REVIEW OF VARIOUS FUELS USED IN BIOMASS GASIFIER AROUND THE WORLD

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Abstract: This study presents the review of various crop residues as a fuel for biomass gasification used around the world. Various crop residues such as hazelnut shells in turkey, Olive tree cutting and olive kernels in Greece, Wood and palm oil empty fruit bunch in Sweden and coffee wastes in Brazil have been studied and compared in this paper. Similar learnings can be applied in India and various crop residues could be used for gasification. Further studies are required to determine a good crop residue for gasification purposes in India.

Index Terms **-Gasifier, Downdraft, Wood, Pallets, Renewable energy.**

I. INTRODUCTION

1.1 Gasification

Gasification is a thermo-chemical process in which gas is produced due to partial burning of biomass. It is a process that converts organic and fossil fuel based carbonaceous material into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting material at high temperatures without combustion and with controlled of amount of oxygen and/or steam. The crop residues can be used as biomass in these gasifiers to generate producer gas. The producer gas is a mixture of CO, CO_2, H_2, CH_4 and N_2. The producer gas can itself acts as a fuel that can be used in generator sets to produce electricity. Literature review carried out shows the use of various crop residues such as sugarcane, coconut husks, hazelnut shells etc. as a fuel in gasifiers. The main aim of the study is to review crop residues such as hazelnut shells, wood pallets, palm oil residue, olive kernels, coffee production wastes etc. used as fuel in the biomass gasifier.

1.2 Biomass in India

India is one of the highest producers of agricultural products in the world. This produce also generates a considerable amount of residue. It is estimated that India produces about 500-550 million tonnes of crop residue every year. The left-over residue is a valuable resource that has been ignored and usually burned off in the fields. Burning of residue in the fields leads to the release of soot particles and smoke that leads to human and animal health problems. It also releases greenhouse gases in the atmosphere. This residue can be put to use in fields of textile composites, animal feed, compost and power generation. It is estimated that one ton of biomass can produce 300 kWh of electricity.

1.3 Potential for Biomass Gasification

Biomass gasification can be used for decentralized power generation systems. It can be used for power generation in remote areas where laying of wires can be a costly affair. It can be used in areas where other forms of electricity generation are very difficult. Biomass gasification can be used in small villages where the overall power requirement is very less. [1]

The advantage of biomass gasification is that it is possible to grow biomass within the village ecosystem itself. Lots of forests and fields are available in and around the village. The residues from forests and fields can be used as a fuel for the gasification process. There are various examples of different gasifiers that work on different fuels available in the surroundings.

The third advantage is that carbon abatement costs of biomass-based technologies such as gasification are much lower. It is a source of renewable energy as well. This can help in generation of electricity without hampering the ecology. Hence this process can help generation of green energy. [2]

II. REVIEW OF VARIOUS STUDIES

2.1 Hazel nut shells- Turkey [5]

M. Dogru et al. used hazel nut as a fuel in gasifier. They used a pilot scale downdraft gasifier (5 kWe – electrical output) to study the potential of hazelnut shells as a fuel. The aim of the study was to use the gas produced directly in an internal combustion engine to produce electricity. The setup consisted of the a down draft gasifier with four distinct reaction zones viz. drying, pyrolysis, oxidation and reduction. The height of the bed was 810 mm, diameter of oxidation zone was 450 mm and diameter of the throat was 135 mm. In the drying zone, moisture was removed from the hazel nut shells. The temperature of the drying zone was 70 – 200 ºC. In the pyrolysis zone, partial oxidation of the shells took place and the degradation of the shells took place. The temperature of the pyrolysis zone was 350 – 500 ºC. The volatile products of pyrolysis are partially oxidised in the oxidation zone. The temperature of the was 1200 ºC due to high exothermic reaction. In the reduction zone, the char was converted in to producer gas. This was the zone where the gases left the gasifier at the temperatures of 300 ºC. Before the start of the experiment, the ultimate and the proximate analysis of the fuel was carried out and it was found that the Gross Calorific value of the fuel was 17.36 MJ/kg. The moisture content in hazel nut shells was around 12%. The gasification trials were carried out a number of times with different feed rates and air fuel ratios. The paper concluded that the optimum air fuel ratios between 1.37 – 1.47 Nm^3/kg and wet feed rate between 4.02 and 4.70 kg/h produced high quality combustible gas with GCV of about 5 MJ/m^3. It was also observed that at this optimum char was produced at a ratio of 0.005 and 0.051 of the feed respectively.

