Temperature Effect on the Products Yield from Pyrolysis of Cassava Peels

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Abstract—The growing world population, industries, technological advancement and transportation had brought energy demand under an increased pressure recently. This research work investigated the temperature effect on the products yield from pyrolysis of cassava peels. A suitable electrically operated pyrolysis furnace was used in obtaining various constituents (Char, Tar and Syngas) from cassava peels of 500 grams weight at a ranged temperature between 400-800 ^{0}C at 10% moisture content for 40 minutes. The compositions of the products obtained at different pyrolysis temperature were compared in terms of weight and percentage yield. At a temperature of 400 ^{0}C lesser tar and syngas were produced with the char yield of 81.92 percent. There was reduction in yield of char at a pyrolysis temperature of 500 ^{0}C with increase yields of both tar and syngas. The percentage yield by weight of both char and syngas was found maximum at 730 ^{0}C. It was discovered that ash begins to form at around 730 ^{0}C which signifies the end of pyrolysis process. Finally, it was observed that the yields in weight of products obtained from pyrolysis of cassava peels increases with increase in pyrolysis temperature till 730 ^{0}C

Index Terms— Bioenergy, Biofuel, Biomass, Bio-Chemical Energy Conversion, Cassava Peels, Char, Pyrolysis, Renewable Energy, Syngas, Tar, Temperature

1 Introduction

The cassava wastes such as the stem, peel and rhizome parts which are not fit for human consumption are kept aside on the cassava field in large quantity [1], [2]. These wastes can be directly used for energy production by means of direct combustion process. Also, it can be converted into biochar and applied to soil. This method can be made to clear the cassava waste field and at the same time preserve the carbon content. Nevertheless, there are approximately 50% of the carbons in the biomass agricultural wastes that can be lost upon burning [1], [2].

Energy is an essential factor in growing process of any nation, the level of socio-economic growth and standard of living of people in any country are largely depend on energy [3]. Biomass has gained a wide range of applications among several renewable energy sources due to its availability, accessibility and high technology used for its conversion into tar, char and syngas which are useful for generation of energy and production of valuable chemicals [4], [5]. The existing technologies available to convert biomass into fuels are classified based on their procedures into three

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categories namely biochemical, thermal and thermochemical conversion. The thermochemical conversion of biomass includes a number of processes such as combustion, liquefaction, gasification and pyrolysis [6], [7]. Emphasis is on pyrolysis because is the main spotlight of thermochemical conversion of biomass that produces solid and liquid fuels, which are easy to handle and transport [8].

Pyrolysis is a thermochemical decomposition of organic material at elevated temperature of about 430^{0}C and above in the absence of oxygen.

Several studies have been conducted on the utilization of cassava plant residues for bio-oil production, for instance Pattiya [9] used rhizome and stalk of cassava plant as biomass feedstock to obtain bio-oil by fast pyrolysis process in two types of reactors namely fluidized-bed reactor and free-fall reactor. Also, Weerachanchai [10] studied slow pyrolysis of cassava pulp residue and palm kernel cake. In their work, cassava peel was used as a raw material to produce bio-oil through slow pyrolysis process in a fixed-bed reactor.

However, findings on cassava peel pyrolysis are scarce. Therefore, this work is aimed at investigating the temperature effect on the products yield (char, tar and syngas) from pyrolysis of cassava peels.

2 MATERIALS AND METHOD

2.1 Preparation of Material

The samples of the residues (cassava peels) were obtained from local cassava processing factory in Ogbomoso, Nigeria. The residues are dumped at extreme part of the town which usually causes environmental hazard to the wellbeing, and therefore obtained at no or low cost. The cassava peels were cleaned by washing in order to remove the foreign particles such as sand, dead leafs among others. Also, the samples were sun-dried for two days and later oven-dried at a very low temperature in order to reduce the moisture content in the residue steadily. The moisture content of the sample was checked at regular intervals until the desired moisture content was obtained.

2.2 Determination of Moisture Content

The moisture content of the dried sample was determined in an oven at a temperature of 105^{0}C. The reduction in weight was checked at every 2 hours interval until constant weight is obtained. The final weight obtained was noted and the recorded values were used in calculating the percentage of the moisture content in the sample on wet basis using (1).

Mathematically;

% of moisture content on wet basis =

$$\frac{w_0 - w_1}{w_0} \times 100 \quad (1)$$

Where;

W_0 = Initial weight of the sample in grams

W_1 = Final weight of the sample in grams

Percentage of the moisture content was determined to be 10.01% as shown in Table 1 on wet basis.

