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Research Article

Experimental Analysis for Improving the Energy Efficiency of Biomedical waste Co-Feeding in the Steam Gasification

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ABSTRACT

The steam gasification of pure Biomedical waste (glucose plastic bottle, syringe) and Indian palm kernel shell is gasified in fluidized bed gasifier and the result is compared with the different mixture of PKS and BMW co-feeding(100%pks,25%bmw,50%bmw, and 100%bmw) using olivine as the primary catalyst. The influences of co-feeding of BMW with PKS on the gas yield, char yield, tar yield, carbon conversion efficiency, tar composition, and gas composition are investigated.

Keywords: Fluidized bed, steam gasification, co-feeding, biomedical waste, PKS.

Nomenclature

A/F	Air-to-fuel ratio
BMW	Biomedical Waste
CCE	Carbon Conversion Efficiency
CGE	Cold Gas Efficiency
EP	Electrostatic precipitator
ER	Equivalence Ratio
FBG	Fluidized Bed Gasifier
GC-FID	Gas chromatography-flame ionization detector
GC-TCD	Gas chromatography-thermal conductivity detector
GR	Gasifying ratio
HDPE	High Density Polyethylene
HHV	Higher heating value
LHV	Lower heating value
PAH	Polycyclic Aromatic Hydrocarbons

PE	Polyethylene
PKS	Palm Kernel Shell
PP	Polypropylene
T1	Thermocouple-1
T2	Thermocouple-2
TEM	Transmission electron microscope
TG	Thermo gravimetric
TGA	Thermo gravimetric analyzer
TG-MS	Thermo gravimetric-mass spectrometric
TRE	Tar removal efficiency

1. INTRODUCTION

India with 1.21 billion populations is the second country next to China. Around 7 million tons of hazardous wastes generated in India every year. The hazardous waste is a hospital and industry wastes [1]. The biomedical waste consists of blood components, sharp objects, specimens, vials, cotton, glucose bottle, syringe, and chemicals, etc, which are from health care institutions, hospitals, dentists, officers of physicians, medical research laboratories, nursing homes, veterinarians and clinics. There are various technologies are used for the treatment of BMW. They are autoclaving, incineration, landfilling, plasma pyrolysis and microwaving [2]. The waste product produces environmental pollution and also hazards so it should be properly treated. For this experiment plastic glucose bottles and syringes are taken for gasification. Increase in demand for transportation and electricity generation due to the population growth, civilization, and modernization. Due to human activities, most of the warming observed over the last 50 years [3-4].

The global population and highly developed industries dependent on fossil fuels. The burning of fossil fuels produces energy and a lot of CO_2 which is considered as the greenhouse gas into the earth's atmosphere. The field of renewable energy has become important due to global warming, climate change, declining availability of conventional fossil fuels and led towards the use of alternative energy sources like solar, wind, hydropower, geothermal and biomass. The consumption of fossil fuels gives out billions of tonnes of CO_2 gases annually to the ecosystem. To ensure sustainability, energy conservation programs and efficient energy utilization methods should be considered. The economic activity is affected by the rise in fuel prices recently. People are now gaining more awareness and knowledge about the renewable energy source. Renewable energy is now becoming important because due to the issue of global warming and also the attempt to meet the world's energy demand [5].

Kyoto protocol has been introduced in 1997 came into enforcement in 2005 due to the increasing contribution of fossil fuels to global warming and climate change [6]. The main feedstock of the biomass such as municipal residues, agricultural, forestry, and wastes. Biomass is one of the substitutions of coal, oil and natural gas. The various energy services of biomass are transportation, electrical energy, and heat. Biomass has the highest potential to contribute to the world's energy needs. For cooking and heating, mostly traditional biomass is used. Biomass can also reduce CO_2 emission, sulfur and heavy metals in the atmosphere. Biomass gasification also used for the production of chemical products via the Fisher-Tropsch process [7].

Biomass categorized as woody plants, herbaceous plants/grasses, aquatic plants, and manure. Biomass contains varying amounts of cellulose, hemicelluloses, lignin and a small number of other extractives. About 40-50 wt% of the biomass, represented for cellulose which is the largest fraction. The hemicelluloses portion represents 20-40 wt% of the material. The intrinsic and extrinsic are the two forms of moisture content in biomass. Extrinsic moisture is the moisture content of biomass influenced by the prevailing weather conditions during harvesting. Intrinsic moisture is the moisture content of the material without the influence of weather effects [8].

The biomass converted into gaseous components by a thermochemical process in gasification. The various applications are for gas turbines, engines, fuel cells, production of methanol and hydrocarbons as well as the production of synthetic gas. The result of gasification is the producer gases, containing carbon monoxide, hydrogen, methane, and some other gases. The various fuel properties which influence the gasification are size, surface, shape, moisture content, volatile matter and carbon content of biomass [9].