2.2 Wood Pallets, palm oil residues and empty fruit bunch (EFB)- Sweden [6]

Catharina Erlich carried out an experimentation of a gasifier using pellets made of wood, palm oil residues and bagasse as a fuel. The main objective of their gasification tests was to study the impact of the char bed properties on gasification performance. They also studied the impact of the fuel size and composition on gasification process. The authors found that fuels such as EFB from palm oil production are usually wasted and never used seen as a biomass. Pelleting such residues would be helpful in gasification. The authors proceeded by firing a pellet fired downdraft gasifier of 20 kW_{th} to compare gasification for wood, bagasse and EFB. Ultimate and proximate analysis of the fuel was varied out. It was observed that the wood has the highest LHV and lowest ash content whereas EFB had high ash, sulphur and chlorine content. Running of gasifier with fuel like EFB for a long time would cause corrosion but was not considered in the study. To start the process a primary char bed was created for each pellet sort. This helped in quick start in next gasification runs. No fuel was mixed and each run was done solely by with one pellet. It was observed that the wood with pellet size of 6 mm diameter produced dry gas at 5.2 to 6.8 m^3/h and consumed fuel at 2.7 to 3.2 kg/h. Bagasse of 6mm diameter consumed fuel at about the same rate and produced gas at rate of 4.8-6.1 m^3/h. EFB were tested for two different diameters of 6 mm and 8mm. 6mm pellets consumed fuel at 2.4-3.3 kg/h and produced gas at 5.0 to 6.2 m^3/h and that of 8mm consumed at 2.0-2.7 kg/h and produced gas at 5.0-5.6 m^3/h. One of the major finding of the study was that mass consumption rate as a function of pellet geometry with smaller rate for high sized pellets.

2.3 Olive tree cuttings and olive kernels- Greece [7]

V. Skoulou et al. carried out gasification using olive tree cuttings and olive kernels as a fuel in a down draft gasifier. Olive kernels and olive tree cuttings very dried in open air before being used as a fuel in the gasifier. Ultimate and proximate analysis was carried out before the experimentations began. Both kernels and tree cuttings contained about 48% carbon. However, the ash content was at 3.46 in kernels compared to that of tree cuttings. Gasification was carried out at temperature range of 750-900 ºC for various air equivalence ratio (0.14-0.42). Experiments showed that gasification with high temperatures (950 ºC) gave better producer gas quantity. It was also observed that CO_2, CH_4, hydrocarbons and tar reduced with high temperatures. It was found that the gas produced form the olive tree cuttings at 950 ºC and air equivalence ration of 0.42 had high LHV (9.41 MJ/Nm^3) compared to olive kernels (8.60 MJ/Nm^3).

2.4 Coffee Waste- Brazil [8]

Jofran Luiz de Oliveira et al. studied the potential for coffee wastes as an attractive option for fuel in a biomass gasifier. Brazil produces high amount of coffee and the approximately 11.4 x 10^6 tons of waste are generated form coffee alone. The waste from coffee are in form of coffee wood form the trees and coffee husks from the coffee beans. Upon carrying out proximate and ultimate analysis of coffee wood and coffee husk, it was found that both the fuels had relatively low moisture content of around 10%. This feature helps in gasification. High volatile matter allows biomass to ignite easily. The volatile matter in both coffee wood and coffee husk is around 80-85% which suggests that both coffee wood and coffee husks will ignite very easily. However, it was found that the density of the coffee husks was lower. Low density biomass is consumed at a very high rate in the gasifier. Hence for the gasification of the coffee husks, large amount of biomass will be required.

2.5 Comparison of Proximate and Ultimate analysis

Table 1: Comparison of Proximate analysis

Fuel	Moisture (%)	Volatile Matter (%)	Fixed Carbon (%)	Ash (%)	GCV (MJ/kg)
Hazelnut Shells	12.45	62.70	24.08	0.77	17.36
Wood pellets	7.5	Not reported (NR)	Not reported (NR)	0.3	18.99
EFB- palm oil residue	11	Not reported (NR)	Not reported (NR)	7.9	18.05
Olive Tree cuttings	4.84	78.31	8.47	0.62	19.13
Olive kernels	4.59	75.56	16.39	3.46	20.39
Coffee Husk	9.22	81.87	16.42	1.71	18.56
Coffee Wood	9.61	85.73	13.33	0.94	18.07

