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Catalytic Microwave Pyrolysis of Albizia Branches Using Iraqi Bentonite Clays

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Abstract

Catalytic microwave-assisted pyrolysis of biomass is gaining popularity as an alternative to fossil fuels due to health, environmental, climate, and economic issues. This study conducted a catalytic pyrolysis process of the Albizia plant's branches using an Iraqi clay catalyst (bentonite) focusing on the variables including the biomass-particle size, experimental time, microwave power level, and the catalyst-to-biomass ratio. The physical and chemical properties of the resulting biofuel were analyzed presented by HHV, acidity, density, viscosity, GC-MS, FTIR for bio-oil and SEM, EDX, BET, HHV, FTIR for biochar. The study revealed that addition of bentonite as a catalyst led to enhanced production of biogas produced from 5% to 45% and decreased the power level used from 700 W to 450 W. Also, it raised the production of bio-oil generated with less power level and duration time. The addition of catalyst also affected the characteristics of bio-oil produced such as reducing the acidity by increasing its pH from 5 to 5.7, lowering the viscosity from 4.8 to 3.3 cSt, and the density from 1045 to 1039.2 kg/m^3. Adding catalyst increased the percentage of aromatic and alcoholic substances in the bio-oil which led to improve the calorific value from 19.5 to 23 MJ/kg. Additionally, the biochar properties also improved, where the surface area and pore volume increased from 0.5512 to 40.384 m^2/g and 0.00011 to 0.0361cm^3/g respectively. The higher heating value was raised from 23.5 to 25 MJ/kg also. CH_4 is also increased from 3.6 to 8.6% which is one of the essential fuel gasses.

Keywords: microwave pyrolysis; Albizia branches; bentonite; bio-oil; biochar.

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1- Introduction

The demand for energy has increased recently due to population growth and technological advances. However, relying on fossil fuels has severe environmental impacts, causes health problems, increases CO_2 and other greenhouse gases leading to global warming, and has unstable and high prices [1, 2]. Fossil fuels have enough proven reserves of oil, natural gas, and coal to sustain current consumption levels, which means that it are finite and non-renewable sources causing a great economic issue, especially in Iraq because it's mainly dependent on fossil fuel exchange [3].

Renewable energy sources like solar, wind, biomass, water, and geothermal energy have become more popular in recent years due to their benefits such as cheaper biofuel production, minimal greenhouse gases, environmental protection, energy security, and economic advantages [4]. Biomass is an alternative resource that can be obtained from various sources presented by natural regrowth forests, plantation forestry, annual field crop production, algae production, or from residues of any of the above, and used to generate electricity and various types of energies also producing chemicals substances additionally to biofuels [5]. It can be converted into biofuel using thermochemical, biochemical, and physiochemical processes [6]. Pyrolysis is a thermochemical conversion method of organic materials like biomass to produce solid, liquid, and gaseous fuels from biomass feedstock in the absence of oxygen [7, 8]. It can be classified into slow pyrolysis, fast pyrolysis, and flash pyrolysis. During the pyrolysis process, biomass is converted into biochar, bio-oil, and biogas, biochar is a solid biofuel mainly consisting of carbon and has multiple environmental applications like soil amendment, carbon sequestration, and pollutant removal [9, 10]. Bio-oil is a dark viscous liquid containing over 300 oxygenated components derived from multiple sources, it can be used as an alternative fuel, gasoline additive, general chemical solvent, and for synthesizing diverse goods [11, 12].

Microwave-assisted pyrolysis is an innovative method that can improve the quality of bio-oil, biochar, and syngas by increasing the heating rate, it offers several benefits, including waste volume reduction, selective heating, rapid and flexible processes, energy savings, overall cost-effectiveness, equipment portability, and the use of cleaner energy sources compared to traditional systems [13].

However, the poor absorption of microwave radiation by biomass materials often requires the use of a microwave absorber to improve heating effectiveness

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during pyrolysis. Converting and upgrading pyrolysis products remains a challenge due to their high oxygen concentration, viscosity, acidity, low heating value, and other weak characteristics [14]. One technique used to increase the ultimate biomass temperature is using catalysts during the pyrolysis process. Different types of catalysts are used in microwave pyrolyzes, such as zeolite, metal oxides, carbonates, clays, and carbon-based materials [15, 16], as well as natural and pillared clays like bentonite, which can decrease the heavy compound fractions in bio-oil and possibly increase bio-oil yield while also improving the stability of bio-oils organic fraction during accelerated aging experiments [17, 18]. *Albizia lebbeck*, a large tree from the Fabaceae family [19], was converted into biofuel using different methods such as flash pyrolysis [20] and fixed bed pyrolysis [21]. Catalytic Microwave pyrolysis of albizia branches to produce the three types of biofuels hasn't been done before.

The current research investigated the use of microwave pyrolysis with bentonite catalysts to produce bio-oil, biochar, and biogas by studying the effect of different variables on the quantity and quality of the resultant fuels, such as power level, duration time, biomass particle size, and catalyst-to biomass ratio. The physical and chemical characteristics of the bio-oil and biochar were discussed using several standard methods such as viscosity, density, acidity, HHV, GC-MS, and FTIR for bio-oil and SEM, EDX, BET, HHV, and FTIR for biochar.

2- Materials and Method

2.1. Materials

Albizia trees, also called silk trees, are fast-growing subtropical and tropical trees consisting of 160 species found across Asia, Africa, America, and Australia. Iraqi raw powder bentonite from Aldwaikhela was used as a catalyst, which was crushed with a hydraulic hand press and compressed into discs before being broken into particles of various sizes and shapes to separate it from biochar after the reaction. Table 1 shows the composition of the bentonite.

