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Evaluation of biomass based combustor for hot air genration using maize cobs

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■ **ABSTRACT :** Agriculture and energy have always been tied by close links, but the nature and strength of the relationship have changed over time. Biomass is considered as a renewable source of energy, because it is renewable in nature unlike fossil fuel like coal, oil and natural gas. Biomass is the third primary energy sources after coal and oil, accounting for about 14 per cent of the world's total energy supply. A biomass based combustor was developed and evaluated to meet the heat requirements for thermal application (drying, cooking, etc.) and power application through turbo charging. The biomass based combustor consists of combustion chamber, heat exchanger, chimney, hot air outlet and ambient air inlet, fuel hopper, primary air inlet with control, grate for proper combustion of the combustible gas. The developed biomass combustor was tested with maize cobs, three air flow rate and five fuel consumption rate. The experimental investigations show that the maximum efficiency of biomass combustor using maize cobs was 66.97 per cent in case of 1 kg/h fuel consumption rate and 400 m^3/h air flow rate. The hot air temperature varied in between 51.55 to 142.35ºC at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system.

■ **KEY WORDS :** Biomass, Combustion, Biomass combustor, Overall thermal efficiency, Hot air temperature

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Biomass is considered as one of the important sources of renewable energy. Biomass is considered as a renewable source of energy, because it is renewable in nature unlike fossil fuel like coal, oil and natural gas. Biomass can be converted into solid, liquid and gaseous fuel depending on their physical availability. Biomass is also considered as a form of solar energy as they absorb solar energy for growing up by photosynthesis process. Solar energy thus stored in the form of chemical energy is Biomass. Widely used as fuel for energy production in either heating or electricity generating applications, biomass is the third primary energy sources after coal and oil, accounting for about 14 per cent of the world's total energy supply (Awasthi and Deepika, 2013). The availability of land and the potential for biomass production in India to meet various demands for biomass, including modern bioenergy (Sudha and Ravindranath, 1999).

Biomass can be converted to energy via either biological or thermo-chemical processes, the latter consisting mainly of combustion, pyrolysis and gasification. Among these, gasification is attractive in terms of energy production because it produces a clean-burning fuel that can be used in many power generation applications, at a greater overall conversion efficiency of a given biomass resource into electric power compared to traditional combustion based technologies.

Gasification means the transformation of solid fuels into combustible gases in presence of an oxygen carrier (air, O_2, H_2O, CO_2) at high temperatures. It is a process for converting carbonaceous materials to a combustible or synthetic gas like bio-methane or producer gas (Tobias, 2004). The gasification process occurs at temperatures between 600-1,000 degrees Celsius and decomposes the complex hydrocarbons of wood (Rezaiyan and Cheremisinoff, 2005). Conversion of solid biomass into combustible gas has all the advantages associated with using gaseous and liquid fuels. Such advantages include clean combustion, compact burning equipment, high thermal efficiency and a good degree of control. Biomass is also economic in places where biomass is already available at reasonable low prices or industries using fuel wood.

Alattab and Zainal (2006) studied that the externally fired "turbo charger based" micro gas turbine using biomass fuel is small scale flexible unit which could be used in the simple form without the electrical generator to fulfill the industrial demands of a cheap and clean hot air for different drying processes. For hot air production unit, a part of hot air after the turbine could be used for the drying process, although it reduces the amount of air that accelerates the gasification and combustion processes in the batch feeding system gasifier - combustor, but the turbine hear is not used for electrical power generation, so the turbine should only produce enough power for the compressor to sustain the high speed Alattab and Zainal (2006).

METHODOLOGY

Physical properties and proximate analysis of maize cobs :

Available biomass namely maize cob considered for combustion-gasification material. The physical properties (*i.e.* size, bulk and true density) and proximate analysis (*i.e.* moisture content, volatile matter, ash content and fixed carbon) properties were determined using ASAE (2006b) and ASTM (1983) standard for maize cob as fuel used in biomass combustor. The calorific value of biomass could be measured using advance bomb calorimeter.

