Original Research Article

INFLUENCE OF SELECTED PARAMETERS ON THE PRODUCT YIELDS OF BROOM WEED (*SIDA ACUTA*) PYROLYSIS

ABSTRACT

Biomass feedstocks have been utilized for the commercial production of a wide range of fuels and chemicals through the pyrolysis process. Broom weed is abundant but it has not been widely used in Nigeria as a means of useful fuel and chemical thereby constituting environmental menace. This study aimed to determine the effects of selected process parameters on the product yields during the pyrolysis of broom weed in a fixed bed reactor. Broom weed was obtained at the premises of the National Centre for Agricultural Mechanization, Ilorin, Kwara State, Nigeria. 0.1kg of a dried sample of broom weed was loaded into a steel retort, and the retort interior was rendered airtight. The retort was then placed into the furnace chamber and was pyrolysed at 300 ^{o}C between 10 - 30 minutes at 5 minutes intervals. This was repeated for temperatures of 350, 400, 450, and 500 ^{o}C, and in each case, the quantities of char, bio-oil, and gas produced were determined. The average minimum values of the product yielded char, bio-oil, and gas for broom weed were 62.43 wt% at 500 ^{0} C, 4.34 wt% at 300 ^{0} C and 12.62 wt% at 300 ^{0} C, respectively, while the maximum values were 83.37 wt% at 300 ^{0} C, 8.80 wt% at 450 ^{0} C and 30.96 wt% at 500 ^{0} C, respectively. This study showed that pyrolysis of broom weed can serve as a renewable source of energy rather than constituting an environmental menace.

Keywords: Pyrolysis, Fixed bed reactor, Broom weed, Char, Bio-oil, Gas.

1. INTRODUCTION

Incessant increases in petroleum product prices and depletion of the crude oil deposits had brought non-conventional and renewable energy sources to greater attention [1]. The dependency on renewable energy sources like solar, wind, geothermal, hydrothermal, and biomass has received extensive recognition in recent years and is considered to be the most suitable and sustainable source of energy and the possible solution to human concerns [2]. Bio-fuel produced from biomass residues is an alternative to petroleum products and has received great attention due to the depletion and environmental problems associated with the usage of fossil fuels. Presently, it provides about 14% of the worldwide energy demand [3]. Apart from its abundant availability, the Combustion of biomass produces lesser oxides of sulphur, nitrogen, and carbon which makes it more suitable for energy generation than conventional fossil fuel thus keeping the environment and the public's health safe [2;1;4]. Nigeria as one of the oil-producing countries, is faced with energy crises and a shortage of petroleum products coupled with the periodic escalation in prices of fuel; therefore, Nigeria as a country must search for an alternative source of energy. Therefore, Nigeria needs to begin and encourage research on biofuel production from available and economically feasible feedstock to back up its dependency on fossil fuels. Broom weed (*Sida acuta*) is an excellent example of such feedstock because it has comparatively few competing food uses, which encouraged research into its potential for biofuel generation.

The method of transforming biomass into a useful wellspring of energy can be accomplished by utilizing various techniques that can be grouped into two fundamental classes namely; thermochemical processes and biochemical/biological processes as in fermentation and aerobic digestion [5]. The thermochemical conversion techniques incorporate pyrolysis, gasification, and combustion and these constitute one of the promising routes among the sustainable energy alternatives for the future since almost all biomass can be utilized as feedstock even waste unlike fermentation and aerobic digestion which are precise in their biomass feedstock requirement. Pyrolysis has pulled in more enthusiasm for producing liquid fuel products out of the conversion process due to its potential benefits in storage, transport, and usefulness in applications such as combustion engines, boilers, and turbines, among others [6]. The product yields (char, bio-oil, and gas) obtained during pyrolysis generally depend upon various operating parameters like residence time, heating rate, and temperature [7]. Similarly, biomass composition, particle size, and density also play a vital role in determining the grade and quantity of pyrolysis products [8]. High heating rates and shorter vapour residence time in fast pyrolysis produce greater pyrolytic-oil yield than in slow pyrolysis which employs low heating rates and longer vapour residence time. Research has been conducted on the effect of process parameters on the pyrolysis characteristics of biomass feedstock [9;10;11]. Others have studied the effect of different types of biomass materials on pyrolysis products [12;13;3]. Therefore, in this study, the influence of pyrolysis temperature and time on the product yields during the pyrolysis of broom weed was investigated.