TABLE 1

DETERMINATION OF MOISTURE CONTENT

Trials	Initial Weight (g)	Final Weight (g)	Loss in Weight (g)	Moisture Content (%)
1	5.29	4.76	0.53	10.02
2	5.08	4.57	0.51	10.04
3	5.02	4.52	0.50	9.96
Average				**10.01**

2.3 Experimental Procedure

500 grams of dried sample of cassava peels of known moisture content was introduced into the retort and coupled. The retort was then introduced in the pre-heated furnace at a temperature of 400 ^{0}C at the same time with the condensate receiver placed inside an ice bath contained the mixture of ice and water for 40 minutes. The outlet valve in the condensate receiver which was initially closed was opened, and then closed to allow the syngas to escape into gas collection unit as at whenever the pressure is built. After the outlet valve was closed, the inlet valve of the gas cylinder was opened which allowed tapping the syngas that was collected over water inside gas collection unit. This was repeated until 40 minutes was reached. The weight of the products were read and noted. The whole process was repeated for another 500g of the same sample at a pyrolysis temperature of 500 ^{0}C, 600 ^{0}C, 700 ^{0}C and 800 ^{0}C.

3 RESULTS AND DISCUSSION

The average values obtained from the process at the operating conditions such as temperatures (400 ^{0}C, 500 ^{0}C, 600 ^{0}C, 700 ^{0}C and 800 ^{0}C), weight of cassava peels (500g) and time (40 minutes). The products obtained from the pyrolysis include the char, tar and syngas. These are discussed as follows.

3.1 Char

The char is the composition of carbon rich solid. The quantity of char produced decreases with increase in pyrolysis temperature at a given time. This causes the weight of the residue to reduce as volatile matters (tar and syngas) are produced. Similar trend was observed in slow pyrolysis of cassava wastes for biochar production and characterization [2]. However, at a certain temperature, there was no further increase in the production of volatiles which indicates the end of the pyrolysis process. Fig. 1 shows that at 400 ^{0}C, the weight of the char produced was 368.63g which represents 81.92% of the sample mass. Between the pyrolysis temperature of 700 ^{0}C and 800 ^{0}C, there is no steady decrease in the char yield representing 18.51% and 17.61% respectively, and designates the region where formation of ash begins. At 800 ^{0}C, there is a mixture of char and ash. Also, from Fig. 1, it can be seen that the pyrolysis process of the cassava peels ends at about 730 ^{0}C (also see Fig. 2 and Fig. 3). A slight increase in temperature beyond 730 ^{0}C leads to formation of ash and therefore reduces the weight of char produced.

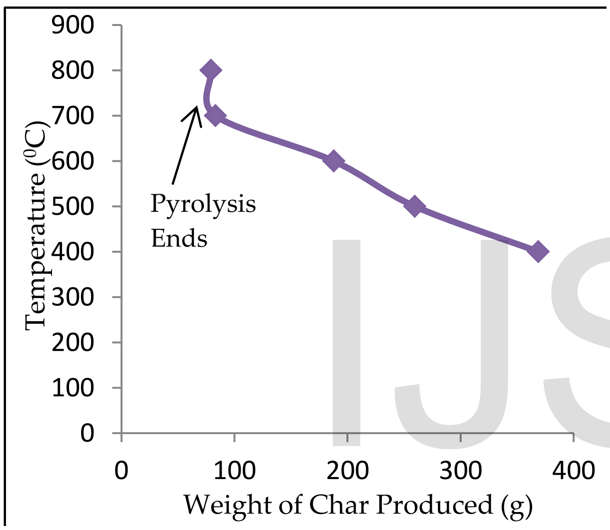

Fig. 1. Effect of Pyrolysis Temperature on Weight of the Char produced

3.2 Tar

The quantity of the tar produced during the pyrolysis increases with increase in temperature at a given time until when all the quantity present in the residue has been extracted. It is the composition of the entire liquid constituents including water which was present in residue as moisture initially. Fig. 2 shows that 33.83g of tar was obtained at 400 ^{0}C which is the minimum, representing 7.52 % of the sample mass. The quantity of the tar produced was low compare to other products and the maximum yield is approximately 16% which may only be affected by the moisture content present in the sample. It can also been seen that the weight of the tar produced increases with increase in temperature until a slight increase above 700 ^{0}C and this indicates that the quantity of tar present in the sample is almost extracted. This disagreed with the work of Ki [7].

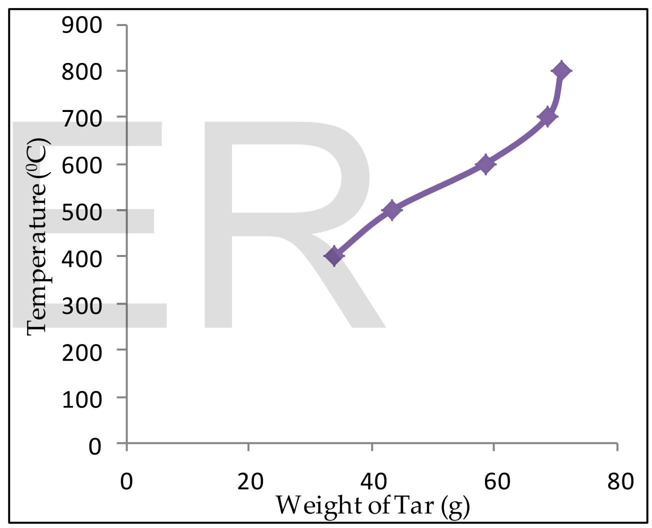

Fig. 2. Effect of Pyrolysis Temperature on Weight of the tar produced.