Table 1. Chemical Composition of Iraqi Raw Bentonite

Composition	**SiO_2**	**Al_2O_3**	**TiO_2**	**Fe_2O_3**	**CaO**	**MgO**	**K_2O**	**Na_2O**	**Other**
mass%	57.4	17.9	1.6	8.9	5.5	3.5	1.57	1.5	2.13

2.2. Method

The same setup of the previous research [22] was used as seen in Fig. 1 below. A Samsung microwave oven 24 L had seven power levels, ranging from 100 W to 800 W was used. The albizia branches were washed with distilled water, dried for 24 hours in an oven dryer, ground, and sorted into categories (1-0.5 mm, <0.5 mm). The pyrolysis reactor was a Pyrex glass cylinder (5*17 cm) with three necks; one for the pyrolysis gases directed to the condensation unit which was made up of three glass cylinders held at -15°C. The other for the inert gas, nitrogen, was introduced into the system through a separate tube. The last one is for a K-type thermocouple to monitor its internal temperature. The gases that were not condensed were analyzed using a gas analyzer before being released into the air. The weight of the bio-gas was determined by subtracting the weight of the bio-oil from the total weight of the materials collected during the experiment.

The products obtained, bio-oil, biochar, and bio-gas, were collected and weighed using the Eq. 1 given below:

$$Y_{(o,c)} = \frac{W_{o,c}}{W_B} * 100\% \qquad (1)$$

Where W_B, is the weight of biomass before pyrolysis (g),$W_{o,c}$ is the weight of bio-oil and biochar obtained from the pyrolysis process (g). The reactor was filled with 5 g to 10 g of biomass with the specified particle size at the beginning of the experiment. Prior to the experiment, an inert N_2 gas was introduced into the system at a flow rate of 1 L/min for a few minutes to eliminate any residual oxygen. Afterward, a specific amount of electricity was applied to the microwave and turned on.

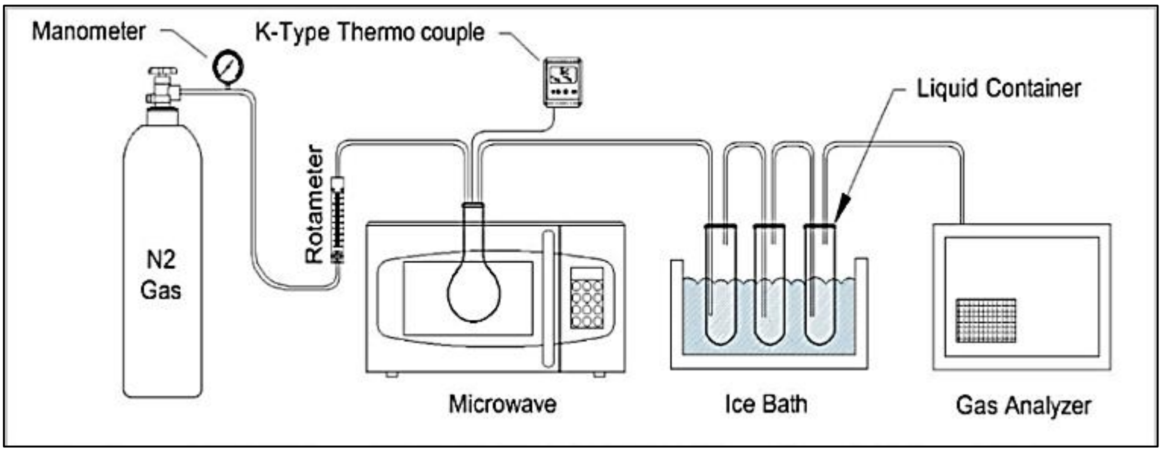

Fig. 1. Schematic System of Microwave Pyrolysis Process

2.3. Products analysis

The properties of bio-oil were analyzed to understand its characteristics and potential uses. Standard methods were used to determine physical attributes such as viscosity, acidity, calorific value, and density. Viscosity was measured using a Cap 2000 device from the USA, acidity was determined with a Starter 2000 pH meter from the USA, and density was calculated by measuring the weight of a known volume. The samples' heating value was calculated using a CAL3K-AP bomb calorimeter from South Africa. GC-MS Agelint (7820A, USA) was used to detect chemical compounds in the bio-oil sample. FTIR spectroscopy (Tensor 27, Germany) was used to identify functional groups and chemical bonds present in the bio0oil and biochar. The specific surface area of biochar was determined using the Brunauer–Emmett–Teller (BET) method, and scanning electron microscopy (SEM) of biochar was performed with a Hitachi VP-SEM with EDX.

3- Results and Discussion

3.1. Effect of Bentonite on Bioproduct Yield

3.1.1. Effect of Power Level with bentonite presence

It appears that the presence of a catalyst affects both the duration time and microwave pyrolysis temperature of an experiment. The heat transfer mechanism starts with heating from the magnetron to the catalyst by convection, and then from the catalyst to the biomass by conduction, which increases the ability of the feedstock to absorb the microwave radiation. This mechanism accelerates the reaction and reduces the duration time required for the reaction to reach completion. A long reaction time after stabilization can lead to a secondary reaction that produces an undesirable product. Different types of adsorbents or catalysts have a specific effect on product formation [23].

