Research Article **Open Access**

Analysis of Biomass in the Indian State of Gujarat for Sustainable Pellet Production

Debajyoti Bose*and Aditya Mekala

College of Engineering Studies, University of Petroleum and Energy Studies, P.O. Bidholi via- Prem Nagar, Dehradun 248007, India

Abstract

Energy from biomass has emerged as a promising source of decentralized energy production from developing countries. This paper highlights the importance of solid biofuel or pellets in the context of green energy. These can be used in co-firing with coal and other heating applications. Assessment is done for certain raw materials which do not create food and fodder conflict in the Indian state of Gujarat. Raw material includes agricultural residues available from that region. Pellets manufactured have low sulfur and chlorine content.

Keywords: Biomass; Pellet; Pelletization; Wood chips

Introduction

Renewable energy primarily refers to solar and wind energy, energy from biomass promises to be a cleaner alternative particularly for developing countries. Green power has very low emissions, carbon neutral and has very low sulfur and chlorine content. Raw biomass material is grinded and undergoes pillarization process where they are compressed to form pellets. These pellets have high mass and energy density compared to the original raw material. The 1990s saw an explosion of energy policy changes around the globe. Driven by economic, environmental, security, and social concerns, energy regulation has been in great flux. Many of the changes are having a profound influence on renewable energy, both from policies explicitly designed to promote renewable energy and from other policies that indirectly influence incentives and barriers for renewable energy [1].

Biomass pellets are proven, cost effective materials which can does not require highly skilled operators as production process is simple and easily understood. Since the operation is eco-friendly, utilities will be eager to develop, acquire and maintain such frameworks. Markets tend to function best when low cost access to good information and skills is available; a pattern pellets confronts to. One third contributor of energy to India is biomass with a potential of 22,536MW – [2] which comprises of solid biomass, which is an organic, non-fossil material of biological origins. Biogas which is principally methane and carbon dioxide is produced by anaerobic digestion of biomass and combusted to produce heat. Currently, India has 3697MW [3] installed capacity. Following is a list of some States with most potential for biomass reduction: Andhra Pradesh (200 MW), Bihar (200 MW), Gujarat (200 MW), Karnataka (300 MW), Maharashtra (1,000 MW), Punjab (150 MW), Tamil Nadu (350 MW), Uttar Pradesh (1,000 MW) [4]. The environmental impacts of fossil fuels often result in real costs to society, in terms of human health (i.e., loss of work days, health care costs), infrastructure decay (i.e., from acid rain), declines in forests and fisheries, and perhaps ultimately, the costs associated with climate change. Dollar costs of environmental externalities are difficult to evaluate and depend on assumptions that can be subject to wide interpretations and discretion [1] (Table 1).

The above mentioned biomass material does not cause food vs. fodder arguments, hence have a pivotal role to play in the fields of bioenergy. These are mostly agricultural residues and energy crops which do not grow food consumed by humans. Importance of pelletization has to be stresses as it reduces tremendously the chlorine, nitrogen and sulfur content of the biomass, hence making them suitable for co-firing with coal to produce electrical power and other heating applications.

Method

Analysis were done in terms of proximate and nitrogen, chlorine and sulfur estimations.

Moisture Determination

10 gm of powdered sample is carefully weighed.

Let Weight of Sample=x_1 Sample is taken on petri dish and kept in oven at 105°C for three hours. After three hours sample is taken out, cooled in desiccator and carefully weighed. Weight of sample after heat=x_2

$$\% \, Moisture = \frac{X_1 - X_2}{X_1} \times 100$$

Ash Determination

One gram of sample (grinded) is taken in a silica crucible. The crucible is then kept in a muffle furnace at 250°C for one hour followed by 550°C for two hours. Hot crucible with sample is taken put and cooled in desiccator. Weight of ash is taken into account.

$$Ash\% = \frac{Weight \, of \, the \, ash}{Sample \, Weight} \times 100$$

Volatile Matter Content Determination

Weight of silica crucible and lid is taken (X_1). One gram sample

Prosopis	Sawdust	Cotton Stalk	Wood chips	Wood strips	Wood waste

Table 1: Present work has studied the following materials for quality combination to produce pellets.

is added to the crucible and lid system and weighed (X_2). Setup is subjected to heat at 900°C for seven minutes in a muffle furnace. Cooled in desiccator, setup is again weighed (X_3); precautions are taken to make sure the lid does not open.

$$Volatile\ Matter\ \% = \{\frac{(X_1 - X_3)}{X_2 - X_1} \times 100) - M\} \times \{100 \div (100 - M)\}$$