3.3 Syngas

In pyrolysis, the syngas is the composition of fuel gases which mainly include methane (CH_4), carbon(II)oxide (CO), hydrogen (H_2), carbon(IV)oxide (CO_2), water vapour (H_2O), and small quantity of sulphur compounds. The weight of syngas also increases as the pyrolysis

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temperature increases. They are separated from the vapourised mixture at a very low temperature from condensate receiver and collected over water. This is because carbon-dioxide does not support combustion and therefore is filtered-off through its dissolution by water inside gas collection unit. The water vapour and sulphur compounds were also dissolved and filtered-off respectively inside gas collection unit. The whole process is described and shown in (2) – (7) as follows;

Reaction Steps:

a) Cassava peels ($CH_{1.4}O_{0.6}$) react with a limited supply of oxygen at high temperature to produce Char (Coke / Carbon) and mixture of Syngas and Tar as shown in (2);

$$CH_{1.4}O_{0.6(g)} + O_2 \rightarrow \text{Char } [C_{(s)}] + \text{Volatiles} \quad (2)$$

b) Carbon(II)oxide with hydrogen gas is produced as hot char come in contact with both moisture and carbon(IV)oxide. This is shown in (3) and (4)

$$CO_{2\,(g)} + C \rightarrow 2CO_{(g)} \quad (3)$$

$$H_2O + C \rightarrow CO_{(g)} + H_{2\,(g)} \quad (4)$$

c) The hydrogen produced in (4) then reacts with more char (carbon) to produce methane as shown in (5);

$$2H_{2\,(g)} + C \rightarrow CH_{4\,(g)} \quad (5)$$

d) The moisture further reacts with carbon(II)oxide to produce both hydrogen and carbon(IV)oxide as shown in (6);

$$H_2O + CO_{(g)} \rightarrow CO_{2\,(g)} + H_{2\,(g)} \quad (6)$$

e) Carbon(IV)oxide is then separated as it does not support combustion by dissolving in water inside gas collection unit to produce trioxo-carbonate(IV) acid and this is shown in (7);

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad (7)$$

Therefore, the left over syngas are mainly CH_4, CO and H_2. Fig. 3 shows how the quantity of syngas produced increases with increase in temperature. This is similar to observation made by Okekunle [5]. At 400 ^{0}C, 47.54 g representing 10.56% yield of the sample mass was produced. Between the temperatures of 700 – 800 ^{0}C, maximum yield of about 66 - 67% of the product was obtained.

Generally, at higher temperature, pyrolysis process ended before 40 minutes as no further pressure is built inside the condensate receiver for the production of syngas.

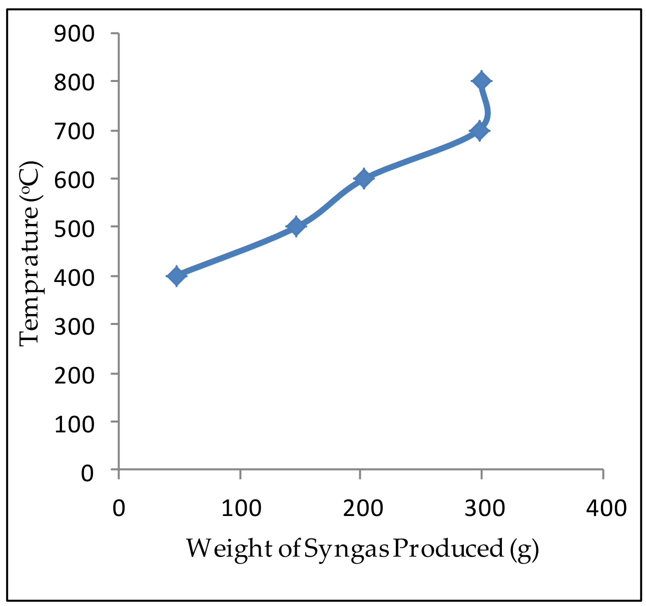

Fig. 3. Effect Pyrolysis Temperature on Weight of the Syngas Produced

4 CONCLUSION

It can be concluded that the pyrolysis of the cassava peels produced desirable products within the chosen range of temperature (400 ^{0}C – 800 ^{0}C). The quality of the char produced increases with the increase in pyrolysis temperature. Also, it was observed that if good quality char and higher quantities of tar and syngas are needed, it is advisable to pyrolyse within the temperature of 700 ^{0}C to 800 ^{0}C.

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