Influence of pretreated coconut shell on gasification product yield

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Abstract. Gasification of untreated and pretreated coconut shell (CS) was carried out in a fixed-bed reactor to assess the effect of temperature (600, 650, 700, 750, and 800 °C) and holding time (30 and 40 min) on gases composition. The untreated CS was first torrefied in a fixed-bed reactor at different temperatures (200 – 300 °C) and holding times (30 min, 60 min and 90 min). Pretreated CS at the optimal torrefaction temperature (275 °C and 60 min) was used for gasification. Under optimal conditions of 750 °C and 30 min holding time, gasification contributed the most gas production. At this optimum condition, the gas composition of pretreated CS was 35.03 % of CH_4, 24.43 % of CO_2, and 40.54 % of H_2 + CO. Untreated CS contains 37.63 % of CH_4, 24.03 % of CO_2, and 38.34 % of H_2 + CO gases. The production of CH_4 gas was higher when untreated CS was used for gasification rather than pretreated CS. Moreover, when untreated CS was used for gasification, the amount of CO_2, H_2, and CO produced was minimal. Therefore, for high H_2 production, pretreatment prior to gasification is appropriate.

1 Introduction

The mass of all living things, including plants, animals, and microorganisms, as well as biochemical substances like cellulose, lignin, carbohydrates, lipids, and proteins, is referred to as biomass [1]. An estimated 16% of the nation's overall energy consumption is made up of biomass fuel, of which 51% is biomass and 22% is wood waste, according to report [2]. A type of biomass that can be utilised to produce energy, heat, organic fertiliser, animal feed, and health beverages is coconuts. In addition, coconut can be used to make coconut milk,

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which is frequently utilised in the food industry, especially by Asians. As a result, Malaysia is home to several kiosks and factories that produce coconut milk. The most quantity of coconut waste, such as coconut shell, will be produced as a result of this condition, and these wastes can be used to produce energy.

Torrefaction is a thermochemical process that has been used to prepare biomass for energy production. Prior to this, it should be noted that torrefaction is a mild pyrolysis or thermochemical process that normally lasts for many minutes or hours in an inert atmosphere at temperatures between 200°C and 300°C [3]. Utilizing this pretreatment method, the sample's or raw material's properties will be changed to improve its performance during future operations like pyrolysis and gasification [4]. This is since the pretreatment process will change the biomass's characteristics, including lowering its moisture content, which could reduce the sample's capacity to burn [5]. The ability to make biomass friable (using 80–90% less energy for grinding), negligible biological activity (providing a longer storage life without fuel degradation), low O/C ratio (improving gasification yield), and the elimination of smoke-causing compounds are some of the advantages of torrefaction, according to Shivangi Jha *et,al.* [6]. Gasification is the process of reacting carbon with air, oxygen, steam, carbon dioxide, or a mixture of these gases at a temperature of 700°C or higher to create a gaseous product that can be used to produce electricity and heat or as a raw material to produce chemicals, liquid fuels, or other gaseous fuels such as hydrogen [7, 8]. O_2, N_2, H_2, and CO concentrations increased whereas CH_4 and CO_2 concentrations decreased as the temperature of the bed increased [9].

Torrefaction pretreatment is thus required to overcome these challenges. Thus, the goal of this study is to improve the fuel properties via torrefaction process and to investigate the possibility of gasification on pretreated PKS in a laboratory scale reactor.

2 Methodology

2.1 Material

The CS biomass sample was obtained from a coconut milk production stall in Kangar, Perlis. As a result, the sample was cleaned and separated from its coconut husk so that only the CS was obtained. The CS was then sun-dried for 3 to 4 days to ensure that it was dry enough to avoid problems during the grinding process. A plastic shredder machine was used to grind the dried CS. The sample was sieved prior to torrefaction and gasification to obtain particle sizes ranging from 425 µm to 600 µm. The properties of untreated and pretreated CS were investigated using proximate and ultimate analyses. The ASTM-D121 was used to analyse and calculate the proximate analysis [10]. The elemental analyzer had been utilised for the elemental analysis.

2.2 Torrefaction

A fixed bed reactor (figure 1) was used for the torrefaction experiment, and 5 g of coconut shell was weighed and placed in the reactor's centre. Before commencing the experiment, 0.5 L/min of nitrogen gas was pushed into the reactor to create an inert atmosphere. The first experiment was conducted at a constant torrefaction temperature of 200 °C, nitrogen flow rate of 0.5 L/min, and holding time of 30 min. The experiment was repeated at constant time (30 min) and several temperatures of 225°C, 250°C, 275°C, and 300°C. The other experiments were conducted at the same temperature but for variable holding times of 60 and 90 minutes to assess the torrefied product yield at different parameters. The optimum parameter that produces the best pretreated sample during torrefaction was used for gasification.

