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PRODUCTION OF SYNTHETIC GAS FROM AGRICULTURE AND FOREST WASTES USING FIXED BED GASIFIER

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ABSTRACT

Gasification is a process that converts organic/agricultural wastes (carbonaceous materials) into synthetic gas. Particularly field crop residues being generated in the country on large scale can be gasified and converted into the synthetic gas (SYNGAS) by the gasification process. This research paper reports the results of gas generated from three different types of agriculture and forest wastes i.e. cotton (*Gossypium hirsutum* L.) crop waste, neem (*Azadirachta indica*) tree barks and leaves through gasification process.The results obtained from the study indicated that the SYNGAS generated from cotton crop waste was almost similar to that of generated from neem tree barks. However, the SYNGAS obtained from neem tree barks and leaves was higher in fixed carbon. There was a slight difference in the composition of gases obtained from different wastes. The gas obtained from cotton crop waste had 27.52% CO and 32.17% H_2; the gas obtained from neem tree barks had 28.72% CO and 31.88% H_2. Similarly, the gases obtained from neem tree leaves had 26.07% CO and 28.12% H_2. It can be concluded from these results that the gasfication process of generating SYNGAS from agricultural and forest wastes available in the country can be used as an alternate of natural gas LPG, Dimethyl ether, etc. to run the power houses and mechanical vehicles.

Keywords: dimethyl ether, gasification, solid waste, synthetic gas, gasifier

INTRODUCTION

The waste should not be considered as waste, until unless it is dumped off. It is currently estimated by various organizations that each year about 140 billion metric tons of agro-waste is generated in the world (Calis, 2002). This huge amount of biomass can be converted into precious volume of renewable energy rather than burning in the agricultural fields. This will not only solve the issue of dumping agriculture and forest wastes, but it would overcome the ever increasing energy crisis and environmental pollution problems in the country and province. Pakistan is an agricultural country. About 70% population of the country is involved in agriculture farming. Several major and minor field crops including, cereal, fiber, oil seed, fruit, vegetable, sugar, pulse and fodder crops are grown in the country on large scale (Tunio, 2008). Huge quantity of waste is generated

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from these crops. Farmers are habitual to burn that waste in their fields. However, these wastes are very useful and can be exploited as an alternative of fuels and energy production through gasification processes using combustion equipment that convert these wastes into CO_2, CO. Combution equipment, like Fixed Bed Gasifier with controlled parameters is used to get desired purity, low contents of harmful gases and also to achieve required ratio of production from the product (Babu and Chaurasia, 2003). The gasification is basically a technology or manufacturing process in which the inexpensive and low value agricultural wastes are converted into high-value products (Ahmed, 2011). In other words, it is the process of converting organic and carbonaceous materials into the mixture of different gasses, such as CO, CO_2 and relative quantity of some other gasses at high temperature (>700 °C) with the controlled ratio of steam or oxygen (Garcia, 2001). Resulting gas is called synthetic gas that can be efficiently utilized as a source of fuels. Although, different types of gasifiers like Fluidized Bed Gasifier, High Temperature Winkler Gasifier and Moving Bed Gasifiers, etc. are used to produce SYNGAS, while in this study we used Fixed Bed Gasifier (Dasapa *et al*., 2006). Forms of energies are categorized on the basis of their uses, types and behavior. There are two main types of energies. 1. Renewable and 2. Non-renewable energies (Calis *et al*., 2002). The SYNGAS produced from agro-waste through Fixed Bed Gasifier is the sub-class of renewable type of energy. This gasifier has a maximum efficiency for batch process with the easily controllable parameters like feed to gasifier, removing of ashes, the temperature and pressure measurement nobs. The main focus of our research was to study the conversion process of agricultural and forst wastes into valuable fuel that can overcome the energy crises in Pakistan.

MATERIALS AND METHODS

Waste material selection

Three types of agricultural and forest wastes included in the study were: A. Cotton crop waste, B. Neem tree barks and C. Neem tree leaves (Plate # 1 A, B and C). Each waste material was selected on the basis of its already reported heating or calorific value (Ibanez, 2004).The waste material collected from the field was initially air-dried for 15 days. The biomass was regularly pulverized to achieve 600 µm particle size, normally considered for the gasification process (Paasen, 2006).

