COMPARATIVE STUDY OF ENERGY POTENTIAL OF MANGO PIT AS BIOMASS WITH COCONUT SHELL GINISYRIA & MIXTURE IN LABORATORY SCALE DEVELOPED UPDRAFT GASIFIER

Muhammad Amin[1], Mahinsasa Narayna[2]

[1] Department of Chemical Engineering, Faculty of Engineering, Balochistan University of Information Technology, Engineering and Management Sciences Quetta, Pakistan. Email: engr_amin63@yahoo.com
[2] Department of Chemical and Process Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka

ABSTRACT

Biomass energy is getting peak level attention from last few years in terms of improvement in technology to increase energy conversion efficiency. The world is facing energy issue so to overcome this biomass energy can play vital role due to its abundant availability in different sectors such as domestic waste, agricultural waste, industrial waste etc. Many of the biomass contains a lot of energy and then it needs attention to be utilized in proper manner. One of the major technologies to produce energy from biomass is thermochemical conversion. Gasification is thermochemical conversion process is of much interest in which carbonaceous material is converted into different valuable products by application of heat in suitable designed unit. This study aims to develop 25 KW updraft gasifier (70% thermal efficiency) with gas cleaning unit for performance analysis of reactor by testing mango pit as new biomass material and its comparison with coconut shell ginisyria and mixture of biomass (50%,25%,25% coconut shell, mango shell & ginisyria respectively). Properties of feed materials such as ultimate and proximate analysis were done for each kind. Performance was analyzed in developed unit without packing plate vs. with packing plate (which was introduced about 609.6 mm above the grate in chamber) in terms of producer gas composition and its variation with equivalent ratio, lower heating value (MJ/Nm^3) of product gas for the said materials and their comparison. Results indicate that that producer gas can be generated from mango pit and its lower heating value was calculated as 3.35(MJ/Nm^3) at equivalent ratio of 0.2while in comparison with others materials coconut shell has more energy contents while mixture has lowest energy contents among all. With increase in air velocity as ER approaches 0.25 LHV of product for all biomass materials was observed in reducing trend .Overall performance of unit gives satisfactory results and from analysis it identify that mango pit is competitive candidate as biomass.

Key words**:** Biomass, Mango pit, Coconut shell, Ginisyria, Gasification, Updraft Gasifier, Packing plate

1. INTRODUCTION

Rising demand of energy and protection of environment with increase in population is global challenge currently. To cope with this issue worldwide focus has been diverted to meet the current energy requirement, enhancement of resources for future generations and to ensure the polluted free environment. Traditional fossil fuels are depleting at sharp rate and playing significant role in polluting the environment by emission of harmful compounds such as NO_x(Nitrogen Oxides) and SO_x(Sulfur Oxides) .Due to this scenario biomass energy is getting peak level attention which can replace traditional fossil fuels in near future.” The primary advantage in the use of biomass as an energy resource is that it is renewable feedstock and does not contribute to global warming [1].

Many biomass materials from agricultural waste, domestic and industrial waste are available & has been studied each of which having different properties and composition and their potential as successful candidate depends on nature, properties & conversion technology utilized. Mango is worldwide favorite fruit and highly cultivated fruit in many countries such as in Pakistan, mango pit (woody shell) are byproducts of jam or juice industries. These are thrown after getting the pulp then mango pits can be utilized as biomass material. Coconut shells are using domestic heating applications since long time as well as popular in charcoal production. Ginisyria (scientifically called as Gliricidia) is also recent addition as biomass crop which has been declared as 4th major crop in Sri Lanka. “On June 30th 2005 the cabinet of ministers of Sri Lanka took the decision to introduce gliricidia as country’s 4th plantation crop, based on cabinet memorandum of ministry of plantation industries [2].

Many technologies have been developed for conversion of biomass into useful end products. Factors that influence the choice of conversion of process are depending on the type and quantity of biomass. It needs to consider; environmental standards; economic conditions; and project specific factors [3]. Biomass is one of renewable energy resources, capable of replacing fossil fuels through a process known as gasification [4].