The PKS as the main resource for brick baking process application; this due to syngas having an HHV of 5.0 MJ/Nm^3 used by co-gasification of PKS-SubA coal in fluidized bed gasifier [10].A medium-scale downdraft gasifier is used in PKS gasification for commercial power generation [11]. About 25 MJ/kg HHV of bio-coal is obtained in torrefaction of PKS in a batch feeding reactor at 300°C under the flow of 300mL/min nitrogen gas for 20 min, which can be used as coal in a coal-fired power plant [12]. High calorific value and low ash content solid fuel briquettes produced from palm kernel shell biochars [13]. During palm kernel pyrolysis various products are formed, a higher yield of biochar, higher phenols and higher bio-oil productivity [14-16].

The modified thermodynamic equilibrium model provides better syngas composition and also highest H_2 production is targeted in gasification of PKS (28.48 g H_2/kg PKS) followed by coconut shell (24.78 g H_2/kg coconut shell), rice husk (21.62 g H_2/kg rice husk) and bagasse (20.96 g H_2/kg bagasse) [17].

Low tar yield, low char yield, and high gas yield are produced for co-gasification of torrefied, preheated PKS and MB coal [18]. During the co-gasification of PKS and coal in fluidized bed gasifier, reduces the fluid dynamic issues, gap flow, and large bubbles plug flow and increases the syngas yield, CO and H_2 yield [19]. The effect of reaction temperature, steam/feedstock ratio, polyethylene waste/biomass ratio on syngas production is investigated and optimized via the Taguchi design of the experiment. The total syngas yield 422.40 g syngas/kg feedstock and hydrogen yield 135.27 g H_2/kg feedstock for the optimized condition of 800°C, P/B ratio: 0.3 w/w and S/F ratio: 1 w/w [20].

Pyrolysis gasification of plastic from municipal solid waste produces an increased value of hydrogen and total gas yield [21]. During gasification of polyethylene in atmospheric argon steam plasma, waste plastic is converted into synthesis gas like H_2, CO, CO_2 and CH_4 [22]. At temperature 900°C in the presence of $NiO/g\text{-}Al_2O_3$ catalyst produces high syngas yield(64.35 mol%), H_2 yield (36.98 mol%), CO yield (27.37 mol%), carbon conversion efficiency and decreasing char, liquid yield is produced for waste polyethylene from municipal solid waste [23].

The combination of PET, PS, PP, PE for steam gasification produces H_2, CO, CH_4, C_2H_4 and also increases the gasification process [24-25]. The co-gasification of a mixture of coal, plastics and wood, with the effect of oxygen-enriched air during fluidized bed gasification and by increasing the bed temperature, there is no remarkable effects are obtained in term of tar reduction, but PAH and the syngas specific yield decreased by O_2 enriched air [26]. The microplastics and biomass gasified at a temperature at 1200°C, produces CO, H_2 are increased and the reduced content of CO_2 and N_2 [27].

The medical waste classified into four bags, white, blue, red, and yellow color bags according to biomedical waste management rule in 2016. The red color bag consists of glucose bottles, syringes, tubes, gloves, and other plastics. Two sample material glucose plastic bottles, the syringe is selected from the red color bag for gasification. The gasification process is conducted with 100% PKS, 25% BMW, 50% BMW, 100% BMW of blended samples.

2. MATERIALS AND METHODS

2.1. Indian palm kernel shell

For co-gasification, the palm kernel shell and biomedical waste are used. The palm kernel shell is collected from Godrej Agrovet Ltd. of Ariyalur, Tamilnadu, India [28]. It is shown below in Fig.1.

Fig.1.Palm Kernel Shell

The dust present in biomass is washed with water and dried in sunlight for 4 days and also dried in an oven to remove moisture after it is sieved to 400µm as shown below in Fig.2. The ultimate and proximate analysis of palm kernel shell is shown in Table 1.

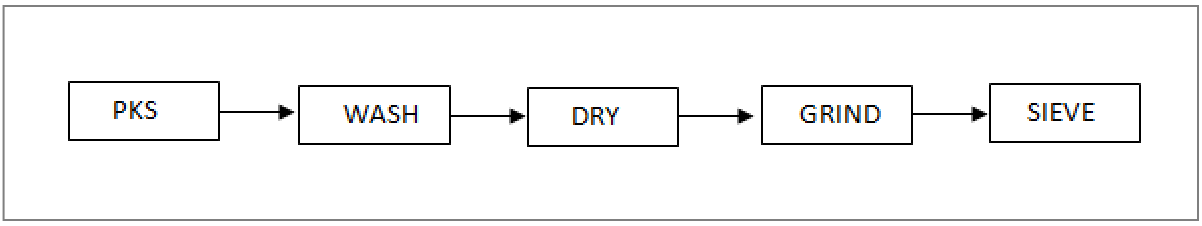

Fig.2. Material preparation

2.2. Biomedical waste

The biomedical waste, the glucose plastic bottle; syringes are taken for the experiment are collected from the hospital. The glucose bottle is made of HDPE and the syringe has two components outer PP barrel and inner PE plunger.

Fig.3.Biomedical waste

The glucose plastic bottle and the syringes are washed with water and dried in sunlight for 5 days to remove moisture. By using a plastic scrap grinding machine the plastic glucose bottle and syringe are crushed to 2 mm as shown below in Fig.3. The ultimate and proximate analysis of polypropylene & polyethylene is shown in Table 2.