Combustor :

The combustor and high temperature heat exchanger was designed and fabricated at Department of Renewable Energy, College of Agricultural Engineering and Technology (CAET), Anand Agricultural University, Godhra. The combustor is a small scale multi-chamber combustor with single stage of chamber namely, combustor chamber. This part is made of a mild steel sheet. It is a batch feeding combustor system, biomass feeding port is placed on the side of the gasifier chamber to feed the biomass into the gasifier, and it has a fit clamped and isolated cover. Air is supplied to the combustion chamber at almost atmospheric pressure. Flow of air is passing through a bottom of the grate to provide a good mixing with the gases from the combustion chamber. A complete combustion in the combustion chamber creates a very hot zone which pushes the gases upward and creates a stack effect which creates a vacuum pressure in the chamber and pulls the air through a controlled air intake in the down side. The high temperature heat exchanger design was based on single pass tube and shell heat exchanger type. The combustion gases temperature is assumed to be 500 - 1000 ºC, and the air temperature after the heat exchanger is assumed to be 60 – 240 ºC to keep the (H.T.H.E.). Different air flow rates of the air blower and fuel consumption rates was used to study the performance of the biomass combustor using maize cobs. The schematic diagram of the experimental setup of the biomass combustor is shown in Fig. A.

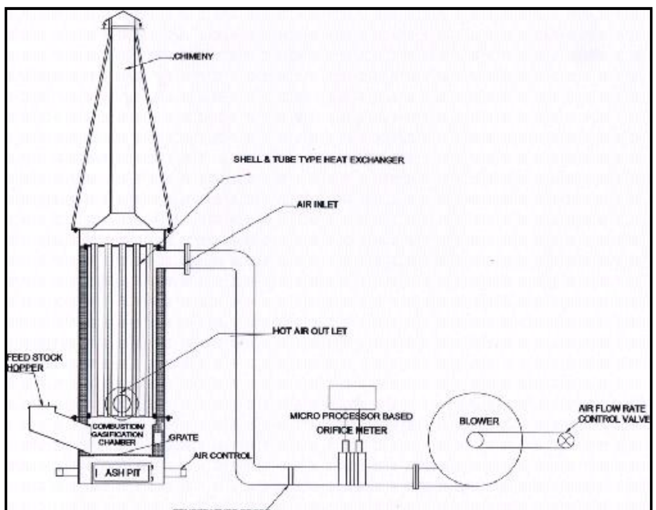

Fig. A : Schematic diagram of biomass gasifier based combustor

Performance calculation :

Fuel consumption rate (FCR) :

This is the amount of maize cobs as fuel used in operating the gasifier divided by the operating time. This was computed using the formula :

$$\text{FCR(kg/h)} = \left[\frac{\text{Weight of maize cob as fuel used (kg)}}{\text{Operating time (h)}}\right]$$

Specific gasification rate (SGR) :

This is the amount of maize cob as fuel used per unit time per unit area of the reactor. This was computed using the formula :

$$\text{SGR(kg/m}^2\text{h)} = \left[\frac{\text{Weight of maize cob as fuel used (kg)}}{\text{Reactor area (m}^2) \times \text{operating time (hr)}}\right]$$

Biomass combustor efficiency (η) :

In order to determine the thermal performance of biomass combustor, efficiency of biomass combustor (η) was calculated using the formula :

$$\eta = \left[\frac{\text{Output of the biomass combustor}}{\text{Input of the biomass combustor}}\right] \times 100$$

$$\text{Input of the biomass combustor} = \text{FCR, (kg/h)} \times \text{CV, (kcal/kg)}$$

where,

FCR = Fuel consumption rate, kg/h

CV = Calorific value of biomass, kcal/kg.

$$\text{Output of the biomass combustor} = \text{AFR, (m}^3\text{/h)} \times C_p\text{, (kcal/kg}^\circ\text{C)} \times \Delta T(^\circ C)$$

where,

AFR = Air flow rate of air, m^3/h

C_p = Specific heat air (kcal/kg ºC)

= 0.2388 kcal/kg ºC (water equivalent)

ΔT = Temperature difference of air, ºC

= Hot air temperature – Ambient temperature.

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Physical and proximate analysis of maize cobs :

The physical and proximate analysis of maize cob fuel used in biomass combustor. The average length and diameter of the maize cobs was 76.19, 21.24 mm, respectively. The moisture content, bulk density and true density of maize cob were 11.26, 158.10 kg/m^3 and 0.38 g/cc, respectively. The other proximate compositions are given in moisture free basis. It can be seen from the Table 1 that the fixed carbon, volatile matter and ash content were found for maize cobs to be 16.82, 82.10 and 1.08 per cent, respectively.