Gasification is a thermochemical process which is most popular and frequently used technology in the world to produce mixture of gas called as producer gas. “Gasification is the conversion of biomass into combustible gas mixture by the partial oxidation of biomass at high temperature typically in the range of 800-900°C [5]. Updraft gasification is one of oldest technique based on counter current phenomena in which biomass are fed from top while gasification medium such as air is introduced from bottom. Complete process carried out in four zones namely drying, pyrolysis, reduction and combustion. Main advantage of updraft gasifier is simplicity in design, operation, lower cost and reduced gas temperature while it produce more tar than others which must be removed to ensure the high performance of downstream units If gas is directly used for heating purpose then there is no need to clean tar. Comparative study of energy potential of mango pit as biomass with coconut shell, ginisyria and mixture was studied in laboratory scale developed updraft gasifier.

2. METHODOLOGY

2.1. Design of Unit

An inexpensive gasifier was fabricated with cyclone separator to generate producer gas good quality product for mango pit, coconut shell, ginisyria and mixture of these with major theme to analyze potential of mango pit as biomass with comparison to other defined materials. Figure 1 shows unit assembly with main components. Major Design calculations were done according to following equations [5].

$$FCR = Qn/HVf * \xi g \qquad (01)$$

Where FCR is fuel consumption rate, Q_n is the power required which we selected 25 Kw for this study, HV_f is heating value of fuel (18.5 MJ/Kg), ξg is efficiency of gasifier assumed to be 70 %

$$\mathrm{D} = 4 * \mathrm{FCR/SGR} * 3.14 \qquad (02)$$

Eq. (2) is used to calculate diameter of reactor in which SGR is specification gasification rate which was selected as 110 kg/m^2.h.

$$H = SGR * T/\ Density\ of\ Fuel \qquad (03)$$

Eq.(3) is used for calculation of height of reactor in which T is time in hours for operation which was selected as 4 for design case while average density of fuel was calculated as 350 kg/m^3.

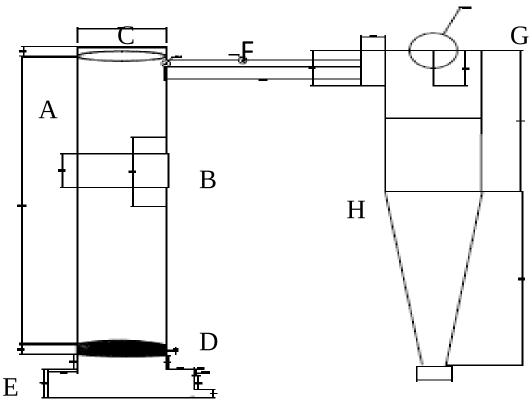

Figure 1: Model of updraft gasifier with cyclone separator. (A) Reactor; (B) Packing plate provision; (C) Feeding section; (D) Grate; (E) Ash chamber; (F) Gas exit; (G) Sampling port; (H) Cyclone separator

Reactor body was made of combination of stainless (4mm thick sheet) and mild steel (4mm thick sheet) for lower and upper section respectively. Diameter & height of reactor is 304.8 mm & 1250 mm respectively calculated based on equation 01, 02, 03 respectively. Grate is made of stainless steel sheet having same diameter as reactor contains circular holes of 10 mm at surface for ash particles removal. This grate is fixed at bottom of reactor and above the ash chamber. Top cover plate (Feed Section) is made of mild steel containing 8 holes for nuts bolts fixture with reactor main body after feeding at different location on the circular plate. This cover plate was sealed to ensure that there is no leakage. Packing plate provision was made in the reactor as can be seen in Figure 1 which was made of mild steel; two flanges were fixed inside the reactor to hold this plate while provision was made outside for easily removal of plate. This plate was made like cage having linear cut layers of 30 mm at top and bottom to prevent from blockage. Mild steel round rings of 31.75 mm were used as packing material. Ash chamber was made like square box with height of 274.32 mm and fixed immediately below grate. Ash collecting window provision was made in ash chamber. Air supply pipe diameter of 31.75 mm was fixed just below the grate. 3 inch 220/110 V blower having 3000/3600 rpm was used. Five K type thermocouples were installed at different locations for temperature measurement. Reactor body was insulated with fiber wool glass of sufficient thickness to minimize the heat losses.