Fig. 2 demonstrates the effects of utilizing 450 W of power and a particle size of 1-0.5 mm for 20 minutes. The results show a significant increase in biogas production with the use of bentonite as a catalyst, rising from 5% to 45%, which greatly improves the biogas production process. However, bio-oil production decreased from 55% to 29%, and biochar production decreased from 40% to 26% with the use of bentonite. These changes in biofuel production are due to the catalyst's effect on absorbing biomass heat and increasing the temperature rise rate. A 10% ratio of catalyst to biomass has been shown to produce a higher percentage of gases due to the significant temperature rise, while pyrolysis of biomass without the use of a catalyst under the same conditions results in a high percentage of bio-oil and biochar production. The biomass used in this study appears to be a good microwave radiation absorber, and the addition of a catalyst at this ratio leads to a large temperature increase, resulting in a reduction in biochar and bio-oil fuels and a notable improvement in gaseous fuels.

Furthermore, the power level utilized during the process had a significant impact on the production of bioproducts. It can be observed from Fig. 2 that by reducing the power level from 450 W to 300 W and using bentonite as a catalyst, the percentage production of bio-oil increased from 29% to 42%. Similarly, the percentage of biochar produced was increased from 26% to 51%. However, the gas production was reduced by 38% when bentonite was used. These results are consistent with the findings of [6] which suggested that the addition of a catalyst reduces the power requirement for the production of bio-oil and biochar by increasing the final temperature.

Additionally, from Fig. 2 at the power level of 300 W, it can be seen a noticeable improvement in the yield of bio-oil produced while using bentonite from 28% to 42%. The biochar and biogas products had a reflect response where it was 62%, 10% without catalyst and reduced to 51%, and 7% while bentonite was used, respectively.

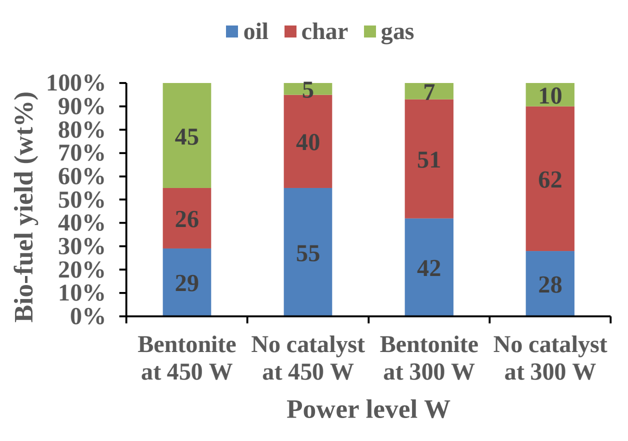

Fig. 2. Effect of Power Levels on Biofuel Production

3.1.2. Effect of Time

Time plays a significant role in the economic feasibility of biofuel production. The use of a catalyst can reduce energy consumption by decreasing the time required for biomass conversion. Fig. 3 shows that the yield of bio-oil increases significantly in the initial few minutes and then increases insignificantly until 20 minutes. With bentonite catalyst, the bio-oil yield increased from 38% to 42% when the time increased from 10 to 20 minutes, while the increase was from 10% at 5 minutes to 28% at 20 minutes without bentonite. The temperature reaches its highest level during the initial phase of thermal analysis where the catalyst maximizes microwave thermal absorption. This may be due to moisture residues in the raw material. Following this, the temperature stabilizes, and there is a negligible increase in ultimate yield, which is barely noticeable in the final bio-oil product.

It is possible to produce the same amount of biochar in less time and with higher quality by using a catalyst. As shown in Fig. 4, adding bentonite as a catalyst can produce 63% biochar in just 5 minutes compared to 62% without any addition after 20 minutes. Bu et al.,[6] and Mohamed et al., [23] also found that higher temperature can be achieved within the first few minutes, resulting in higher biofuel production

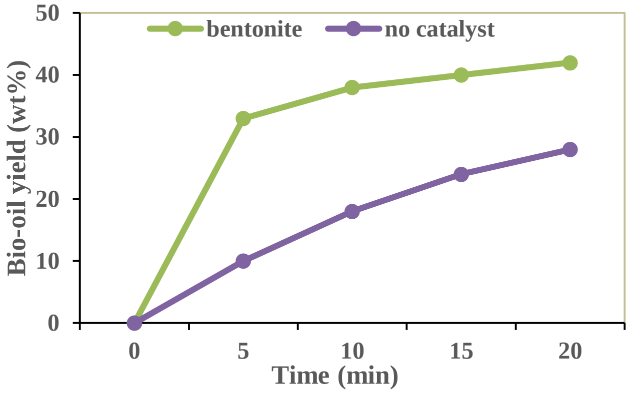

Fig. 3. Effect of Time on Bio-Oil Production

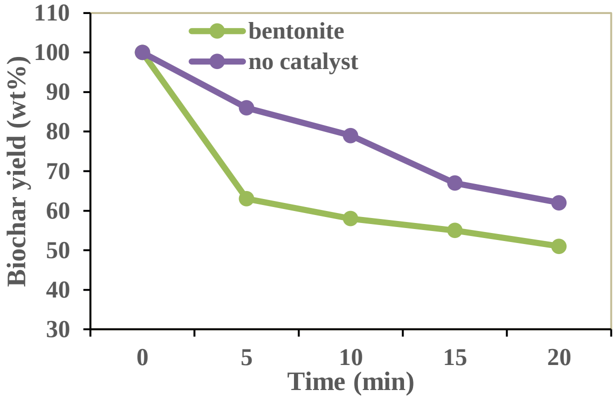

Fig. 4. Effect of Time on Biochar Production

3.1.3. Effect of Particle Size

The size of biomass particles is another parameter that affects the proportions of biofuels. When comparing the effects of two particle sizes, 1-0.5 mm, and less than 0.5 mm, at a power level of 300 W, it was observed that the bio-oil yield decreased with a decrease in particle size. For instance, when bentonite was used, the bio-oil yield decreased from 42% to 35%. A similar trend was also observed in the case of biochar, where the yield decreased from 51% to 45% with a decrease in particle size.