System performance :

The system was extensively tested to evaluate biomass combustor performance through close monitoring of the system operation and suitable data collection. The performance parameter like known

Table 1 : Physical properties and Proximate analysis of maize cob biomass

Sr. No.	Property of biomass	Maize cobs as a fuel
1.	Length (mm)	76.19
2.	Diameter (mm)	21.24
3.	Bulk density (kg/m^3)	158.10
4.	True density (g/cm^3)	0.38
5.	Moisture content (%,w.b.)	11.26
6.	Volatile matter (% d.b.)	82.10
7.	Ash content (%, d.b.)	1.08
8.	Fixed carbon (%, d.b.)	16.82
9.	Calorific value (kcal/kg)	3650.00

Table 2 : Variation of combustion zone temperature at different fuel consumption rate with time using maize cob at different air flow rate

Air flow rate (m^3/h)	Fuel consumption rate (kg/h)					Equation	R^2
	1	2	3	4	5		
200	302.00	445.20	621.52	721.12	852.12	$y = 296.5\ x^{0.649}$	0.995
300	353.08	461.20	642.15	745.23	865.21	$y = 338.3\ x^{0.568}$	0.981
400	383.00	482.23	671.12	763.23	868.23	$y = 367.0\ x^{0.524}$	0.975

amount of fuel consumption rate, air flow rate, combustion temperature, hot air temperature, ambient temperature, exhaust gas temperature. Also calculated the overall biomass combustor efficiency of the system at different flow rates and different fuel consumption rate for hot air production.

Variation of combustion zone temperature at different fuel consumption rate with different air flow rate using maize cobs :

The variation of combustion zone temperature of biomass combustor system at different fuel consumption rate with different air flow rate using maize cob with time. Table 2 shows that the variation of combustion zone temperature from the fuel is a function of time and rates of fuel. The combustion zone temperature varied in between 302.00 to 868.23º C at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The maximum and minimum combustion zone temperature, 868.23 ºC and 302.00 ºC was observed in case of 400 m^3/h air flow rate, 5 kg/h fuel consumption rate and 200 m^3/h air flow rate and 1 kg/h fuel consumption in the system, respectively. These is because of the fuel consumption was high in 5 kg/h and minimum in case of 1 kg/h fuel consumption rate as shown in Fig. 1.

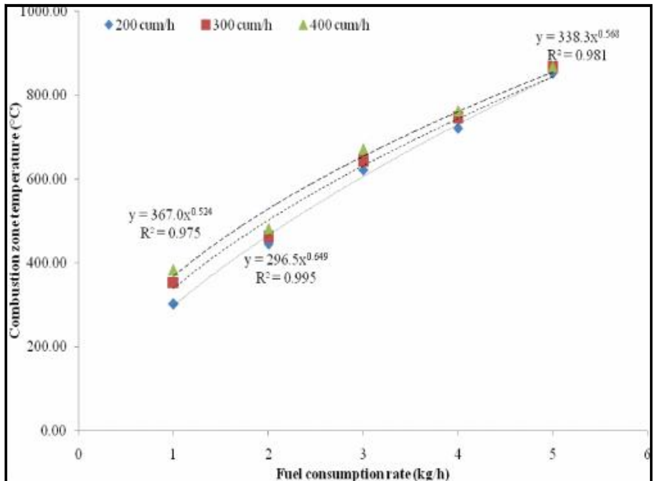

Fig. 1 : Effect of fuel consumption rate on combustion temperature using maize cob with different air flow rate

Variation of hot air temperature at different fuel consumption rate with different air flow rate using maize cobs :

The variation of hot air temperature of biomass combustor system at different fuel consumption rate with different air flow rate using maize cob with time. Table 3 shows that the variation of hot air temperature from the fuel is a function of time and air flow rate. The hot air temperature varied in between 51.55 to 142.35 ºC at

Table 3 : Variation of hot air temperature at different fuel consumption rate using maize cob at different air flow rate

Air flow rate (m^3/h)	Fuel consumption rate (kg./h)					Equation	R^2
	1	2	3	4	5		
200	66.42	95.24	112.43	129.05	142.35	$y = 67.20x^{0.470}$	0.998
300	57.23	76.44	99.25	107.88	121.24	$y = 56.83x^{0.471}$	0.992
400	51.55	68.95	84.15	94.65	108.00	$y = 51.03x^{0.455}$	0.997

Table 4 : Variation of exhaust gas temperature at different fuel consumption rate using maize cob at different air flow rate

Air flow rate (m^3/h)	Fuel consumption rate (kg/h)					Equation	R^2
	1	2	3	4	5		
200	87.90	109.83	128.16	155.12	175.62	$EGT= 4.75FCR^{0.426}$	0.974
300	67.22	85.33	115.28	145.32	160.84	$EGT=63.52FCR^{0.564}$	0.970
400	55.21	76.21	105.62	135.24	154.25	$EGT=52.54FCR^{0.656}$	0.983

Table 5 : Variation of biomass combustor efficiency at different fuel consumption rate using maize cob at different air flow rate