2.2. Preparation of Biomass Feedstock

All biomass raw materials were collected and sun dried to remove moisture. After sun drying sizing was done by hammer mill & cutting tools to get the 25 mm average size particles of each material. After cutting it was weighted by using calibrated weight balance. For each batch 28 kg of each feed stock was prepared and packed to air tight bags for prevention from moisture. Mixture feed stock was prepared by measuring quantity of coconut shell, mango pit and ginisyria by defined weight percent as arbitrary selection (50%, 25%, 25% respectively).

2.3. Gasifier Experimental Procedure

These experiments were carried out in batch operation so design was accordingly to hold sufficient amount of material for complete operation with proposed design time of four hours. For each test top cover plate of reactor was unbolted and reactor was filled gently with biomass in such a way that feeding should not disturb installed thermocouples. After feeding from top, top plate was bolted tightly to make the reactor air tight. Panel power switched on and verified that all thermocouples are working correctly by measuring initial temperature. Fire lit was introduced below the grate via ash chamber window for sufficient time of ignition of material after that blower was turned on and air velocity was measured by anemometer at point and that velocity was adjusted according to desired parameters. After making sure that ignition has been started by noting the increase in temperature of combustion zone ash window plate with its seal was fixed and bolted tightly. During this white smoke was observed coming out from exit and approximately after 15minutes combustible gasses coming out and was observed by flaring. Flame lasted continuously for long time however for short time (few minutes) it disappears during operation which might be due to some moisture contents. Samples were collected in gas bags from sampling port by passing the tube through cold water to lower the temperature of gas. Tar and condensate was collected at bottom of cyclone separator. After complete operation gas exit and blown air supply valve was closed and let the unit to cool down for next batch. Before to start another batch unit was cleaned, bio char and ash was collected from respective portions. Same procedure was applied for each run.

3. RESULTS

Proximate and ultimate analysis was carried out to determine the properties of biomass materials according to standard procedure which are presented in the Table 1. Heating value was measured by using bomb calorimeter while average density was calculated as 350 kg/m^3.

Table 1: Properties of biomass feed stock

Proximate Analysis				
Properties	**Coconut shell**	**Mango Pit**	**Ginisyria**	**Mix**
Ash %	12.2	1.4	6	7.6
VM %	84.4	81.9	83.8	87.6
FC%	19.08	11.06	14.63	11.2
Moisture %	10.8	17	13.6	11.6
HHV(MJ/kg	18.5	16.8	20.7	18.6
Ultimate Analysis				
C%	50.6	48.1	50.4	53.5
N_2 %	0.83	0.98	0.911	0.87
H2 %	5.6	5.41	5.48	5.52

(VM=Volatile Matters, FC=Fixed Carbon, HHV= Higher Heating value)

The producer gas composition without packing plate was analyzed at ER 0.2 and 0.25 results of which are presented in Table 2 and 3 respectively while lower heating value was calculated and results are plotted in Figure 2.

Table 2: Producer gas composition at ER 0.2

Components	Coconut shell	Mango Pit	Ginisyria	Mix
H_2	7.01	2.78	7.74	5.4
N_2	46.26	42.99	46.10	49.2
CH_4	2.13	3.49	1.98	2.0
CO	21.73	11.54	20.11	13.0
CO_2	14.46	24.07	11.10	12.9
C_2H_4	0.08	0.26	0.05	0.13
C_2H_6	0.12	0.27	0.12	0.15

Table 3: Producer gas composition at ER 0.25

Components	Coconut shell	Mango Pit	Ginisyria	Mix
H_2	5.62	5.89	4.35	4.89
N_2	48.2	45.3	50.9	53.3
CH_4	1.14	2.40	0.68	2.11
CO	22.0	11.1	22.4	9.12
CO_2	7.67	17.96	6.32	13.3
C_2H_4	-	0.14	-	0.09
C_2H_6	0.10	0.16	-	0.12

