Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 148 (2016) 409 – 416

Procedia Engineering

www.elsevier.com/locate/procedia

4th International Conference on Process Engineering and Advanced Materials

Parametric Study and Optimization of Methane Production in Biomass Gasification in the Presence of Coal Bottom Ash

Muhammad Shahbaz [a,] *, Suzana Yusup[a], Angga Pratama[a], Abrar Inayat[b], David Onoja Patrick[a] , Muhammad Ammar[a]

[a]*Biomass Processing Lab, Centre of Biofuel and Biochemical Research, Department of Chemical Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 32610 , Perak, Malaysia..*

[b]*Department of Sustainable and Renewable Energy Engineering, University of Sharjah, 27272 Sharjah, United Arab Emirates*

Abstract

Methane production from biomass gasification is an alternative route compared to conventional techniques for the efforts to reduce the carbon foot print. In the current work, production of methane is studied from steam gasification of palm kernel shell (PKS) in thermo gravimetric analyser (TGA) and mass spectrometer (MS). Response surface methodology (RSM) is applied to investigate the effect of operating parameters and to identify the optimized parameters. The four main process variables were investigated within the specific range of temperature of 650 -750°C, particle size of 0.5-1 mm, CaO/biomass of 0.5-2 and coal bottom ash % of 0.02-1. Temperature and CaO/biomass ratio were found to be the most influencing variables on methane production. The optimised conditions obtained were temperature of 750 °C, particle size of 0.99 mm, CaO/biomass of 1.25 and coal bottom ash of 0.08%. The presence of Fe, Mg, Al oxides in the coal bottom ash catalysed the process and enhanced the methane yield from 37 to 43.3 vol %.

Peer-review under responsibility of the organizing committee of ICPEAM 2016

Keywords: Methane;Gasification; Biomass; H_2; Syn gas; ANOVA; RSM;

1. Introduction

Natural gas is an important part of world energy mix. From last two decades its importance has dramatically increased due to vast utilization in industry. Natural gas has been considered as a clean fuel among the fossil fuel.

* Corresponding author. Tel.: +605-368-7642; fax: +605-368-8205.
E-mail address: shabimooz@hotmail.com

Peer-review under responsibility of the organizing committee of ICPEAM 2016
doi:10.1016/j.proeng.2016.06.432

Natural gas is not abundantly available and current global proven reserves at current consumption rate are only enough for the next 5 to 6 decade [1].

Bio methane or synthetic natural gas production has an advantage in that it could be used directly in existing gas distribution net without any major modification [2]. The 200-700 EJ per annum availability of biomass [3] has made it as a prominent renewable sources for fuel production like methane (CH_4) [4]. Biomass has been utilized for methane production by both digestion and thermochemical conversion in the form of biogas [5] and syngas or synthetic natural gas (SNG) [6]. The production of methane from fermentation of biomass or manure known as biogas are widely used all over world [7]. The biogas production is not commercially viable at large scale due to the problems associated with it regarding pre-treatment process, feeding problem of different type of biomass, inefficient fermentation due to flotation, removal of wasted feed continuously and excess volatile fatty acids [8]. The thermochemical conversions of biomass are classified into pyrloysis, combustion and gasification [4]. Gasification is the most efficient among the above mentioned technologies to convert biomass into methane [2, 4]. The major reactions involved in the gasification of biomass for CH_4 production are given below [9].

Bourdouard reaction	$C + CO_2 \leftrightarrow 2CO$	+175 MJ/kg	(R1)
Methanation reaction	$C + 2H_2 \rightarrow CH_4$	-75 MJ/kg	(R2)
Methanation reaction	$2C + 2H_2O \rightarrow CH_4 + CO_2$	+ 103 MJ/k	(R3)
Water gas shift reaction	$C+ H_2O \leftrightarrow CO + H_2$	+131 MJ/kg	(R4)
Water gas shift reaction	$CO+ H_2O \leftrightarrow CO_2 + H_2$	- 41 MJ/kg	(R5)

The high content of CO and H_2 in the product gas is due to water gas shift reaction. This high content of CO and H_2 can be converted into methane by methanation reaction. Van der Meijden et al. [3] studied three different types of gasifiers i.e. fluidized, allothermal and entrained flow for the syngas production and conversion to methane by methanator. Molino et al. [2] developed a thermodynamic model for production of methane from syngas via wood gasification. Gasification of biomass has been done by using gasifying agent like O_2, steam, air and CO_2. Methane production is low in the case of steam due to methane reforming and water gas shift reaction [10]. Gasification process has an advantage to utilize biomass waste for methane production which does not affect cultivated land for food crops. Malaysia is rich in biomass wastes that includes palm oil waste, rice husk, forest residue [11]. This large scale production yields about 51.2 Mt/year of palm oil wastes consisting mainly of palm kernel shell (PKS), empty fruit bunches (EFB) and palm oil fronds (POF). Many researchers utilized palm oil residue for gasification process. Zakir et al. [12] produced 84.2 vol% H_2 from steam gasification of PKS at 600 – 750 °C in which maximum methane is 11.9 vol% as by product. The lower yield of methane is due to water gas shift reaction and use of commercial Ni catalyst for methane reforming. Mohammed et al. [13] reported about 16 vol% methane production from air gasification of EFB between 700-900 °C.

The use of catalyst does not only enhance the gasification but also directs the targeted product. Basically three types of catalyst are used, namely dolomite, Ni and alkaline metal catalyst [14]. Each catalyst has its pros and cons. Some are effective for tar reduction, some enhanced H_2 yield, some reduced CO_2, some are costly and some has short active life. Coal bottom ash (CBA) is the waste product of coal power plants. It is mostly dumped or used in construction industry. Recent research explored the presence of some alkali metals and Ca in CBA. Xiong et al. [15] reported the oxides of Fe, Ca, Mg and Al in coal bottom ash. He used CBA as bed material for coal pyrolysis and gasification process and noted the good effect on tar yield. Wood ash has been utilized as catalyst to increase the gasification reactivity [14]. In literature, use of CBA in biomass gasification has very less coverage. Furthermore, very little investigation has been done to produce methane specifically from palm oil waste gasification. Reza et al. [16] used Ni for steam gasification of PKS with polyethylene and reported 12 vol% methane and 76 vol% H_2. Khan et al. [17] studied PKS gasification in the presence of a new Fe based catalyst in TGA and gas chromatography set up and obtained about 20 mole % of methane up to 530 °C. Water gas shift reaction and reforming reaction was enhanced at steam to biomass ratio of 1 which suppressed the methane formation [17]. Limited work has been reported for methane yield from direct gasification of biomass. The aim of this investigation is to produce the methane from gasification of PKS in the presence of steam in TGA with MS to measure the evolved gas. In