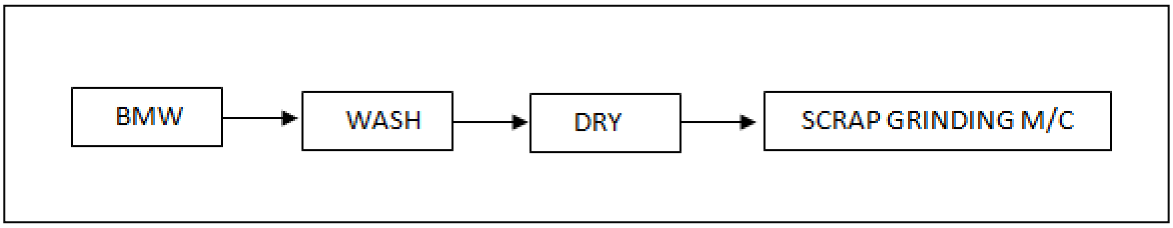

Fig.4. Material preparation

Table 1 Proximate and ultimate analysis of palm kernel shell

Property	Value
Proximate analysis (wt%, dry basis)	
Volatile matter	81.02
Fixed carbon	14.58
Ash content	4.40
Moisture content (wt%)	9.4
Ultimate analysis (wt%, dry basis)	
C	49.70
H	5.98
N	0.56
S	0.45
O (by difference)	43.32
Higher heating value, HHV (MJ/kg)	18.30

Table 2 The proximate and ultimate analyses of polypropylene & polyethylene

Property	PP	PE
Proximate analysis (wt%, dry basis)		
Volatile matter	98.87	99.86
Fixed carbon	0.0	0.0
Ash content	0.4	0.13
Moisture content (wt%)	0.01	0.02
Ultimate analysis (wt%, dry basis)		
C	86.23	85.73
H	12.03	13.50
N	0.70	0.13
S	0.16	0.05
O (by difference)	0.01	0.0
Higher heating value, HHV (MJ/kg)	44.05	46.55

2.3. Catalytic materials

Olivine is used as bed material. The particle size of the bed material is 400µm. olivine is used as bed material due to better performance in the tar removal for biomass and plastics and also a high potential for the production of hydrogen [29]. The olivine property as shown in Table 3.

Table 3 Catalyst properties

Chemical composition (wt %)	
MgO	48.1
CaO	-
SiO_2	42.3
Al_2O_3	0.46
Fe_2O_3	7.5
Cr_2O_3	0.2
NiO	0.1
Physical properties	
BET surface area (m^2 /g)	nd
Total pore volume (ml/gr)	nd
Total pore area (m^2 /gr)	nd
Average pore diameter (A)	0.55

3. EXPERIMENTAL WORK

Steam co-gasification is conducted in 100 kW capacity of fluidized bed reactor using olivine as bed material. An atmospheric lab-scale bubbling fluidized bed reactor of 45mm internal diameter and 1000mm height of circular shape of material stainless steel is used. The setup consists of a fluidized bed reactor, steam generation system, superheater, biomass feeding system, cyclone separator, wet scrubber, water separator and gas analyzing system. The experimental setup of the schematic drawing is shown in Fig.5. Along the axis of the gasifier, thermocouples T-1, T-2, are provided to measure and to control the temperature of gas particles both in the freeboard and bed. (Thermocouples of type K are used).

The outer surface of the gasifier has an electric furnace, is used to heat the reactor which is controlled by the PID control units. The pressure transducer is placed inside the reactor to monitor to determine the pressure and fluidization velocity. Biomass from hopper continuously fed into the reactor bed by using a screw feeder which is controlled by a speed controller. At a feed rate of 5 g/min, the bed material and feedstock is heated by the LPG gas till the bed temperature of 700°C. When the temperature within the gasifier reaches 900°C, gasification starts. The backflow of the biomass is prevented by using nitrogen gas from a cylinder which is measured by using the rotameter. By using steam generator the steam is provided into gasifiers at saturated conditions.

The saturated steam is converted into superheated steam from the steam generator is supplied into the gasifier. The chronometer and precision weight scale were used to measure the discharged mass and mass flow rate of the steam. The hydrogen formation is increased when steam is used as a gasifying agent. In the distributor plate, the holes are arranged in a circular pattern with 50 holes with a 1 mm diameter. The wind box is used to makes the steam supplied at the bottom of the gasifier. At the top side of the gasifier, the cyclone is attached, in which the solid particles present in the product gas is removed by the cyclone. The various gases like CO, CO_2, H_2, O_2, and CH_4 are analyzed in the gas analyzer. The entire setup is controlled by the following system, temperature control, pressure control, feeding control and flow control of FBG.

