain in the biochar so what will be the effect of absorber on biochar characteristic that need more research.

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