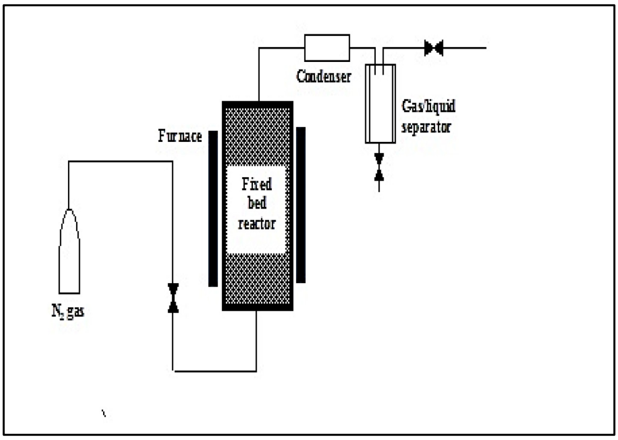


Fig. 1. Schematic diagram of the reactor set-up

2.3 Gasification

The feed basket for 5 g of sieved CS was placed within the reactor tube for gasification. As soon as the system was ready, 0.5 L/min of nitrogen gas was pumped into the reactor to create an inert environment. The sample was then heated to the desired gasification temperature of 600°C at a rate of 50°C/min. When the reactor reached the gasification temperature, the nitrogen flow was stopped, and the steam generator's output was fed into the reactor. The reactor was run at the desired gasification temperature for 30 min.

3 Results and discussion

3.1 Gasification

Table 1 shows the characteristics of CS proximate and elemental analysis. According to Table 1, the moisture content of CS was 5.67%, and this value was obtained by adhering to the ASTM D-121 standard. A high moisture content reduces the heating value of the feedstock and leads to incomplete combustion. Thus, the necessary thermal pretreatment allowed for the removal of the high moisture content in CS. The volatile matter content of the CS is very high in comparison to other values (73.89%). The high volatile matter content is not suitable for gasification because it can contribute to the formation of a large amount of tar, soot, and smoke, which can reduce the efficiency of the gasification process [11]. The CS had a very low ash content when compared to other analysis values, which were only 0.899%. The value of fixed carbon content was determined by difference to be 19.55%. This value is very similar to the results of the thermogravimetric analysis [12,13].

Table 1 shows that the untreated CS has a high concentration of carbon (48.35%) and oxygen (45.25%). Because a high carbon content can boost syngas output, a higher carbon percentage is required to improve gasification products. Excessive levels of oxygen and nitrogen, on the other hand, reduce the calorific value and energy efficiency of the fuel material [14]. As a result, pretreatment is required to increase the carbon content while decreasing the oxygen level to effectively gasify this CS.

Table 1. Proximate and ultimate analysis of CS

Proximate analysis (%)				
Moisture content	Ash	Volatile Matter	Fixed Carbon	
5.67	0.899	73.89	19.55	
Ultimate analysis (%)				
C	H	O	N	S
48.35	6.21	45.25	0.18	0.01

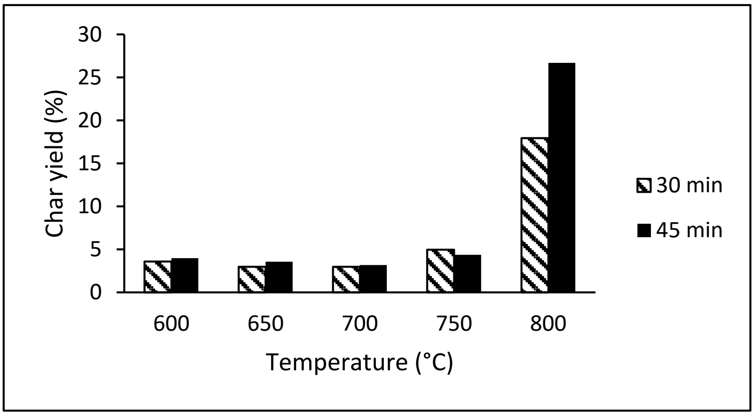
3.2 Gasification

Figure 2 depicts the percentage yields of char, tar, and gas. As shown in the graph, gasification contributes more to gas output than char and tar. Essentially, the yield of char is higher at 800 °C for both holding times, but it is higher when the holding times are longer (45 min). While tar production decreased as temperature increased, it still produced 5.96 % of its yield at 750 °C for both 30 and 40 minutes of holding period. The longer the gasification process takes, the more tar is produced.