3.1 Product analysis

This is done in GC-TCD and GC-FID as described elsewhere [30]. The methods of analysis and tar extraction are given elsewhere [31]

3.2 Experimental conditions

Bed material		olivine
Bed material particle size	(μm)	400
Gasification agent		steam

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Biomass sample	PKS and BMW
Feeding system	over bed water-cooled screw feeder
Feeding rate of the screw feeder (g.min^{-1})	4
Range of bed temperatures (°C)	700-950
Biomass feed rate (g.h^{-1})	300
N_2 to biomass feed system (L.min^{-1})	1.69
Steam to fuel ratio	1

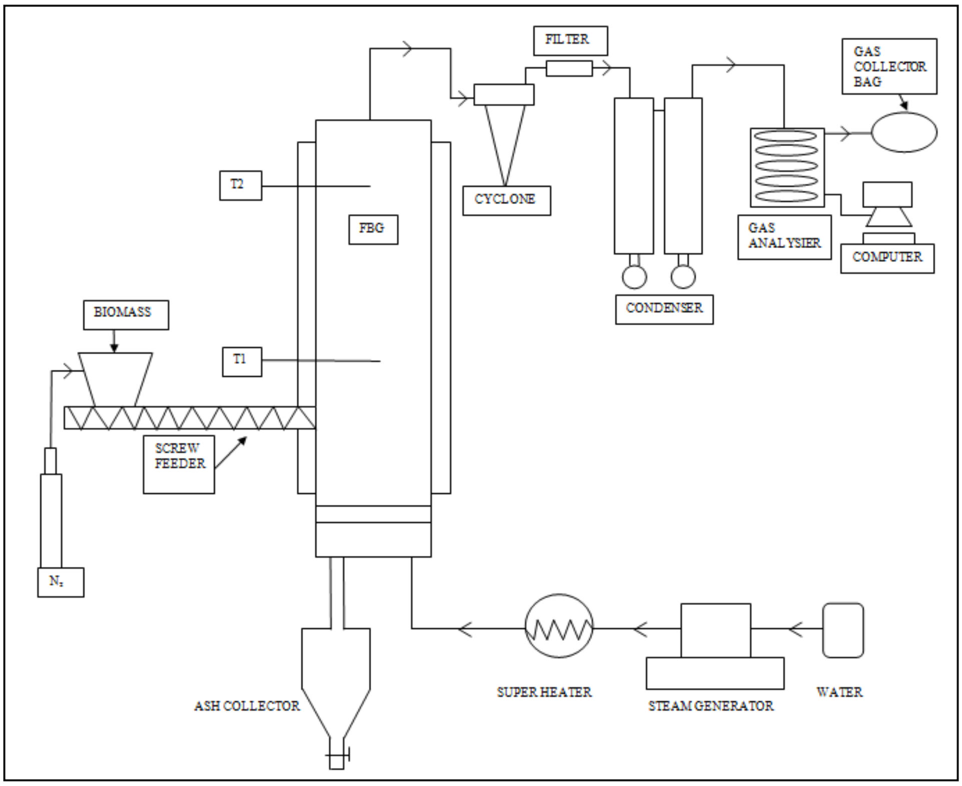

Figure 5.Scheme of the experimental system

4. RESULT AND DISCUSSION

4.1. Product Yields

The mass unit of the mass flow rate in the feed (pks+bmw) by which the yields are calculated. Gas yield, tar yield, and Char yield are shown below for different proportions of PKS/BMW. It is seen from the Fig.6, the gas yield formed in the steam gasification of BMW is higher than that of the gasification of PKS. It is observed from the Fig.7, the tar content in the gaseous stream is lower for the gasification of BMW (3.6 g Nm^{-3} on the dry basis) when compared to that of the gasification of PKS (53.56 g Nm^{-3} on a dry basis). It is founded from Fig.6, the char yield is lower in the gasification of BMW (0.4 wt %) and the char yield is higher in the gasification of PKS (4.9 wt %).

The different chemical gas composition takes place through the following endothermic and exothermic reactions of co-gasification of PKS and BMW:

PKS pyrolysis: PKS → gas + tar + char. (1)

BMW pyrolysis: $(CH_2)_m \rightarrow m/nC_n H_{2n} \rightarrow$ tar. (2)

Tar cracking and reforming: tar $+ n_1 H_2O \rightarrow n_2H_2 + n_3CO$ (3)

Boudouard reaction: $C + CO_2 \rightarrow 2CO$ (4)

Char steam gasification: $C + H_2O \rightarrow CO + H_2$ (5)

Water-gas shift reaction: $H_2O + CO \rightarrow H_2 + CO_2$ (6)

Olefins steam reforming: $C_nH_{2n} + nH_2O \rightarrow 2n\ H_2 + nCO$ (7)

Methane steam reforming: $CH_4 + H_2O \rightarrow CO + 3H_2$ (8)

The olivine catalyst makes the HDPE, PP, and PE of biomedical waste tar in the syngas to increase the reaction rate of the gas fraction by the process of high temperature thermal decomposition. The use olivine catalyst for gasification of polyethylene in bench-scale downstream fixed bed reactor at temperature 900°C with ratio of 1 includes increase tar cracking, carbon conversion efficiency, gasification efficiency, product gas yield and decrease char, liquid yield [23].