Table 2: Comparison of ultimate analysis

Fuel	Carbon (%)	Hydrogen (%)	Oxygen (%)	Nitrogen (%)	Sulphur (%)
Hazelnut Shells	46.76	5.76	45.83	0.22	0.67
Wood pellets	50.4	5.9	43.3	0.1	0.01

EFB- palm oil residue	47.2	6	38.2	0.6	0.12
Olive Tree cuttings	47.27	6.41	44.98	Not reported (NR)	0.05
Olive kernels	48.61	6.41	46.32	Not reported (NR)	0.05
Coffee Husk	47.71	5.93	43.96	Not reported (NR)	Not reported (NR)
Coffee Wood	47.50	6.01	44.86	Not reported (NR)	Not reported (NR)

If the moisture content of the biomass is low, it is suitable for gasification. If we compare all the biomass we have reviewed, they all have low moisture content and hence are suitable for gasification. A high proportion of volatile matter allows biomass to ignite easily. And the ratio of fixed carbon to volatile matter determines the flame stability during the combustion. Coffee wood and coffee husks have high volatile matter and so they would flame easily however due to low fixed carbon the flame may not be stable. Olive tree cuttings have lowest fixed carbon content. Hazel nuts have the highest fixed carbon content. The flame of hazelnut shells will be stable but will be difficult to flame due to its high moisture content.

III. LITERATURE GAPS

Very few papers test for different blends of biomass gases. Blending of crop residues may give us better fuels as they combine the characteristics of two or more crop residues. Testing of different concentrations of the best blends can also help in achieving a better-quality fuel.

Very less work has been carried out in using different size pellets of the same fuel. Pellet size plays an important role in determining the gasification characteristics of a fuel.

As far as Indian scenario goes, the literature review carried out suggested that there are 39 crop residues of 26 crops that are produced in excess in India. However only few of them are tested. There is large gap that exists in the crop residues that are currently used in biomass gasification and crop residues that could be used in biomass gasification.

IV. SCOPE FOR FURTHER STUDIES

Very less work has been done on characterization of fuels in India. Many crop residues are available in the agriculture sector in India. These fuels need to be characterized. All over the world, it has been observed that the prime agriculture products' waste are used as a biomass. Similar thing can be done in India.

Once the characterization has been carried out, the best crop residues that can be used for gasification can be narrowed down. Experimentations can be carried out of that biomass using pellets of various sizes.

Further two or more crop residues can be combined to create new biomass fuels. Studies of this blends can also be carried out.

V. REFERENCES

[1] N. H. Ravindranath, biomass gasification: environmentally sound technology for decentralized power generation, a case study from india, Biomass and Bioenergy Vol. 4, No. 1, pp. 49-60, 1993

[2] V.V.N. Kishore, Preety M. Bhandari*, Pratul Gupta, Biomass energy technologies for rural infrastructure and village power—opportunities and challenges in the context of global climate change concerns, Energy Policy 32 (2004) 801–810

[3] Jasvinder Singh, Sai Gu, Biomass conversion to energy in India—A critique, Renewable and Sustainable Energy Reviews 14 (2010) 1367–1378

[4] Hiloidhari M, Das D, Baruah DC. Bioenergy potential from crop residue biomass in India. Renewable and Sustainable Energy Reviews 2014; 32: 504-512.

[5] M. Dogru, C.R. Howarth, G. Akay, B. Keskinler, A.A. Malik, Gasification of hazelnut shells in a downdraft gasifier, Energy 27 (2002) 415–427

[6] Catharina Erlich, Torsten H. Fransson, Downdraft gasification of pellets made of wood, palm-oil residues respective bagasse: Experimental study, Applied Energy 88 (2011) 899-908

[7]V. Skoulou, A. Zabaniotou, G. Stavropoulos, G. Sakelaropoulos, Syngas production from olive tree cuttings and olive kernels in a downdraft fixed-bed gasifier, International Journal of Hyderogen Energy 33 (2008) 1185-1194

[8]Jofran Luiz de Oliveira, Jadir Nogueira da Silva, Emanuele Graciosa Pereira, Delly Oliveira Filho, Daniel Rizzo Carvalho, Characterization and mapping of waste from coffee and eucalyptus production in Brazil for thermochemical conversion of energy via gasification, Renewable and sustainable energy reviews 21(2013) 52-58