2. MATERIALS AND METHODS

2.1 Feedstock Procurement and Preparation

Broom weed used for the pyrolysis experiments in this study was obtained from National Centre for Agricultural Mechanization, Ilorin, Kwara State, South-Western Nigeria. The residues were cleaned to remove foreign particles such as stones, leaves, debris, and other unwanted components in order not to contaminate the pyrolysis product and as well sun-dried for 21 days. The weight of the sample (W_1) was measured using an Ohaus top loading digital weighing scale of sensitivity ± 0.001 g (Model: PA4102, range: 0-4100 g, Ohaus company, Manufactured in Switzerland) and then oven-dried at a temperature of 105 ^oC until constant weight (W_2) was obtained following official methods of the [14].

2.2 Determination of effect on the selected parameters.

Pyrolysis experiments were carried out to determine the effect of selected parameters on the product yields of broom weed. 0.1kg of dried broom weed was fed into the retort. The retort was placed into the furnace and pyrolysed within the temperature range of 300 to 500 ^{0} C, at 50 ^{0} C intervals with a retention time of 10 to 30 minutes at 5 minutes intervals. The retort was connected through a pipe to the condensate receiver which was placed in an ice-cooling unit for the quick recovery of the condensable products (bio-oil), and from the condensate receiver, the uncondensed gases moved through a lagged pipe into the gas collection unit. The char in the retort and the bio-oil in the condensate receiver were collected and weighed using Ohaus's top-loading digital weighing balance. The weight of the gas was evaluated by subtraction. The percentage of product yields was determined by equation 1.

$$\text{Percentage product yield (Y)} = \frac{M_p}{M_s} \times 100 \qquad 1$$

Where M_p is Mass of product, and M_s is the Mass of the sample

3. RESULTS AND DISCUSSION

3.1 Effect of temperature on the product yields during pyrolysis of broom weed for 10 minutes.

The result of the product yields during the pyrolysis of broom weed for 10 minutes is illustrated graphically in Figure 1. When broom weed was pyrolysed at 300 ^{0} C for 10 minutes, the char, bio-oil, and gas produced were 89.32%, 1.90%, and 8.78%, respectively. At a temperature of 350 ^{0} C, the char reduced to 81.10%, that of the bio-oil increased to 2.11% and the gas increased to 16.79%. At a temperature of 400 ^{0} C, the char decreased to 76.22%, the bio-oil increased to 2.98% and the gas increased to 20.08%.

At a temperature of 450 ^{0} C, the char drastically decreased to 70.92%, the bio-oil increased by 21.11% and the gas increased by 23.41%. At a temperature of 500 ^{0} C, the char decreased to 64.04%, the bio-oil decreased to 3.44% and the gas increased to 32.52%. The drop in the bio-oil yield at a pyrolysis temperature range of 450–500 ^{0} C was mainly due to the secondary cracking and reaction of the liquid fraction volatiles thereby increasing the gas yield further and reducing the char yield which implies the end of the pyrolysis. According to the reviewed literature, it was observed that the quantity of char produced decreases with an increase in pyrolysis temperature [2;1;4].