Three main processes occur in the gasification of biomass. (a) A volatile matter and char residue are formed at low temperatures during the pyrolysis process. (b) Tars are formed at high temperatures. (c) Char gasification [20]. For BMW there is no devolatilization step. BMW molecular structure breakdown into small molecular radicals and atoms at a high temperature which involved in various reactions [32]. Due to steam gasification reaction and catalytic reaction, lead to syngas production. In the gasification process, the cracking of PKS takes place which yields gases, tars, and chars (Eq. (1)). The pyrolysis of biomedical waste at high temperatures gives out light olefins and aromatic hydrocarbons (Eq. (2)). The lighter products are formed due to the thermal cracking of tar at 600 to 1200°C [33]. (Eq. (3)) give way to homogeneous reforming and cracking of tars in which multiple rings aromatic structures are formed with tar forms smaller gaseous molecules. (Eq. (4) and (5)), is the limiting step in biomass gasification, in which reaction rate is slower than that of pyrolysis. (Eq. (6)) the water–gas shift (WGS) reaction. (Eq. (7) and (8)), for steam/feedstock mass ratio of 1 and temperature 900°C, the H_2 yield increases due to the enhancement of secondary cracking and shift reactions. From Le Chatelier's principle, an endothermic reaction is formed at a higher temperature, in which reforming reactions makes to increase the in syngas composition and a decrease of CO_2 content and hydrocarbons. Methane reforming and water-gas shift reactions are formed due to using steam as the gasifying agent which increases the syngas production.

4.2 Gas yield

Fig.6 shows the variation of gas yield with respect to the different proportions of BMW.

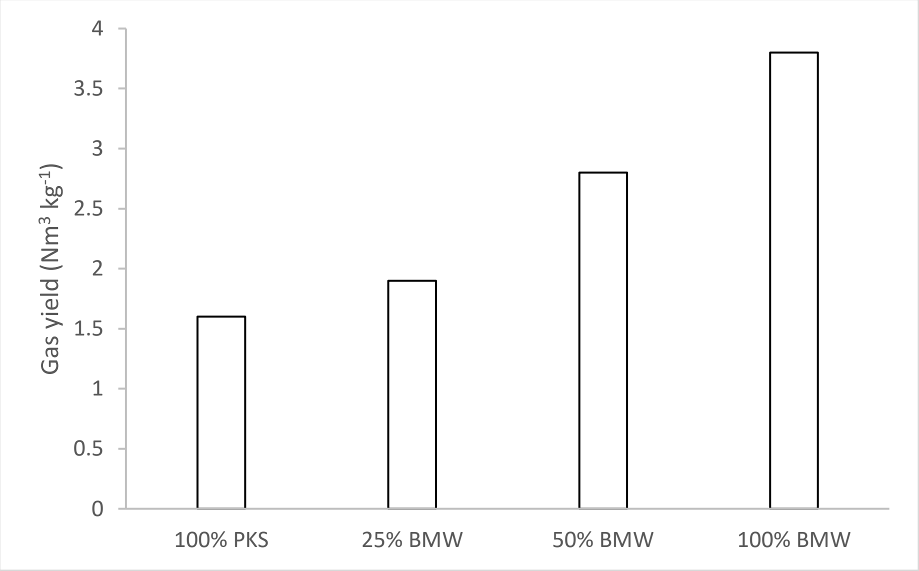

Fig.6. Gas yield for the co-feeding of different proportions of BMW.

The gas yield for the steam gasification of 100%BMW is 2.2 times higher than that of the gasification of 100%PKS. This is due to the aliphatic molecular structure makes the formation of radicals when 100%BMW used which increases gas yield. The BMW mixed with PKS the gas yield content increases. Thus, the gas yield corresponding to the mass of 25% BMW increased to1.9Nm^3/kg for 50% BMW, increased to 2.8 Nm^3/kg. This is due to olivine catalyst plays a significant role when higher BMW is present in the mixture. By using the catalyst Ni the value of gas yield is increased [34]. For 100%PKS, the lower gas yield is obtained, for the highest temperature. The gasification of 100% PKS led to gas yield to lower when compared to that of 25%BMW, this is due to easy to gasify BMW than PKS, and hence the increase of temperature easily cracks the polymeric structure of BMW [32]. The co-feeding of BMW with the PKS, increase the gas yield, due to BMW in the co-feeding increased the conversion of solid feedstock to gases[35].

4.3 Tar Yield

On dry based the tar is defined as the tar mass per syngas volume unit. Fig.7 shows the variation of tar yield with respect to the different proportions of BMW.