Air flow rate (m^3/h)	Fuel consumption rate (kg/h)					Equation	R^2
	1	2	3	4	5		
200	52.98	45.38	37.76	33.77	30.50	$y = 54.73x^{-0.34}$	0.976
300	61.40	49.58	48.00	40.24	37.45	$y = 62.02x^{-0.29}$	0.956
400	66.97	56.29	50.81	44.99	42.99	$y = 67.65x^{-0.28}$	0.991

three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg./h using maize cob as a fuel in the system. The maximum and minimum hot air temperature, 142.35 ºC and 51.55 ºC was observed in case of 200 m^3/h air flow rate, 5 kg./h fuel consumption rate and 400 m^3/h air flow rate and 1 kg./h fuel consumption in the system, respectively. These is because of the minimum air flow rate and fuel consumption was high and minimum in case of maximum air flow rate and minimum fuel consumption rate as shown in Fig. 2.

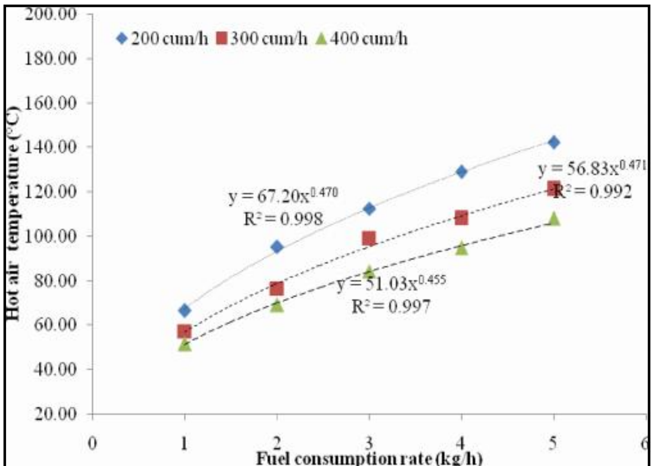

Fig. 2 : Effect of fuel consumption rate on hot air temperature using maize cob with different air flow rate

Variation of exhaust gas temperature at different fuel consumption rate with different air flow rate using maize cobs :

The variation of exhaust gas temperature of biomass combustor system at different fuel consumption rate with different air flow rate using maize cob with time. Table 4 shows that the variation of exhaust gas temperature from the fuel is a function of air flow rate and fuel consumption rate. The exhaust gas temperature varied in between 55.21 to 175.62 ºC at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The maximum and minimum exhaust gas temperature, 175.62 ºC and 55.21 ºC was observed in case of 400 m^3/h air flow rate, 5 kg/h fuel consumption rate and 200 m^3/h air flow rate and 1 kg/h fuel consumption in the system, respectively. Fig. 3 shows the variation of exhaust gas temperature using the different fuel consumption rate and different air flow rate using in the biomass combustor.

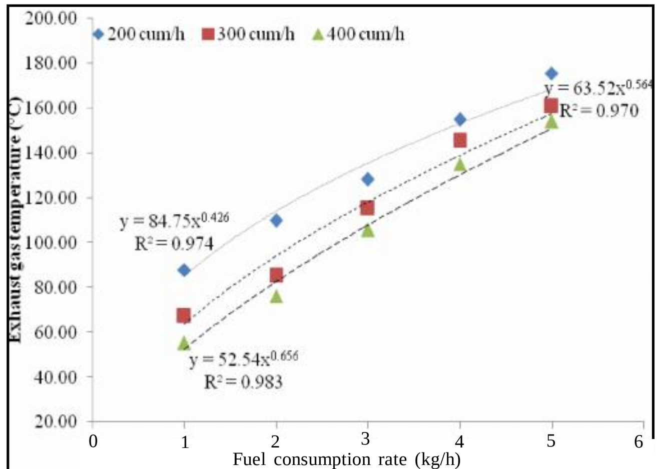

Fig. 3 : Effect of fuel consumption rate on exhaust gas temperature using maize cob with different air flow rate

Variation of biomass combustor efficiency at different fuel consumption rate with different air flow rate using maize cobs :

The variation of biomass combustor efficiency of biomass combustor system at different fuel consumption rate with different air flow rate using maize cob. Table 5 shows that the variation of biomass combustor efficiency from the fuel is a function of air flow rate and fuel consumption rate. The biomass combustor efficiency varied in between 30.50 to 66.97 per cent at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The maximum and minimum biomass combustor efficiency, 66.97 and 30.50 per cent was