Plate 1. A. Cotton crop waste, B. Neem tree barks waste C. Neem leaves waste

The utilization of biomass for the purpose of energy production is divided into two main categories that are: “Wet” biomass (including marine algae and organic waste fluids, etc.) and “Dry” biomass including agricultural biomass like baggas, rice husks and forest biomass (Babu, 2003). For this study, the material was selected on the basis of dry biomass (Jone *et al*., 2007). Before utilization, each type of waste was prepared and processed in the following way:

Drying of the materials

Each waste collected from the field was dried in an open environment for 15 days (Garcia *et al*., 2001).

Grinding and sieving of materials

Materials were initially crushed using hammer mill and sieved through 1 inch sized sieve. After crushing, the materials were passed through disc pulverizer to obtain fine particle size of 600 µm (Nobel *et al*., 2006).

Briquetting

Briquetting was carried out at IMPLEMENT II by BUEHLER. The force of 10 thousand pounds was applied to the material and continuous heat of 400^{o}C was supplied to lose the lignin content of biomass which may act as binder (Dasapa *et al*., 2006).

Proximate analysis

The proximate analysis was done for characterization of the biomass. The proximate analysis shows that the biomass with good quantity of volatile matter and fixed carbon should be suitable for the gasification purpose.

Determination of moisture content

Moisture content of biomass was noticed by heating material at 110^{o}C for 1 hour. The weight difference between initial and later stage was considered as moisture content of the respective biomass.

Determination of volatile matter

Volatile matter of the biomass was determined by heating the biomass in platinum crucible for 7 minutes at 950^{o}C. The weight at later stage was calculated and the weight difference was considered as volatile matter.

Analysis of ash content

The ash content was calculated by combusting the biomass under oxidized conditions in a muffle furnace. The residue remaining after combustion was calculated as ash content.

Determination of fixed carbon

The difference between volatile matter free biomass and biomass ash difference was calculated as fixed carbon. The formula used in the calculation of fixed carbon is given as:

$$\text{Fixed Carbon} = \text{Volatile free biomass} - \text{Biomass Ash}$$

Ultimate analysis

Ultimate analysis was carried out to identify the amount of hydrogen, carbon, oxygen, and nitrogen (Table 2).

Carbon and hydrogen

The 0.2 g of biomass was weighed and then the sample was burnt in presence of oxygen to air ratio of 0.21:1 in a gasifier apparatus. The carbon and hydrogen gases from the biomass were converted into CO_2 and H_2O, respectively.

Oxygen

The percentage of oxygen was determined by the following formula:

$$\text{Percentage of } O_2 = 100 - \text{Percentage of } C+H+O+N+ \text{Ash}$$

Nitrogen

The percentage of nitrogen was calculated using the following formula:

$$\text{Percentage of } N = \text{Volume of Acid used} \times \text{Normality} \times 14 / \text{Weight of biomass sample taken}.$$

Emission analysis

Emission analysis was done using Testo 454 Stack Gas Analyzers.

Gasification process

In gasification process, three main types of reactions occur, pyrolysis, combustion and gasification. The gasification was done at partially oxidized atmosphere and air fuel molar ratio set at 0.21: 1. The gasification temperature was set at 900^{o}C. The gasification was done on 1 kg biomass briquettes. The emission analysis was also done at 900^{o}C temperature when synthetic gas was tested by flame formation and color identification. In the Fixed Bed Gasifier, mostly used for solid waste as used in this research work (Plate #2), the operating mechanism is that the solid biomass is introduced from top of the gasifier and the steam plus oxygen enter from the bottom of the gasifier. It consists of four zones named drying, pyrolysis, combustion, and reduction zones then finally ash is removed (Paasen *et al.,* 2006).