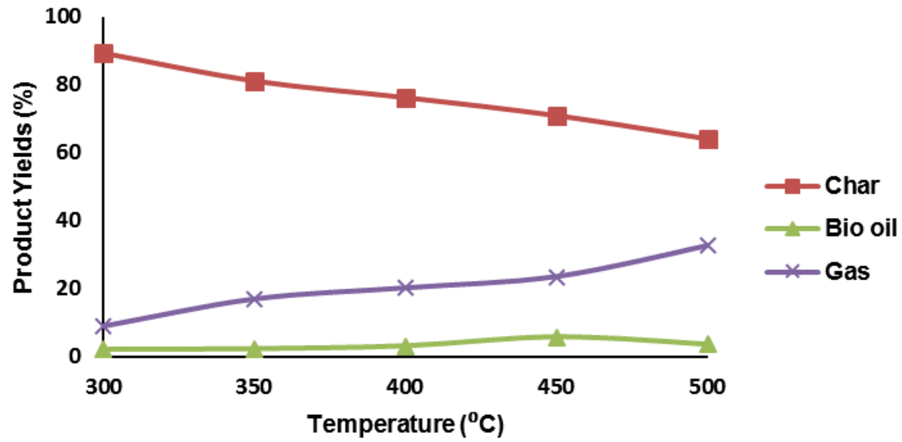

Fig. 1: Effect of temperature (^{0} C) on the product yields (%) during pyrolysis of broom weed for 10 minutes.

3.2 Effect of temperature on the product yields during pyrolysis of broom weed for 15 minutes.

The result of the product yields during the pyrolysis of broom weed for 15 minutes is illustrated graphically in Figure 2. When broom weed was pyrolysed at 300 ^{0} C for 15 minutes, the char, bio-oil, and gas produced were 85.17%, 2.58%, and 12.25%, respectively. At a temperature of 350 ^{0} C, the char reduced to 80.21%, that of the bio-oil increased to 3.12% and the gas increased to 16.67%. At a temperature of 400 ^{0} C, the char decreased to 74.33%, the bio-oil increased to 3.89% and the gas increased to 21.78%.

At a temperature of 450 ^{0} C, the char drastically decreased to 71.03%, the bio-oil increased by 5.50% and the gas increased by 23.47%. At a temperature of 500 ^{0} C, the char decreased to 64.49%, the bio-oil decreased to 4.28% and the gas increased to 31.25%. The drop in the bio-oil yield at a pyrolysis temperature range of 450–500 ^{0} C was mainly due to the secondary cracking and reaction of the liquid fraction volatiles thereby increasing the gas yield further and reducing the char yield which implies the end of the pyrolysis. According to the reviewed literature. It was observed that the quantity of char produced decreases with an increase in pyrolysis temperature [2;1;4].

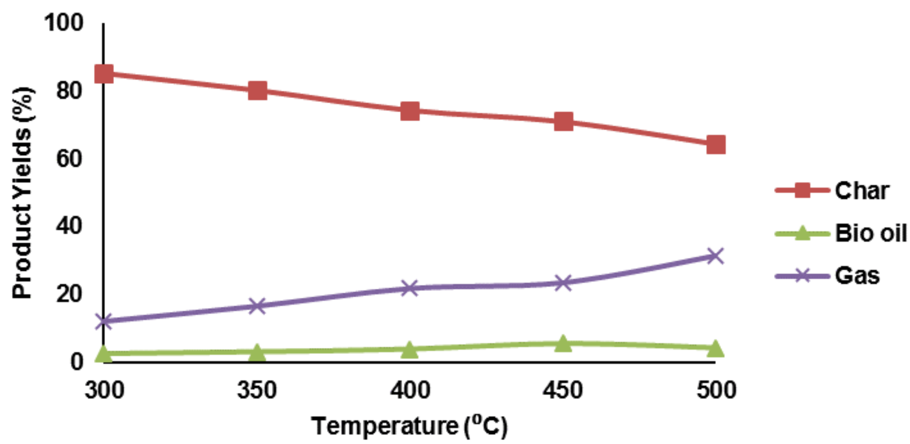

Fig. 2: Effect of temperature (^{0} C) on the product yields (%) during pyrolysis of broom weed for 15 minutes.

3.3 Effect of temperature on the product yields during pyrolysis of broom weed for 20 minutes.

The result of the product yields during the pyrolysis of broom weed for 20 minutes is illustrated graphically in Figure 3. When broom weed was pyrolysed at 300 ^{0} C for 20 minutes, the char, bio-oil, and gas produced were 82.24%, 4.20%, and 13.56%, respectively. At a temperature of 350 ^{0} C, the char reduced to 78.15%, that of the bio-oil increased to 5.98% and the gas increased to 15.89%. At a temperature of 400 ^{0} C, the char decreased to 71.48%, the bio-oil increased to 8.28% and the gas increased to 20.24%.