However, the gaseous fuel showed a reverse response compared to bio-oil and biochar. As shown in Fig. 5, the gas yield increased from 12% to 20% when the particle size decreased from 1-0.5 mm and less than 0.5 mm, and bentonite was used. The increase in gaseous fuel yield may have resulted from the decrease in particle size, which increases the surface area available for contact, leading to an increase in the potential temperature of the biomass. This, in turn, causes a reduction in the amount of bio-oil and biochar fuels and a tendency towards an increase in gaseous fuels.

3.1.4. Effect of Catalyst-to-Biomass Ratio

To examine the impact of using a catalyst on bioproducts, the final parameter that was studied was the ratio of catalyst to biomass. The results of the study, shown in Fig. 6, clearly indicate that there is an improvement in the production of bio-oil and biochar fuels when the catalyst-to-biomass ratio is reduced. The use of bentonite has been found to increase the yield of bio-oil by 4% when the catalyst ratio to biomass is decreased from 10% to 5%. There was also a slight increase in the production of biochar, which was found to be 1% higher when bentonite was used. However, the use of bentonite resulted in a 5% reduction in gas products. Similar results were reported by Liu et al.,[24], and Seo et al., [25] It has been observed that increasing the catalyst-to-biomass ratio leads to the biomass absorbing higher temperatures, which in turn aids in the formation of gaseous fuel while reducing the production of bio-oil and biochar. Therefore, a low catalyst-to-biomass ratio is optimal for bio-oil and biochar production.

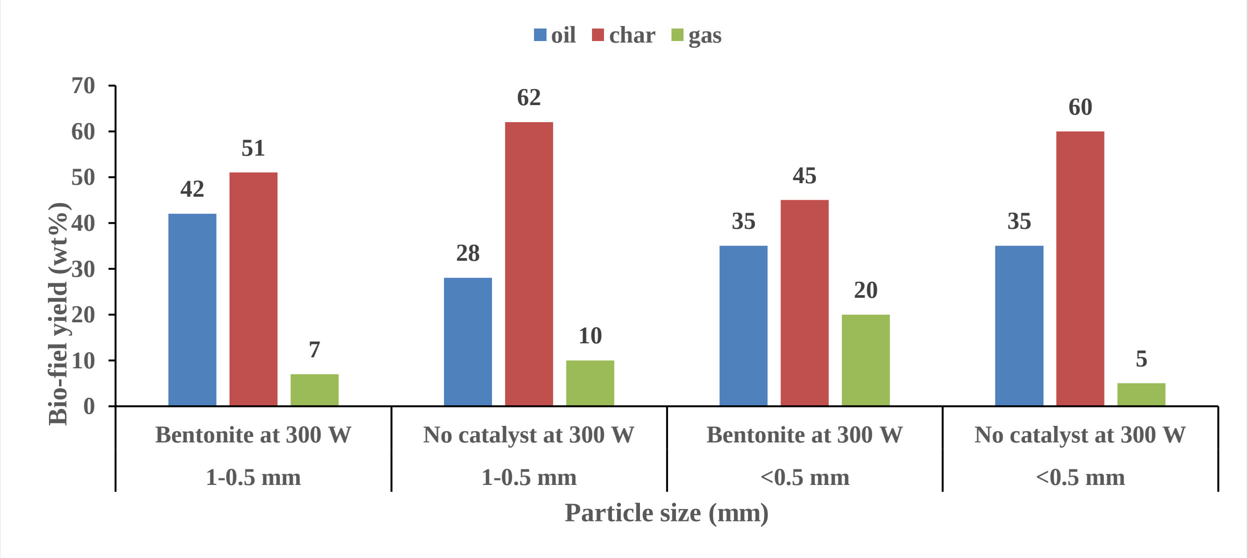

Fig. 5. Effect of Particle Size on Biofuel Product

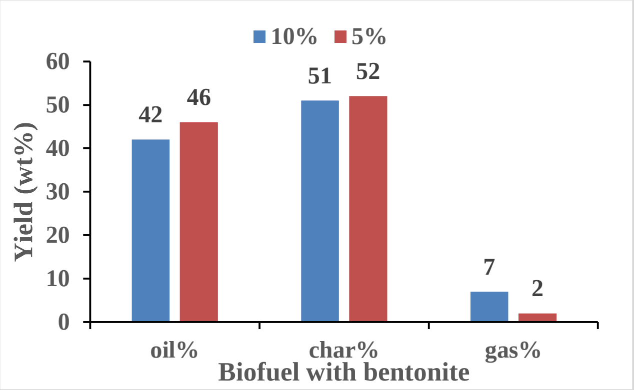

Fig. 6. Effect of Catalyst to Biomass Ratio on Biofuel Using 300W

3.1.5. Biogas Production

During the pyrolysis process, various gases are produced, such as methane and carbon dioxide. The type of catalyst used determines the type and amounts of gases generated. Methane is a crucial gas that contributes to energy production. On the other hand, carbon dioxide is essential for photosynthesis. Under different experimental conditions, methane generation increases from 3.6% (without a catalyst) to 8.6% (with bentonite). In contrast, the highest value of CO_2 is 5.7% (with bentonite) which is slightly increased from 4.8%.