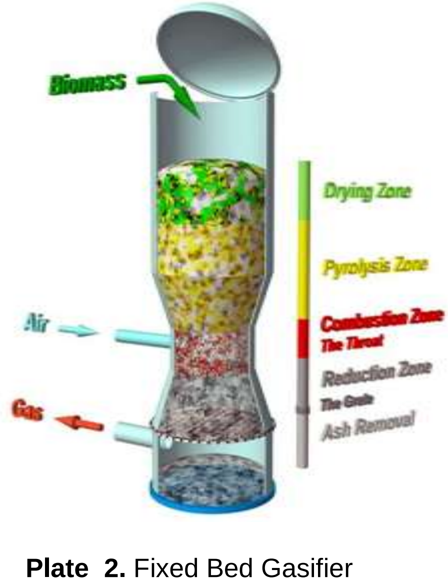

Plate 2. Fixed Bed Gasifier

RESULTS AND DISCUSSION

Proximate analysis

The proximate analysis which was done for the characterization of biomass (Table 1) showed that the biomass with good quantity of volatile matter and fixed carbon is favorable for the gasification of the organic material. The material with excessive moisture content required excessive energy to dry at initial stage, but its yield depends upon fixed carbon and volatile matter (Kersten, 2003; Jones, 2007). The material with higher content of the moisture was neem tree barks waste that was noted as 13.3% whereas, cotton crop waste contained 12.23% moisture and neem tree leaves waste had 12.81% moisture. The study showed that cotton crop waste had almost same production of synthetic gas as of tree barks. The productivity was achieved higher from neem tree barks which had greater quantity of fixed carbon (14.13%) and the neem tree barks had lowest ash content that was 9.06%, it means that the product obtained from tree barks is favorable. Cotton crop waste had most volatile matters as compared to neem tree barks and neem tree leaves. Neem tree leaves also had higher fixed carbon which was noted as 12.85% but the ash content in tree leaves was higher which was noted as 18.92% which makes tree leaves less favorable for the process.

Table 1. Proximate analysis of biomass

Feed stock	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)
Cotton crop waste	12.23	69.73	9.52	8.52
Neem tree barks waste	13.30	63.51	9.06	14.13
Neem tree leaves waste	12.81	65.42	18.92	12.85

Table 2. Ultimate analysis of biomass

Feed stock	C (%)	H (%)	N (%)	O (%)
Cotton crop waste	50.50	5.5	2.01	41.99
Neem tree barks waste	47.73	6.0	1.10	45.17
Neem tree leaves waste	47.35	5.7	0.71	46.24

Ultimate analysis

The ultimate analysis has direct relation with proximate analysis. Table 2 shows that the tree leaves were highly oxidized in nature and contained 46.24% of O_2. It was assumed that possibly due to nerves and porosity within the structure of the neem tree leaves, they contained higher level of oxygen. The second highest O_2 content was noted with tree a bark which was observed as 45.17% and O_2 content noted with cotton crop waste was 41.99%. The ultimate analysis revealed that carbon in cotton crop waste was highest than any other agriculture waste which was noted as 50.50%. For that reason the productivity of the gas of cotton crop waste was much similar to the tree barks. The neem tree barks were found most favorable material for the process, because of good quantity of hydrogen that is 6% present with its structure. The organic materials and fossil fuels contain hydrocarbon in excessive quantity (Dasappa *et al*., 2006; Bouvet *et al*., 2010).

Emission analysis of biomass gasification

The plants do not have much sulfur in their basic structure, but they do contain very minute level of sulfur within their structure due to environmental conditions and raw materials which are provided to plants as feed. The hard woods have more carbon and less nitrogen, because of the firmness of fibers of the neem tree barks. The fibers of neem tree barks do not work as energy carrier which also play important role in the nitrogen content (Babu and Chaurasia, 2003). The data from the emission analysis reveals that the cotton crop waste has greater value of nitrogen compound emissions such as NO and other NO_x as shown in Table 3. It is assumed that cotton crop has greater emissions of nitrogenous compounds, because of extra nutrients provided to cotton crop for better growth in the form of fertilizers, etc. The CO_2 emitted in this lab scale gasification process is higher than other commercial scale plants. This is because of excessive oxygen in the system or some other problems generated while analyzing the emissions (Calis *et al*., 2002). The data reveals that neem tree barks waste has lowest CO_2 emissions (31.76%), whereas neem tree leaves have greater CO_2 emissions (35.62%). This proves that with high volatile matters and high CO_2 emissions, neem tree leaves are easily combustible and may be difficult to handle in gasification process.This makes them less reliable material for production of synthetic gas. The O_2 evolved is the uncreative oxygen which did not participates into the combustion process. The statistics of neem tree leaves proved that neem tree leaves require very less oxygen for combustion and it already has higher level of oxygen within its structure that can be used in combustion process.

Table 3. Emission analysis of biomass gasification

Feed stock	**CO (%)**	**NO (%)**	**CO_2 (%)**	**H_2 (%)**	**NOx (%)**	**O_2 (%)**	**SO_2 (%)**
Cotton crop	27.52	0.0195	33.32	32.17	0.02278	3.75	0.0003
Neem tree barks	28.72	0.0183	31.76	31.88	0.020117	2.53	0.0002
Neem tree leaves	26.07	0.0170	35.62	28.12	0.01607	4.15	0.0006