At a temperature of 450 ^{0} C, the char drastically decreased to 68.93%, the bio-oil increased by 11.24% and the gas increased by 19.83%. At a temperature of 500 ^{0} C, the char decreased to 62.92%, the bio-oil decreased to 9.35% and the gas increased to 27.93%. The drop in the bio-oil yield at a pyrolysis temperature of 450–500 ^{0} C was mainly due to the secondary cracking and reaction of the liquid fraction volatiles thereby increasing the gas yield further and reducing the char yield which implies the end of the pyrolysis. According to the reviewed literature, it was observed that the quantity of char produced decreases with an increase in pyrolysis temperature [2;1;4].

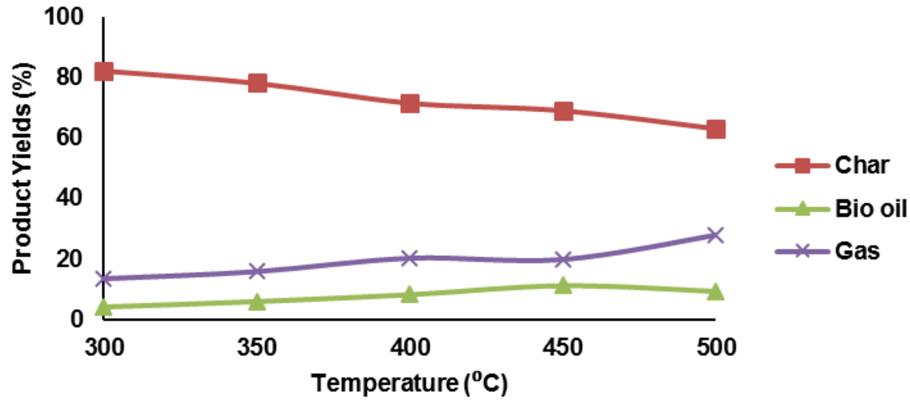

Fig. 3: Effect of temperature (^{0} C) on the product yields (%) during pyrolysis of broom weed for 20 minutes.

3.4 Effect of temperature on the product yields during pyrolysis of broom weed for 25 minutes.

The result of the product yields during the pyrolysis of broom weed for 25 minutes is illustrated graphically in Figure 4. When broom weed was pyrolysed at 300 ^{0} C for 25 minutes, the char, bio-oil, and gas produced were 80.13%, 6.11%, and 15.76%, respectively. At a temperature of 350 ^{0} C, the char reduced to 76.33%, that of the bio-oil increased to 6.97% and the gas increased to 16.70%. At a temperature of 400 ^{0} C, the char decreased to 70.15%, the bio-oil increased to 7.82% and the gas increased to 22.03%.

At a temperature of 450 ^{0} C, the char drastically decreased to 67.56%, the bio-oil increased by 9.11% and the gas increased by 23.33%. At a temperature of 500 ^{0} C, the char decreased to 60.63%, the bio-oil decreased to 8.01% and the gas increased to 31.36%. The drop in the bio-oil yield at a pyrolysis temperature range of 450–500 ^{0} C was mainly due to the secondary cracking and reaction of the liquid fraction volatiles thereby increasing the gas yield further and reducing the char yield which implies the end of the pyrolysis. According to the reviewed literature, it was observed that the quantity of char produced decreases with an increase in pyrolysis temperature [2;1;4].