3.2. Bio-oil Characteristics

3.2.1. Physical Analysis

Catalysts can be used in microwave pyrolysis to improve the physical properties of bio-oil. They aid in the removal of oxygen from the bio-oil by promoting a deoxygenation reaction, which leads to improved stability, enhanced energy density, and increased heating value. Using bentonite as a catalyst, for example, can increase the heating value from 19.5 to 23 MJ/kg, and reduce the density of bio-oil from 1045 to 1039.2 kg/m^3, which is a crucial factor in its use as a biofuel in engines, so it is important to measure it [26, 27]. The presence of carboxylic acids like acetic, formic, and oleic acids in bio-oils indicates high acidity, which can cause problems such as corrosion when used as fuel or chemical feedstock. The use of catalysts can inhibit the production of acid by preventing the devolatilization of hemicellulose in the feedstock, resulting in a bio-oil with a higher pH [29] such as 5.7 with catalyst, instead of 5. Using a catalyst can also lead to the formation of lighter aromatic compounds, which can decrease the viscosity of the bio-oil. This is because catalytic processes speed up pyrolysis reactions when adsorbents are used, increasing the proportion of lighter chemicals in the bio-oil. For instance, using bentonite can decrease the viscosity from 4.8 to 3.3 cSt (centistokes equivalent to mm^2/s). These findings are consistent with those of previous studies conducted by Mahmoud Fodah et al.,[30]; Lin et al., [31], which found that the use of a catalyst can reduce the oxygen content and increase the calorific value of the bio-oil.

3.2.2. Chemical Analysis of Bio-oil

- GC-MS of Bio-oil

The bio-oil obtained with and without a catalyst was analyzed using GC mass analysis to identify and analyze its components. The use of bentonite as a catalyst in the pyrolysis process can result in different bio-oil compositions compared to non-catalytic or other catalytic pyrolysis methods and can increase the active ingredients from 59.21% to 89.53% as shown in Fig. 8.

Mequinol is also found in a neat percentage of (9.55%), whilst 10.89% and 10.85% were the percent of 2-Methyl-3-furanthiol and 1,2-Cyclopentanedione, 3-methyl- respectively. The sensory importance of 2-methyl-3-furanthiol is commonly recognized and it includes a vitamin-like quality to many cooked or meaty food products [31, 32]. the utilization of bentonite enhanced the bio-oil by increasing alcohol percent from 8.8% to 18.16%, also heterocyclic compound increased from 5.8% to 19.27%, and other families are shown in Fig. 7 below. In addition to phenolic compounds, the bio-oil produced with bentonite catalyst also contains aldehydes, such as pentanal (6.16%), which can be used as a flavor and fragrance agent [34]. The catalyst seems to promote certain reactions and thus changes the product distribution. This type of catalyst could increase alcohol, aromatics, and esters components and reduce the acidity, which makes the bio-oil highly preferable due to its properties such as higher heating value and lower pH value.

The uses of bio-oil can be diverse depending on its composition. If bio-oil contains a high concentration of phenolic and aromatic compounds, it can be utilized as a chemical feedstock [35], On the other hand, bio-oil rich in hydrocarbons can serve as a fuel or be upgraded for use as a biofuel. Additionally, the presence of valuable chemicals such as 2,6-Dimethoxyphenol suggests a potential for pharmaceutical and cosmetic applications.

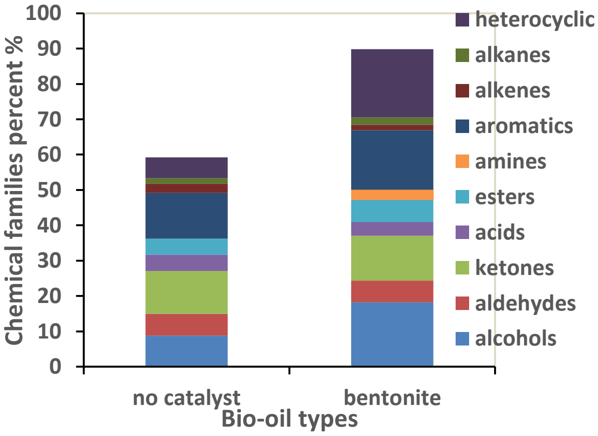

Fig. 7. Chemical Composition of Bio-oil

- FTIR of Bio-oil

Fourier-transform infrared (FTIR) spectroscopy is an effective method for identifying functional groups and molecular structures in organic substances. Based on the Fig. 8 provided, the primary functional groups in all types of oil are the same, and they vary depending on the density of the oil. For example, there is an increase in the absorbance peaks of the O-H stretching between 3000 cm^{-1} and 3500 cm^{-1}, when bentonite was used, which indicates the presence of alcohols, phenols, and water. This suggests that the addition of bentonite to the biomass during pyrolysis resulted in an increase in the alcohol and aromatics compounds, which is consistent with the GC-MS results. However, when the absorbance peaks of C≡C stretching appeared between 2000 cm^{-1} and 2500 cm^{-1}, the variation is almost imperceptible, indicating that the two types of oil contain relatively similar concentrations of functional groups of alkyne and nitrogen-containing compounds. C-H bending indicated the presence of aromatic compounds visible at wavelengths 1650 cm^{-1} and 2000 cm^{-1} for both types of oil, with the most abundant found in bentonite oil, which aligns with the GC-MS analysis. The vibration between 1000 cm^{-1} and 1300 cm^{-1} is shown in nested proportions with bentonite, indicating the convergent presence of phenols, esters, amine, and fluoro compounds. Overall, FT-IR spectra suggested that the bio-oil gained from pyrolysis was mostly composed of aromatic compounds.