Combustible gases from gasification of biomass

The major portion of the gases contains CO and H_2 which is basic requirement of the SYNGAS (Table 4). These two major gases were directly dependent on fixed carbon of biomass and volatile matter. The data reveal that hard wood has favorable processing behaviors and should be used for gasification process (Calis *et al*., 2002). Our data further reveal that neem tree barks and cotton crop wastes have similar productivity of carbon monoxide but cotton crop waste has very little lead in the productivity of H_2. The data also shows that almost the productivity is similar; hence both of the materials can be used in gasification process (Ahmed and Gupta, 2011). Tree barks had lower CO emissions, which made it more favorable also that CO from tree barks contributed up to 28.72% where as from cotton crop waste it contributed 27.52% which only has difference of 1%. In terms of hydrogen, the cotton crop waste generated more hydrogen than neem tree barks, which is 32.17, whereas neem tree barks generated 31.88%. The difference between the generations of hydrogen is very minute and is negligible (Raskin *et al.* 2001).

CONCLUSION

The conclusion of study revealed that the hard materials with lower moisture content and higher level of fixed carbon had better yield for synthesis of gas from biomass.The common agriculture waste (cotton crop waste) had very little deviation in gas production to tree barks. The energy derived from the cotton crop waste may be used for power generation and synthesis of some higher chemicals too. The results also disclosed that H_2 gas produced during the process was in sufficient quantity which may further be used and hydrogen fuel cells may be developed for more effective utilization and conservation of energy.

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REFERENCES

Ahmed, I.and K. Gupta. 2011. Characteristic of hydrogen and syngas evolution from gasification and pyrolysis of rubber. Int. J. Hyd. Ener., 36: 4340-4347.

Babu, B. V. and A. S. Chaurasia. 2003. Modeling for pyrolysis of solid particle: kinetics and heat transfer effects. J. Ener. Conv. Manag., 44: 2251-2275.

Bouvet, N., C. Chauveau, S. Gökalp, Y. Lee and R. J. Santoro. 2010. Characterization of syngas laminar flames using the bunsen burner configuration. Int. J. Hyd. Ener., 36: 992-1005.

Calis, H. P., J. P. Haan, H. Boerrigter, A. V. Drift, G. Peppink, R. Vanden Broek, A. Faaij and R. H. Venderbosch. 2002. Technical and economic feasibility of large scale synthesis gas production in the Netherlands from imported biomass feedstock- a Strategic Decision Analysis study. Pyrolysis and gasification of biomass and waste, 30 September-1 October, 2002, Strasbourg, France.

Dasappa, S., H. V. Sridhar, G. Sridhar, P. J. Paul and H. S. Mukunda. 2006. Biomass gasification-a substitute to fossil fuel for heat application". J. Biom. Bio., 25: 637-649.

Duraisamy, P. 1992. Effects of educational and extension contacts on agriculture production. Indian J. Agric. Econ., 47 (2): 205-214.

Garcia, L., M. L. Salvador, J. Arauzo and R. Bilbao. 2001. Catalytic pyrolysis of biomass: influence of the catalyst pretreatment on gas yields. J. Analy. App. Pyro., 58 (59): 491-501.

Ibanez, G., P. A. Cabanillas and J. M. Sanchez. 2004. Gasification of leached Orujillo (Olive oil waste) in a pilot plant circulating fluidised bed reactor. Preliminary results". J. Biom. Bio., 27: 183-194.

Jones, J. M., L. I. Darvell, T. G. Bridgeman, M. Pourkashanian and A. Williams. 2007. An investigation of the thermal and catalytic behaviour of potassium in biomass combustion. Proceedings of the Combustion Institute, 31: 1955-1963.

Kersten, S. R. A., W. Prins, B. Drif and W. P. M Van-Swaaij. 2003b. Principles of a novel multistage circulating fluidized bed reactor for biomass gasification. Chem. Eng. Sci., 58: 725-731.

Noble, D., Q. Zhang, A. Shareef, J. Tootle, A. Meyers and T. Lieuwen. 2006. Syngas mixture composition effects upon flashback and blowout; Proceedings of GT2006 ASME Turbo Expo: Power for land, sea and air.

Paasen, V. S. V. B., M. K. Cieplik and N. P. Phokawat. 2006. Gasification of non-woody biomass chlorine and sulphur removal; economical and technical perspectives. ECN, ECN-CX-06-080. 2006. The Netherlands.

Raskin, N., J. Palonen and J. Nieminen. 2001. Power boiler fuel augmentation with a biomass fired atmospheric circulating fluidized bed gasifier. Biomass and Bioenergy, 20: 471-481.

Tunio, S. D. 2008. Sindh Ja Fasal: Jadid Pookh and Paydawar. 1st Ed. S.D. Tunio. Roshni Publication, Kandiaro.

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