Fixed Carbon Determination

Fixed Carbon %=100 – {%Volatile matter + %ash + %moisture}

Bulk Density Calculation

Empty container is taken and weighed (X_1). Container is now filled with the sample whose BD is to be measured. Surplus material is removed. Container is weighed (X_2). Result is repeated and an average value is taken.

$$BD = \frac{Weight\ of\ the\ filled\ conainer - Weight\ of\ the\ empty\ conatiner}{Volume\ of\ the\ conatiner}$$

BD=Bulk Density in Kg/m³

Gross Calorific Value Determination

Two important component of the setup are the oxygen cylinder and the bomb calorimeter. A 5 cm Nichrome wire is measured and taken and inserted into slots in electrodes and compressed by adjustable caps. Ignition requires 10 cm thread to carry flame and accordingly it is setup. To the bomb 1-2 ml distill water is added. The oxygen assembly is connected to the bomb, connections are made tight. Pressure gauge is observed as oxygen flows into the system, taken up to 20 kg/cm³ and then valve is closed. Bomb is placed in calorimeter and distill water is added until it is fully immersed. Water temperature is setup at 24.5°C. Bomb has the pellet sample (weighing less than 1.10 gm) which is connected to the nichrome wire through the cotton thread, in a pure oxygen environment for ignition. After adjusting the zero, the bomb is triggered, rise in temperature is noted. Value reaches peak point and then starts dropping. The peak value is recorded.

$$GCV = \frac{T \times W - (CV_T - CV_W)}{M}$$

GCV: Gross Calorific Value in Kcal/Kg

T: Final Temp. Rise in deg. Celsius

W: Water Constant (2561.85)

M: Mass of biomass sample

CV_T: Calorific Value of cotton thread (1 cm=2.1 Kcal/Kg)

CV_W: Calorific Value of ignition wire (1 cm=2.33 Kcal/Kg)

Nitrogen Analysis

0.5 gm of sample with 2.5 gm Kjeldahl mixture is taken in Kjeldahl flask. To this 12.5 ml conc. H_2SO_4 is added, a dark red color forms, and the flask is kept in a digester, next part of the operation begins when the solution in the flask turns light green. In a beaker, 25 ml 2% boric acid is added with 1-2 drops methyl red + methyl blue indicator and set aside. Now in a graduated cylinder the following is measured and carefully added to the Kjeldahl flask:

- 100 ml distill water.
- 65 ml 40% NaOH.
- Glass beads (3-4).

- 1-2 drop phenolphthalein indicator.

Now distillation process is started by connecting the flask with the condenser setup, where cooling fluid is liquid water. The outlet of the condenser is directed towards the beaker with boric acid in it, solution in it changes from dark red to light green as distillation progresses. Around 80 ml of the solution is taken from the beaker, and then titrated with 0.1 (N) H_2SO_4. End point of titration is when the light green solution turns dark pink. Burette reading is noted.

$$Nitrogen\ \% = \frac{(Burette\ reading - blank) \times 1.4 \times 100}{Smaple\ weight \times 1000}$$

Blank=0.3 ml

Chlorine Analysis

Pellet made from pellet maker (0.7-0.9 gm) and 0.2 gm Benzoic acid is weighed into a quartz crucible. Absorbing solution; 10 ml Chorine solution is added to the bomb. The bomb is pressurized with 99.5% Oxygen at >30 bar pressure. Bomb calorimeter process is followed, bomb is taken out after the process, after a short interval, the bomb is shaken for 3 minutes. Material inside is washed in 40 ml distill water, filtered and clear solution is obtained. 10 ml of this clear solution is taken, two drops potassium dichromate ($K_2Cr_2O_7$) as an indicator is added. Titration with 0.1 (N) $AgNO_3$, end point is a yellowish red solution where precipitate can be clearly seen. Burette reading is noted.

$$Chlorine\ \% = \frac{Burette\ reading \times Normality\ of\ AgNO_3 \times 35.44 \times 50}{10 \times Weight\ of\ Biomass\ pellet \times Filtrate\ Volume}$$

Chlorine solution used is a mixture of Na_2CO_3, $NaHCO_3$ and H_2O_2 solution at a specified combination.