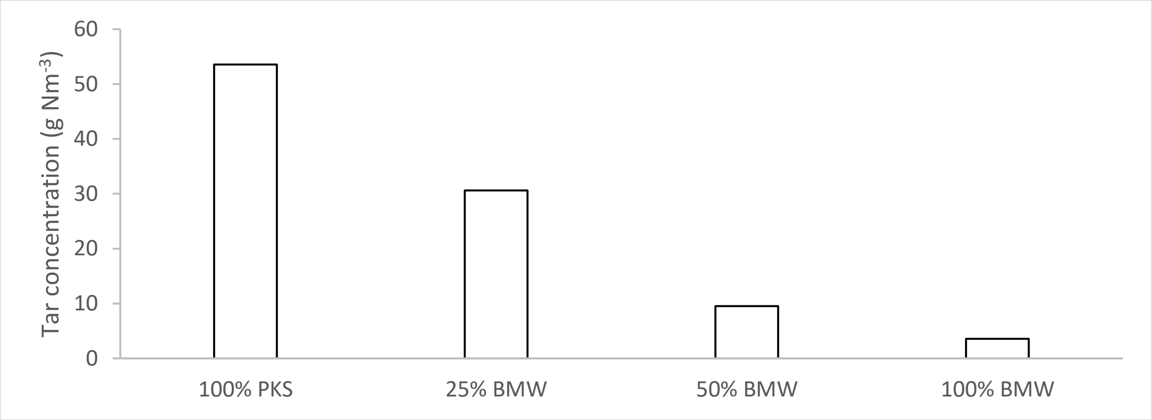

Fig.7. Tar Yield for the co-feeding of different proportions of BMW.

It is seen from the Fig.7, the tar yield decreased to 3.6 gNm^{-3} for 100%BMW due to the increase of temperature and the enhancement of thermal cracking of BMW when compared to PKS. Tar yield of 30.6 gNm^{-3} is produced for the gasification of 25% BMW and 9.5 gNm^{-3} are formed for 50% BMW. Tar is cracked of waste plastic by using steam and air as a gasification agent due to the positive effect of high temperature. And also tar cracking formed by the residence time of the tar in the gasifier [36].

4.4 Char Yield

Char yield is defined as the mass percentage of the char produced per biomass mass unit.Fig.8 shows the variation of char yield with respect to the different proportion of BMW

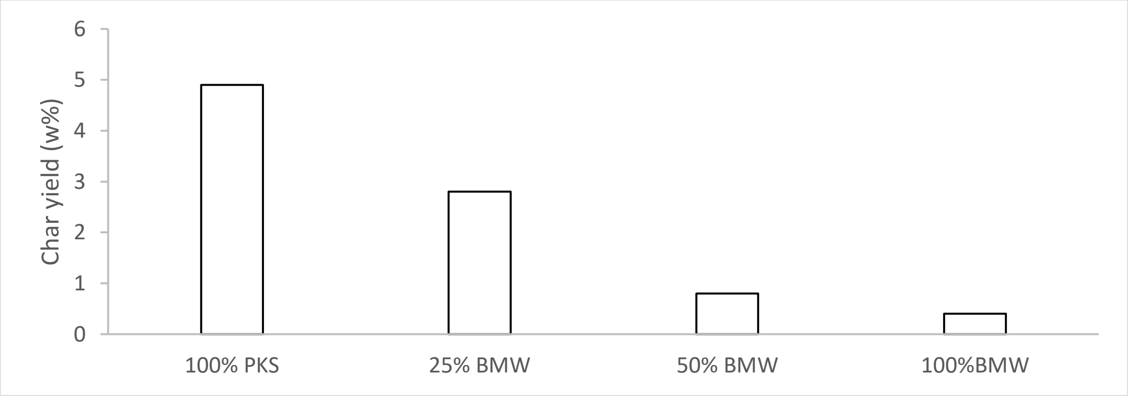

Fig.8. Char Yield for the co-feeding of different proportions of BMW.

Char yield of 4.9 wt% is formed for 100%PKS, 2.8 wt% produced for 25%BMW, 0.8 wt% for 50%BMW and 0.4 wt % for 100%BMW [37].

4.5 Carbon Conversion Efficiency

The carbon conversion efficiency (CCE) is determined by the ratio between the mass of carbon present in the produced dry gas and the mass of carbon present in the solid fuel fed to the reactor.

The carbon conversion efficiency = Carbon content in the producer gas/ Carbon content in the biomass feed.

Fig.9 shows the variation of carbon conversion efficiency with respect to the different proportions of BMW.

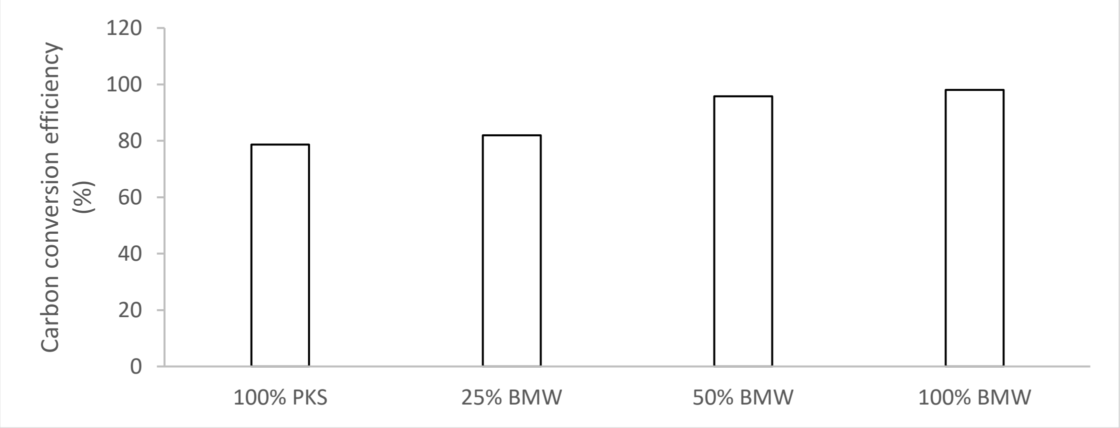

Fig.9. Carbon Conversion Efficiency for the co-feeding of different proportions of BMW.