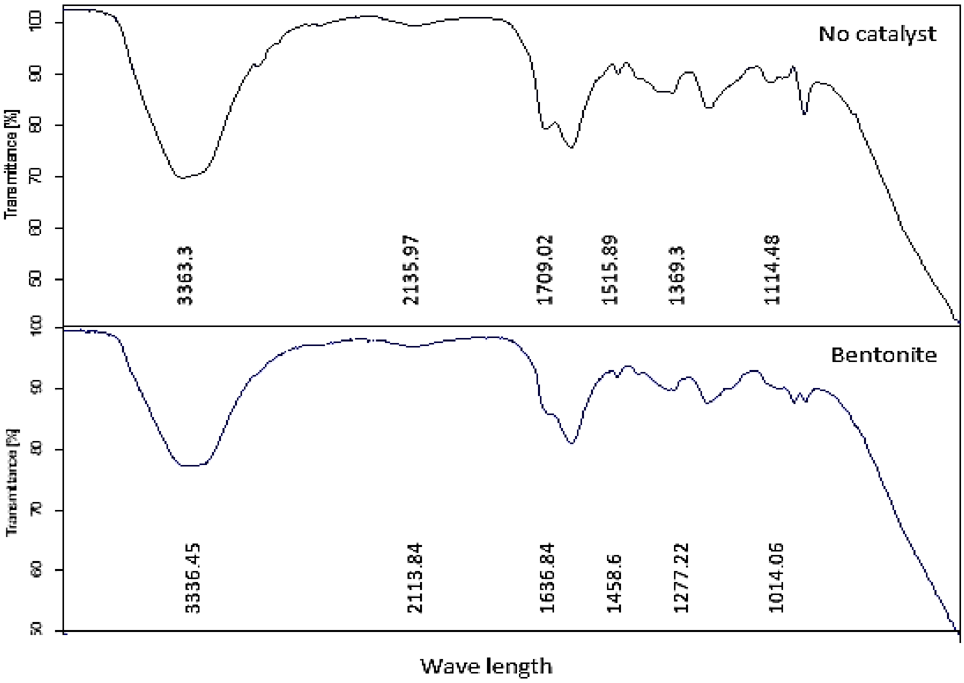

Fig. 8. FTIR of Bio-Oil

3.3. Biochar analysis

3.3.1. Physical analysis of Biochar

- BET (surface area and pore volume) and HHV (higher heating value)

The surface area and the pore volume are among the most essential characteristics that affect the ability of the resulting biochar to be used in many applications, including water and soil treatment and the ability to adsorption [36]. The surface area and pore volume of the resulting biochar is 0.5512 m^2/g and 0.00011 cm^2/g, which is very small, making it unsuitable for various uses. The addition of bentonite significantly increases the surface area and pore volume, reaching 40.384 m^2/g and 0.0361 cm^2/g respectively, due to the higher increasing in the internal temperature of the resultant biochar, which greatly improves its properties, that means the biochar characteristics are affected by several factors, including reaction temperature, catalyst, and type of biomass used [36, 37]. The formation of internal voids occurs through the evaporation of moisture present inside the molecules with the resulting biogas, which leads to the formation of internal channels for the combusting fuel that help increase the proportion and size of the surface area of the fuel, which develops the porosity of the resulting biochar molecules [6, 29, 38].

The calorific value of fuel is one of the very important properties that shows the importance of fuel and its usability in burning fuels as an alternative to fossil fuels. The ratio of carbon and oxygen greatly affects this, as increasing the proportion of carbon and decreasing oxygen increases its calorific value. The use of bentonite increased the calorific value of the resulting biofuel from 23 to 25 due to the high percentage of carbon and low percentage of oxygen in It [40].

- SEM and EDX

In general, SEM (Scanning Electron Microscopy) images provide insights into the physical structure and morphology of biochar produced via microwave pyrolysis.

It may clearly notice several differences between the surfaces of biochar by examining the illustration. Thus, Fig. 9 A below describes the structure of biochar in the absence of a catalyst. The surface of biochar appears to have a cube-like structure, which is relatively smooth and uniform. However, there are some lengthy cracks that separate the cube molecules. This is also visible in Fig. 9 A2, where the surface is almost flat and lacks any ridges or pores, indicating a lower surface area and pore volume as recorded in the Brunauer-Emmett-Teller (BET) analysis. Nevertheless, biochar particles without catalysts may still exhibit some degree of porosity [29, 36].

Fig. 10 B shows that the surface of biochar is highly complex with numerous folds and crumples. It has speckles of cubic particles of varying sizes, which have straight edges and a spongy, broken appearance with different types of scarring. The uneven distribution of pores due to the heterogeneous nature of bentonite leads to an uneven and rough surface morphology of the biochar, the surface is covered with small cubic particles in large quantities, which results in increased roughness and a surface area of 40.384 m^2/g.

The feedstocks, catalyst types, and pyrolysis reaction conditions can affect the size and distribution of these pores. If the feedstock comprises a lignocellulosic material, one might observe remnants of the plant's cellular structure, which could appear as larger, irregular voids in the SEM images [41]. In general, the use of a catalyst can enhanced the surface area and pore volume of biochar based on the reaction occurring during pyrolysis.