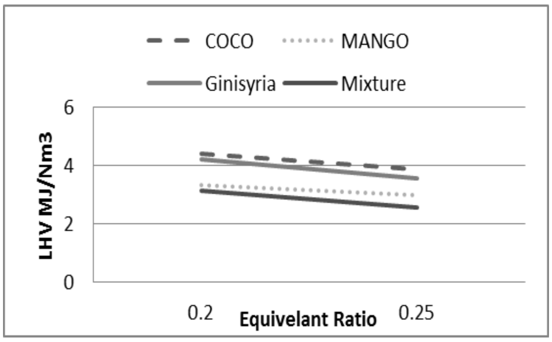

Figure 2: Impact of variation of ER on LHV of Producer gas for different biomass materials

The producer gas composition with packing plate was analyzed at ER 0.2 and 0.25 results of which are presented in Table 4 and 5 respectively while lower heating value was calculated and results are plotted in Figure 3.

Table 4: Producer gas composition at ER 0.2

Components	Coconut shell	Mango Pit	Ginisyria	Mix
H_2	8.18	5.33	7.2	6.0
N_2	45.3	42.9	45.8	47.0
CH_4	3.08	3.40	2.37	1.72
CO	14.45	9.85	14.99	14.2
CO_2	19.3	23.14	14.53	11.8
C_2H_4	0.18	0.18	0.1	0.15
C_2H_6	0.15	0.21	0.18	0.07

Table 5: Producer gas composition at ER 0.25

Components	Coconut shell	Mango Pit	Ginisyria	Mix
H_2	5.62	5.89	6.06	7.01
N_2	48.24	45.3	50.9	46.2
CH_4	1.14	2.40	1.7	2.06
CO	22.0	10.7	14.2	6.8
CO_2	7.67	18.9	11.5	12.3
C_2H_4	-	0.14	0.15	-
C_2H_6	0.10	0.16	0.07	-

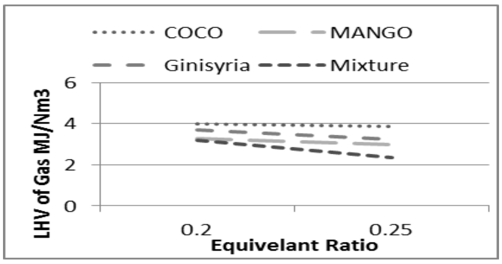

Figure 3: Impact of variation of ER on LHV of Producer gas for different biomass materials

4. CONCLUSION AND DISCUSSION

Results indicates that mango pit has energy potential in a good range when compare to other biomass which can be further improved by careful pre treatment of feed stock and critical control on process parameters such as air velocity, exit flow and temperature.

Black condensate obtained from bottom of cyclone separator can be further studied which might contain heavy hydrocarbons and by suitible treatment can be converted into useful products. Biochar obtained from all process was of black dense particles which can be utilized for heating purpose as well as flyash in treatment process. Ash obtained was mixture of black and white soft particles.

After getting pulp, mango pits thrown away, which create environmenal issue, these can be utilized as biomass to produce energy by using designed updraft gasification system in this study. This is more significant in fruit processing industry in term of fulfil thermal energy requireemnt of same industry.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] S. C. Capareda, "Biomass *energy conversion*", Sustainable Growth and Application in Renewable Energy Sources, Chapter 10, 2011.

[2] A. Abegunawardana, "Gliricidia-Fourth plantation crop of Sri Lanka", A Report.

[3] P. McKendry, "*Energy production from biomass (part2): conversion technologies*", Bio resource Technology, vol.83, pp.47-54, 2002.

[4] S. Hassan, F. M. Nor, Z. A. Zainal, and M. A. Miskam, "*Performance and emission characteristics of supercharged biomass producer gas diesel dual fuel*", Journal of Applied Sciences, vol.11, pp1606-1611, 2011.

[5] S. J. Ojolo, S. M. Abolarin, and O. Adegbenro, "*Development of a laboratory scale updraft gasifier*", International Journal of Manufacturing System, 2012.