The carbon conversion efficiency for 100%PKS is 78.7%, 82% for 35%BMW, 95.8% for 50%BMW and 98% for 100%BMW. From Eq. (3), (4), (5), the carbon and steam converted into gas due to the decomposition of char and secondary reaction of the tar vapors. So the carbon conversion efficiency increased and char decreased. From [38] the carbon conversion efficiency favored due to higher temperature and presences of the catalyst. About 88.5 to 91.8% carbon conversion efficiency is formed at 720°C to 855°C for rice husk in FBG. Due to the increase of gas formation and the catalytic gasification of polyethylene conversion which makes to increase carbon conversion efficiency.

4.6 Gas Composition

Fig.10. shows the variation of gas composition with respect to the different proportions of BMW.

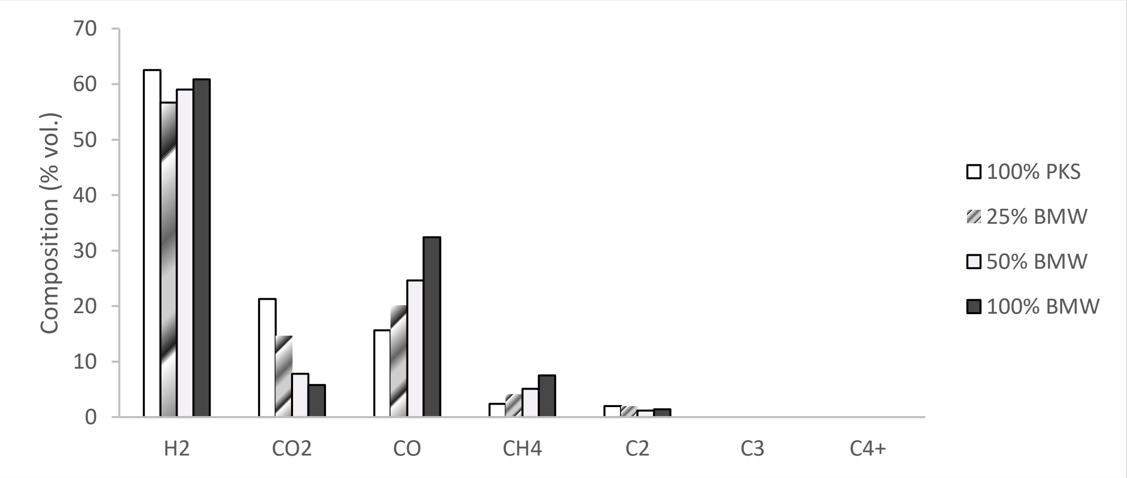

Fig.10. Effect of BMW co-feeding on the gaseous product composition.

The co-feeding of different proportion percentages of 25, 50 BMW are carried out with PKS, along with a single feed of 100%PKS and 100%BMW for gasification. The various gas compositions such as CH_4, CO, CO_2, and H_2 are formed in the product gas and some aromatic hydrocarbons along with benzene are formed. Fig.10 shows the various composition of syngas formed for the co-gasification of PKS and BMW at different proportion ratios.

4.6.1 H_2

It is observed from Fig.10, 62.56 vol% H_2 gas formed for 100%PKS due to the low ash content, moisture content, high proportion of fixed carbon and volatile matter [39]. For 50%BMW the hydrogen yield is lesser when compared to that of 100%BMW and for the hydrogen produced by 100%PKS is higher than 25%BMW. The higher percentage of PKS gives more hydrocarbons and volatile matter for the pyrolytic reactions [28]. This also a preferred feedstock for H_2 production via the gasification process due to its high proportion of fixed carbon and volatile matter, low ash and moisture content. For 100%BMW the H_2 content is increased to 60.87 vol%. For 25%BMW the H_2 content is 56.67 vol% and for 50%BMW the H_2 content is 59.01 vol%. The increased content of H_2 is due to the presence of the steam in gas-phase reaction. The result is similar to the gasification of polyethylene in bench-scale downstream fixed bed reactor at temperature 900°C with steam, when increased H_2, and CO contents, while CO_2, CH_4, C_2H_4, and C_2H_6 contents decreased [23].

4.6.2 CH_4

For 100%PKS the methane is 2.4 vol%, for 25% BMW the methane produced is 4.12 vol%, for 50%BMW co-feeding the methane is 5.1 vol% and for 100%BMW is 7.5% vol%. The value of CH_4 gas is increase due to the BMW (PP, PE, and HDPE) contains low ash content, high volatile matter, and absence of fixed carbon when compared to PKS.