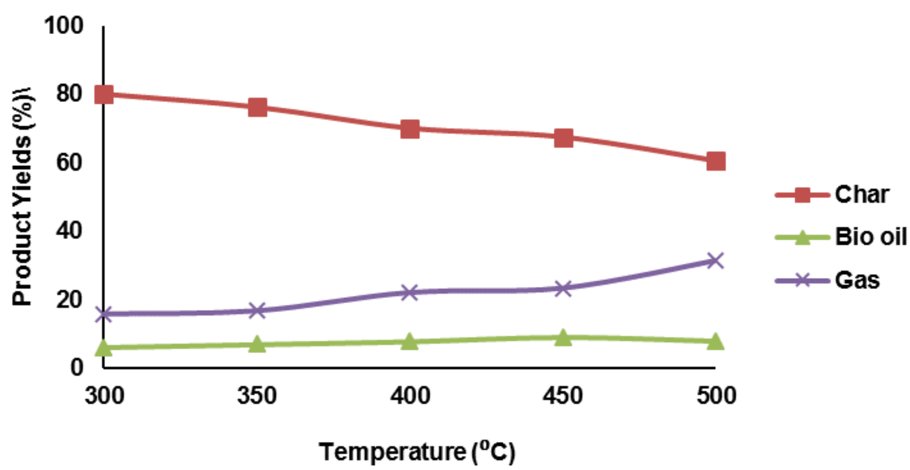

Fig. 4: Effect of temperature (^{0} C) on the product yields (%) during pyrolysis of broom weed for 25 minutes.

3.5 Effect of temperature on the product yields during pyrolysis of broom weed for 30 minutes.

The result of the product yields during the pyrolysis of broom weed for 30 minutes is illustrated graphically in Figure 5. When broom weed was pyrolysed at 300 ^{0} C for 30 minutes, the char, bio-oil, and gas produced were 80.00%, 6.89%, and 13.11%, respectively. At a temperature of 350 ^{0} C, the char reduced to 74.82%, that of the bio-oil increased to 7.78% and the gas increased to 17.40%. At a temperature of 400 ^{0} C, the char decreased to 69.94%, the bio-oil increased to 9.21% and the gas increased to 20.85%.

At a temperature of 450 ^{0} C, the char drastically decreased to 65.04%, the bio-oil increased by 12.47% and the gas increased by 22.49%. At a temperature of 500 ^{0} C, the char decreased to 60.07%, the bio-oil decreased to 8.07% and the gas increased to 31.86%. The secondary cracking and reactivity of the volatiles in the liquid fraction contributed significantly to the decrease in bio-oil yield at pyrolysis temperature 450-500 ^{o}C which also signified the end of the pyrolysis process by increasing the gas yield and decreasing the char yield. The literature revealed that when pyrolysis temperature rises, there is a decrease in the amount of char formed [2;1;4].

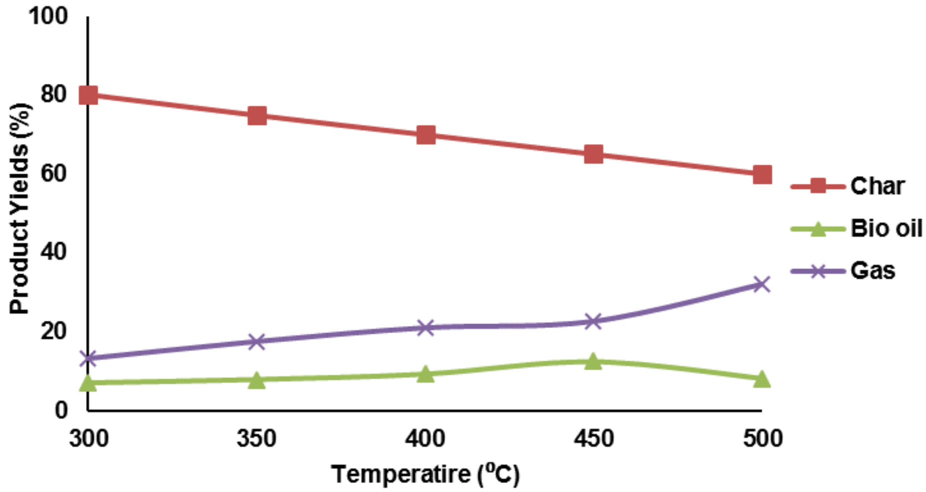

Fig. 5: Effect of temperature (^{0} C) on the product yields (%) during pyrolysis of broom weed for 30 minutes.

4. CONCLUSION

Production of biofuel from the pyrolysis of broom weed has been studied. The results showed that a change in pyrolysis temperatures has significant effects on the pyrolysis product yields. It has also been established that broom weed can serve as an alternative fuel for domestic and industrial application use rather than being considered as waste and environmental menace

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