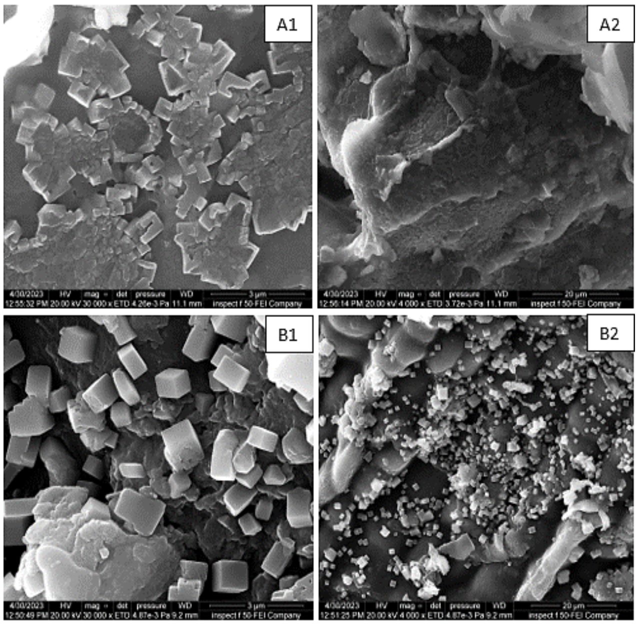

Fig. 9. SEM Micrography A) Biochar without Catalyst, B) Biochar with Bentonite

Based on the EDX analysis, the attached minerals in the sample contain elements such as C, O, Mg, Si, and Al, along with trace amounts of Cl, K, Ca, P, and Si. C and O are the dominant elements as shown in Table 2 below, with carbon making up about 60.3 atomic % and 51.0 weight %, and oxygen accounting for approximately 36.5 atomic % and 41.1 weight %. This was to be expected, as carbon is the primary component of biomass and remains a significant part of biochar after the pyrolysis process. Oxygen is inherent to the biomass structure and is also present in large quantities in the resulting biochar. Catalysts are often used in pyrolysis to enhance the chemical composition of solid fuels, particularly by increasing carbon content and reducing oxygen percent [42], as shown below, the use of bentonite as a catalyst has been shown to greatly improve the biochar's composition, with carbon accounting for approximately 75.1 atomic % and 67.0 weight %, and oxygen significantly reduced to 22.2 atomic % and 26.4 weight %.

Biochar is a material with high carbon content and a large surface area, making it ideal for applications such as water treatment and soil amendment [43].

It contains trace amounts of elements such as Magnesium, Aluminum, Silicon, Phosphorous, and Sulfur, which are likely from the biomass feedstock's mineral matter. Chlorine, Calcium, and Potassium are present in slightly higher amounts and can slowly release into the soil, enriching its nutrient content. Biochar's mineral element concentration depends on the feedstock, and chicken manure-derived biochar contains high Ca and K, crucial for soil quality [42, 43]. Moreover, It can also be used for carbon sequestration and as a fuel source [45].

Table 2. Element Analysis (EDX)

Element	**Without catalyst**		**bentonite**	
	Atomic%	**Weight%**	**Atomic%**	**Weight%**
C	60.3	51.0	75.1	67.0
O	36.5	41.1	22.2	26.4
Mg	0.4	0.7	0.7	1.3
Al	0.1	0.2	0.2	0.3
Si	0.1	0.2	0	0
P	0.1	0.2	0	0
S	0.1	0.2	0.2	0.4
Cl	0.5	1.3	0.1	0.2
K	1.2	3.2	1.3	3.7
Ca	0.7	1.9	0.3	0.8

3.3.2. Chemical Analysis of Biochar

- FTIR

The biochar materials that were prepared underwent an evaluation of their chemical compatibility using FTIR spectroscopy measurements. In general, Fig. 10 below shows that the basic functional groups of the biochar are about the same, but there are some minor differences between them, and the intensity of the appearance of the functional group is primarily determined by the catalyst used. For instance, the O-H stretching between (3200-3550 cm-1) showed that the presence of carboxylic acid or water was more significant when the biochar was pure and less with catalyst. The clear absorption peaks at 2920.23 cm-1 and 2850.79 cm-1 correspond to C-H stretching vibration, which only appeared with pure biochar. The presence of aromatic and benzene rings is indicated by the C=C and C=O stretching (1600-1700 cm-1) and C=C stretch (1400-1600 cm-1), which is found in bentonite biochar more than the others. Furthermore, bentonite biochar has a higher concentration of C-O (1000-1300 cm^{-1}) vibration, which indicates aromatic, alcohol, phenol, and aliphatic (Aryl-alkyl ethers) than the pure biochar. The peaks of =C-H bending between (675-1000 cm-1) vibration indicated the presence of alkene, aromatic, and peroxide. This is improved by using the catalyst and is highly found with the catalyst than without the catalyst.