4.6.3 CO_2

The CO_2 content of 100% PKS, 25% BMW, 50% BMW, and 100% BMW are 21.3 vol%, 14.6 vol%, 7.8vol%, 5.8vol%. The CO_2 gas decreased gradually due to the endothermic reaction of the Boudouard reaction at high temperature.

4.7 Tar Composition

For different co-feeding gives various tar composition as shown in Fig.11. According to [40] the classification of tar compounds given by

(i) Class: 1 (C1), GC-undetectable, such as heavy tars, cannot be detected by GC. (ii) Class: 2 (C2), Heterocyclic, such as cresol, phenol.

(iii) Class: 3 (C3), Light aromatic, such as Toluene, Xylene.

(iv) Class: 4 (C4), Light polyaromatic hydrocarbon (PAH) compounds, such as Naphthalene, Biphenyl.

(v) Class: 5 (C5), Heavy PAH compounds, such as Fluoranthene, Pyrene.

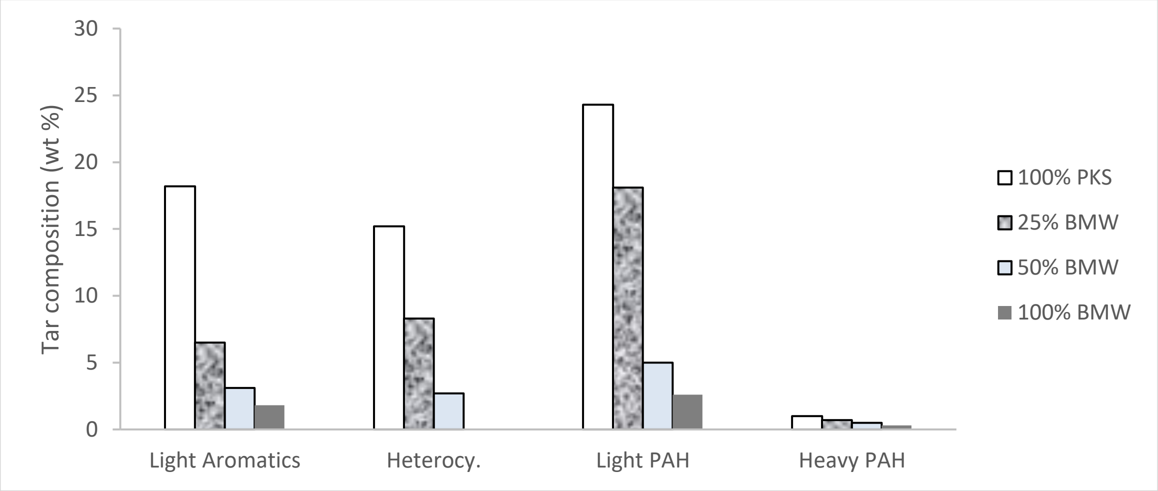

Fig.11. Tar composition for the co-feeding of different proportions of BMW.

4.7.1 Heterocyclic compounds

The co-gasification of PKS and BMW reduces the tar fraction. During gasification, the compound heterocyclic reduces gradually. At temperature 900°C the heterocyclic compounds changed into stable aromatic compounds. The light aromatics, heterocyclic compounds, and heavy polyaromatics are also decreased. When compared to light PAH the compound heterocyclic aromatics are very less [41].

4.7.2 Light PAH

1. At 900°C the light aromatic decreases to 3.5 wt% but the light PAH increases to 79.5 wt%. These results confirm that tar decomposition reactions (cracking and reforming) are endothermic and, therefore, favored by increasing the temperature.

2. PAH tar compounds are formed from N-based tar, toluene, and phenol which are the light tar compounds due to the increase in the temperature by which tar yield decreases. On comparing to Heavy PAH, Light aromatic and heterocyclic compounds, Light PAH has become the increased value at 800°C [40]

4.7.3 Heavy PAH

For 25%bmw in feed, the heavy PAH is very less. This is due to the increase in temperature the amount of tar is less so the heavy PAH compound decreases gradually. These results are similar for [42] in which the light aromatics, heterocyclic compounds, heavy polyaromatics are decreases for 25% of HDPE.

4.7.4 Phenol

The presence of aromatic hydrocarbons in the tar reduces the phenol compounds, with the PAH and aromatic compound are about 90% when compared to phenols 10%

5. CONCLUSIONS

The main conclusions of this study are:

1. The conversion of BMW products into useful product gas yield by the olivine catalyst, steam gasification of polyethylene, polypropylene, PKS.

2. The H_2 and CO content increase 100%BMW but CH_4, CO_2, C_2H_4 content decreases due to the usage of steam as a gasification agent.

3. The process efficiency and gas composition increase due to the use of BMW, PKS catalytic co-feeding.

4. During the co-feeding at 900°C strongly decreases the monoaromatic tars and yield of light hydrocarbons and increasing PAH and benzene.

5. A positive synergetic effect in the biomass gasification by co-feeding BMW.

From the experiment, by steam gasification process with olivine as catalyst produces syngas form biomedical waste and Indian palm kernel shell. The higher hydrogen content in plastics makes biomedical waste into useful syngas generation throughout the year which solves the plastic disposal issues into value-added products.

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