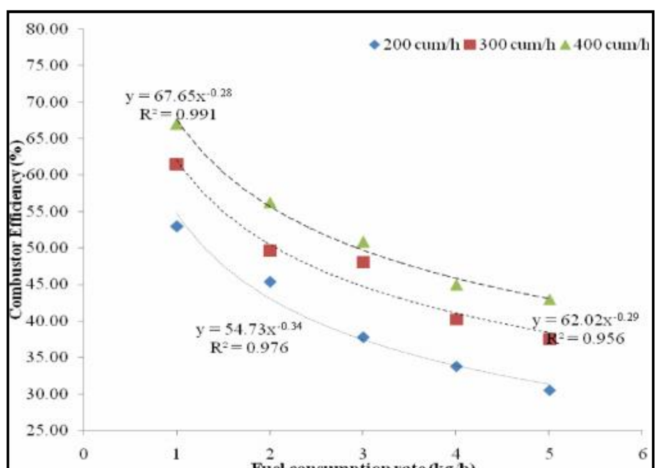

Fig. 4 : Effect of fuel consumption rate on biomass combustor efficiency using maize cob with different air flow rate

observed in case of 400 m^3/h air flow rate, 1 kg/h fuel consumption rate and 200 m^3/h air flow rate and 5 kg/h fuel consumption in the system, respectively. Fig. 4 shows the variation of biomass combustor efficiency using the different fuel consumption rate and different air flow rate using in the biomass combustor. Wasu (2013) worked on the economic feasibility of biomass based downdraft gasifier power generation system and Pathgi and Sharma (2012) on the design and techno economic evaluation of biomass gasifier for community cooking.

Conclusion :

A biomass combustor was performed and evaluated in this study with readily available materials for maize cobs as feed stock. The physical properties and the proximate analysis of biomass briquettes was obtained and as good fuel for developed combustor. The physical properties of maize cob in terms of length, diameter, bulk density and true density were found to be 36.16 mm, 21.24 mm, 158.10 kg/m^3 and 0.38 g/cm^3, respectively. The proximate analysis of maize cob in terms of moisture content of the biomass was found 11.26 per cent (w.b). The fixed carbon, volatile matter and ash content were found to be 16.82, 82.10 and 1.08 per cent, respectively. The calorific value of maize cob was obtained as 3650 kcal/kg. The combustion zone temperature varied in between 302.00 to 868.23 ºC at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The hot air temperature varied in between 51.55 to 142.35 ºC at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The exhaust gas temperature varied in between 55.21 to 175.62 ºC at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The biomass combustor efficiency varied in between 30.50 to 66.97 per cent at three air flow rates *i.e.* 200, 300 and 400 m^3/h and five fuel consumption rate *i.e.* 1 to 5 kg/h using maize cob as a fuel in the system. The maximum efficiency of biomass combustor using maize cobs was 66.97 per cent in case of 1 kg/h fuel consumption rate and 400 m^3/h air flow rate.

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■ REFERENCES

Alattab, K.A. and Zainal, Z.A. (2006). Externally fired gas turbine for small scale power unit / hot air production unit for drying processes using biomass fuel. International Conference on Energy and Environment, August 28-29, 2006. University Tenaga National, Kuala Lumpur, Malaysia.

ASABE (2006b). ANSI/ASAE S424.1 – Method of determining and expressing particle size of chopped forage materials by screening. In: ASABE Standards, 619-621. St. Joseph, MI.: American Society of Agricultural and Biological Engineers.

ASTM (1983). *Annual book of ASTM standards*. American society for testing of materials. Philadelphia, PA, 19103.

Awasthi, M. and Deepika, K.R. (2013). Biochemical characterization of agricultural residues for utilization in gasification process: a necessity for rural sector. *Special Issue of Internat. J. Sust. Develop. & Green Econ.*, (IJSDGE), ISSN No.: 2315-4721, **2**(1, 2).

Pathgi, Shrikant P. and Sharma, Deepak (2012). Design and techno economic evaluation of biomass gasifier for community cooking. *Internat. J. Agric. Engg.*, **5**(2) : 244-248.

Rezaiyan, J. and Cheremisinoff, N.P. (2005). *Gasification technologies: A primer for engineers and scientists*, CRC Press, USA.

Sudha, P. and Ravindranath, N.H. (1999). Land availability and biomass production potential in India. *Biomass & Bioenergy*, **16** (3): 207-221.

Tobias, P. (2004). Solid biomass gasification as fuel source for fuel cells; workshop: hydrogen- and fuel cell based energy systems in a future sustainable energy world; Research Group for Sustainable Energy Technology.

Wasu, Gajanan (2013). Economic feasibility of biomass based downdraft gasifier power generation system. *Internat. J. Agric. Engg.*, **6**(2) : 427-430.