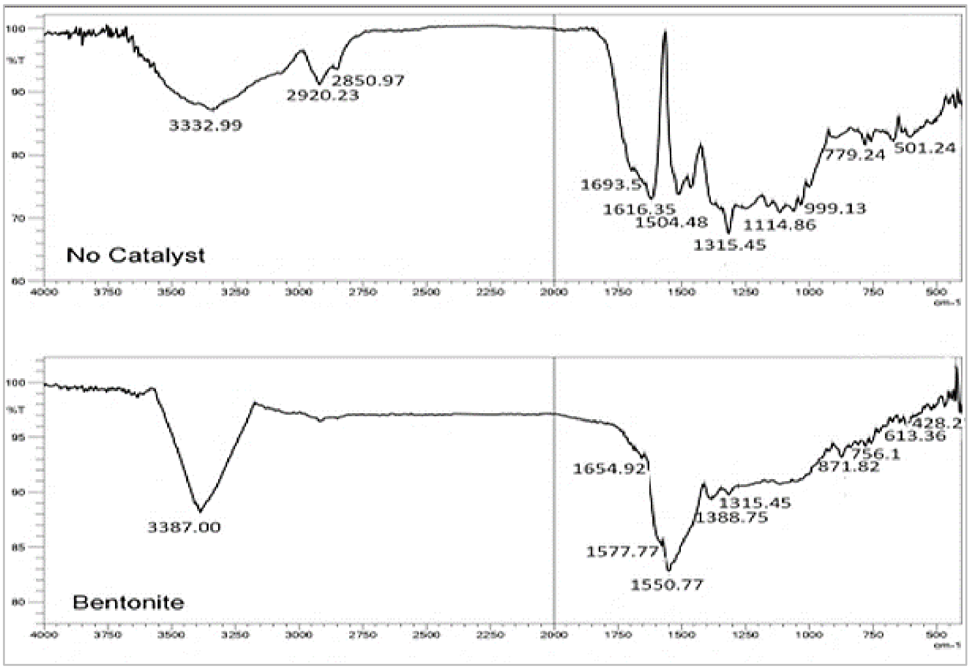

Fig. 10. FTIR of Biochar

4- Conclusion

The main objective of this research is the possibility of applying microwave technology in the pyrolysis process of albizia branches in the production of three types of biofuels; bio-oil, biochar, and biogas. As well as finding the difference in the fuel produced after using bentonite as a catalyst and finding its effect on the quantities and qualities of biofuel produced. This was done by studying several variables, including the experiment time, biomass particle size, microwave power level, and catalyst-to-biomass ratio. It was noted that the catalyst leads to the production of large quantities of gases, as the percentage of gas produced increased from 5% to 45% in the same conditions. It was also noted that it is possible to increase the quantities of liquid fuel in light of the presence of the catalyst when reducing the power level used, as the percentage of liquid fuel increased from 28% to 42% using 300 W. It was noted that the catalyst has a direct effect on the duration time, as it is possible to produce larger quantities of the resulting bio-oil in half the time it takes without a catalyst, and this is also the case with biochar. It was also noted that a decrease in the percentage of the catalyst also leads to an increase in the bio-oil and biochar fuel output in varying proportions. The physical and chemical properties of biochar and bio-oil fuels were examined, and the extent of improvement in the presence of the catalyst was noted. It led to improving the properties of the bio-oil in terms of reducing acidity, viscosity, and density, increasing its calorific value from 19.5 to 23 MJ/kg, and significantly increasing the percentage of aromatic and alcoholic substances, which led to the possibility of using the fuel in wider areas. As for the biochar, its surface area and the pore size were greatly increased from 0.5512 to 40.384 m2/g, and pore volume from 0.00011 to 0.0361cm3/g, respectively. and its calorific value was also increased from 23.5 to 25 MJ/kg, which also makes it usable in many fields as a fuel.

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التحلل الحراري بوساطة الميكروويف لاغصان نبات الالبيزيا بأستخدام طين البنتونايت العراقي

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الخلاصة

يعد إنتاج الوقود الحيوي باستخدام عملية الانحلال الحراري التحفيزي للكتلة الحيوية بمساعدة الميكروويف طريقة جديدة وبديلة تكتسب شعبية في السنوات الأخيرة بسبب العديد من القضايا الصحية والبيئية والمناخية والاقتصادية وغيرها من القضايا المتعلقة بالوقود الأحفوري. أجريت في هذه الدراسة عملية التحلل الحراري التحفيزي لفروع نبات البيزيا باستخدام محفز طيني عراقي الصنع وهو البنتونيت. وتناولت الدراسة المتغيرات التي تؤثر على نوعية وكمية الوقود الحيوي المنتج. وشملت هذه المتغيرات حجم جسيمات الكتلة الحيوية، والوقت التجريبي، ومستوى طاقة الموجات الصغرية المستخدمة، ونسبة المحفز إلى الكتلة الحيوية. تم تحليل الخواص الفيزيائية والكيميائية للوقود الحيوي الناتج عن طريق HHV، الحموضة، الكثافة، اللزوجة، GC–MS، FTIR للزيت الحيوي وSEM، EDX، BET، HHV، FTIR للفحم الحيوي. وكشفت الدراسة أن إضافة البنتونيت كعامل محفز أدى إلى تعزيز إنتاج الغاز الحيوي المنتج من ٥% إلى ٤٥% وانخفاض مستوى الطاقة المستخدمة من ٧٠٠ واط إلى ٤٥٠ واط. كما أدى إلى رفع إنتاج النفط الحيوي المتولد باستخدام مادة البنتونيت كعامل مساعد. مستوى طاقة أقل ومدة زمنية. كما أثرت إضافة المحفز على خصائص الزيت الحيوي المنتج مثل تقليل الحموضة عن طريق زيادة الرقم الهيدروجيني من ٥ إلى ٥,٧، وخفض اللزوجة من ٤,٨ إلى ٣,٣ سنتي ستوك، والكثافة من ١٠٤٥ إلى ١٠٣٩,٢ كجم/م٣. أدت إضافة المحفز إلى زيادة نسبة المواد العطرية والكحولية في الزيت الحيوي مما أدى إلى تحسين القيمة الحرارية من ١٩,٥ إلى ٢٣ ميجاجول/كجم. بالإضافة إلى ذلك، تحسنت خصائص الفحم الحيوي أيضًا مثل زيادة مساحة السطح وحجم المسام من ٠,٥٥١٢ إلى ٤٠,٣٨٤ م٢/جم ومن ٠,٠٠٠١١ إلى ٠,٠٣٦١ سم٣/جم على التوالي، وهو ما يرجع إلى التعزيز الأعلى في شكل سطح الفحم الحيوي الناتج. كما ارتفعت قيمة التسخين الأعلى من ٢٣,٥ إلى ٢٥ ميجا جول/كجم. كما يتأثر توليد الميثان بإضافة البنتونيت بنسبة تزيد من ٣,٦ إلى ٨,٦% وهو أحد غازات الوقود الأساسية.

الكلمات الدالة: الوقود الحيوي، الانحلال الحراري، طين البنتونايت، الكتلة الحيوية، تقنية الميكروويف.