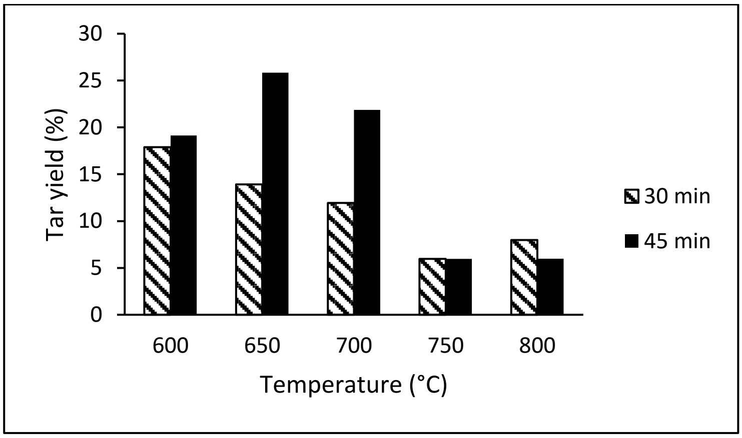
Gasification at 30 min of holding time showed larger production of gas yield than 45 min of holding time at all temperatures, except for 750 °C. At 750 °C, the gas yield for a 45 min holding period is 89.67%, which is 4.6% higher than the yield for a 30 min holding time (85.07 %). Only 0.02 % differentiates the gas yields at 700 °C and 750 °C for the 30 min holding period, which are 85.09 % and 85.07 %, respectively. This experiment's findings indicate that gasification at 750 °C with a 30 min holding time is ideal.

3.3 Gases composition of gasification on untreated and pretreated CS

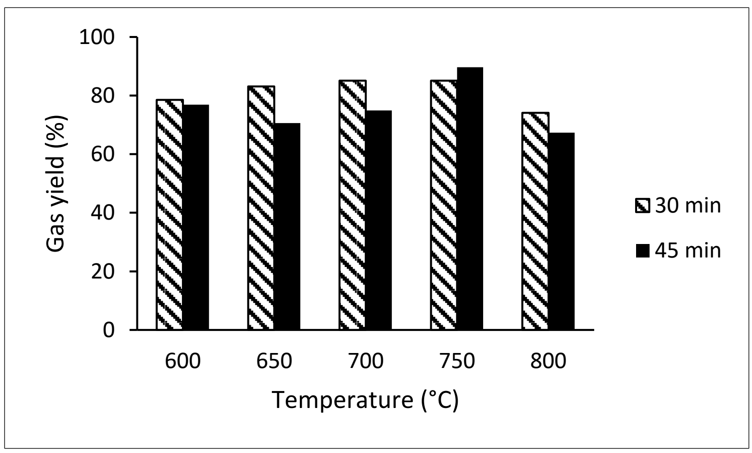
The optimal gasification conditions of 750 °C for 30 minutes are shown in Figure 3 along with a comparison of the gas composition produced by pretreated and untreated CS. In comparison to pretreated CS, the production of CH_4 from untreated CS is 2.6% higher. The production of CO_2, H_2, and CO were higher when pretreatment CS was utilised for gasification at 750 °C and 30 min, but the difference in production from untreated CS is negligible, only 0.4% and 2.2% for CO_2 and balancing gas (H_2 + CO), respectively. The lower content of moisture, ash, and volatile materials may be the cause of the larger production of both gas compositions.



(a)



(b)



(c)

Fig. 2. Percentage of the (a) char yield, (b) tar yield and (c) gas yield of gasification

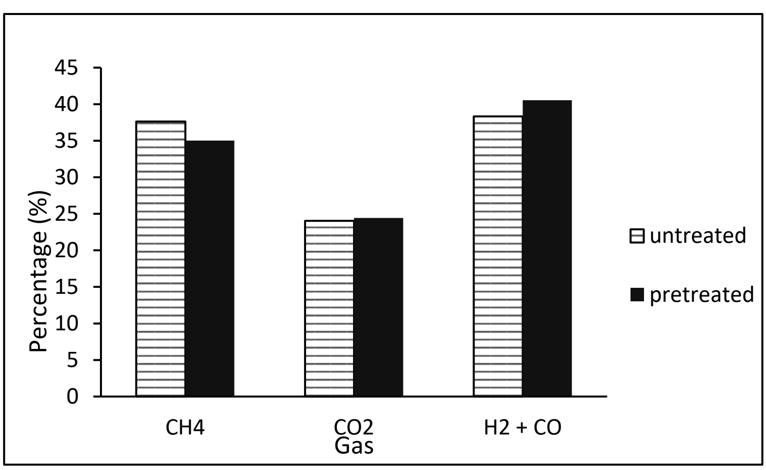


Fig. 3. Gas composition between untreated and pretreated CS

4 Conclusion

The production of H_2 + CO was higher during gasification of pretreated CS than during gasification of untreated CS. Although, the CH_4 composition of pretreated CS gasification was generally low. Furthermore, the amount of CO_2 changed insignificantly for untreated and pretreated CS. As a result of the enhancement of pretreated biomass, pretreatment prior to gasification is recommended for large H_2 generation.

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