Sulfur Analysis

Pellet is made from biomass sample using pellet maker (X_1), weighing in the range between 0.7-0.9 gm. Benzoic acid (around 0.2 gm) is taken. Both the above are weighed into a quartz crucible. Bomb calorimeter process is followed for combustion, process remains same except 10 ml distill water is taken in bomb using pipette, then after combustion the bomb is taken out, and a ten minute interval is taken, after that it is shaken for 3 minutes. 90 ml distill water is poured in the bomb and crucible is also washed in it, inside the bomb. The above is filtered using Number 1 filter paper and clear solution is obtained. To 100 ml clear solution, one drop methyl orange, and one gram barium chloride salt is added. The above is boiled at 250°C for one minute and covered with glass plate; kept overnight. Solution is then filtered with Filter paper 542 (ash-less). Filter paper is then washed with hot water repeatedly to remove chlorine, it can be checked using a solution of $AgNO_3$; washing is done till white precipitate of AgCl no longer forms. Filter paper is dried in oven at around 50°C for one hour. Dried paper is now kept in a silica crucible, and put into muffle furnace for 2 hours at 550°C. Ash formed is pure sulfur it is weighed for completion of calculation (X_2).

$$Sulfur\ \% = \frac{Weight\ of\ biomass\ pellet\ (X_1)}{Weight\ of\ Ash\ (X_2)} \times 13.73$$

Results and Discussion

The materials taken for analysis are considered for quality combination to produce bio-pellets, which have good GCV and VM. Initially to understand how compressing a biomass material makes it energy rich is understood from Table 2 given below. Here raw material is wood chips and the finished pellets made from the same material are taken for analysis and compared to see the changes (Table 2).

Bulk density is an important parameter which indicates the ease of packing, the greater the value, more is the ease of packing, and we see a significant increase in the value from the feedstock to the end pellet. GCV for the raw material was relatively less but after pelletization the GCV is almost similar to Indian coal (Lignite) which has a GCV of around 4200 Kcal/Kg.

It can be seen that moisture content has reduced and a significant increase in the volatile matter content is achieved, which signifies the combustible material present in the biomass. The ash content has also reduced in the final pellet.

Biomass is an energy lean fuel when it undergoes pelletization its mass density nd volume density increases and given that another comparison is made on the effect of pelletization on elemental analysis given below (Table 3).

Given that we have established the importance of pelletization, quality combination is now approached by mixing these biomass materials and then making them undergo pelletization. The binder used is starch diluted in certain percentage of water. A ring roll mill produces these pellets from the raw biomass (Table 4).

Average chlorine content in raw material for this combination=**4.14%**

Average sulfur content in raw material for this combination=**0.96%**

Average nitrogen content in raw material for this combination=**2.25%**

From this analysis it is inferred that the pellet produced will have high VM content as in the raw material it is already 73.36%, and there will be corresponding reduction in moisture and ash content as Table 2 has shown us (Table 5).

Average chlorine content in raw material for this combination=**4.33%**

Average sulfur content in raw material for this combination=**0.91%**

Average nitrogen content in raw material for this combination=**1.86%**

This combination is undesirable as it can be seen that sawdust has very low volatile matter content and hence has an effect on the overall quality of pellets that will be produced from it. Wood waste and wood strips being different kind of waste available maintains their quality (Table 6).

Average chlorine content in raw material for this combination=**5.44%**

Average sulfur content in raw material for this combination=**0.98%**

Average nitrogen content in raw material for this combination=**1.98%**

For this combination given in Table 6 wood waste is considered which in Gujarat is locally known as Jalau waste, since this is only available here. And this yields the best possible combination for the raw biomass material and in the raw material itself 0.98% sulfur is present hence in the pellet it will go further down which is important, as high percentage sulfur stremas contribute to corrosion of stacks in power plants (Table 7).

Average chlorine content in raw material for this combination=**5.25%**

Average sulfur content in raw material for this combination=**0.45%**

Average nitrogen content in raw material for this combination=**2.66%** When cotton stalk is considered as raw material which is an agricultural residue, the sulfur content is the lowest, but volatile matter content is less compared to the woody biomass material, and hence it brings down the VM percentage. A good fuel has volatile matter content in the range of 72-83%, but since pelletization has the potential to increase this value, this combination is also accepted in the raw material for making pellets, which can be used for co-firing with coal in thermal power plants.

Hence the following observations are made from the analysis:

- Sawdust has the lowest Volatile matter.
- Wood strips have lowest moisture content.
- Prosopis has low ash content.
- Wood waste has low fixed carbon content.

Conclusion

Biomass can be compressed to form pellets using suitable binders and then use them in co-firing with coal in steam turbine based power

Raw Material Analysis	Pellet (Biofuel) Analysis
Bulk Density = 253.46 Kg/m³ GCV = 3469.63 Kcal/Kg	Bulk Density = 578.01 Kg/m³ GCV = 4084.17 Kcal/Kg
Moisture = 8.95% Volatile matter = 68.88% Ash = 5.30% Fixed Carbon = 16.87%	Moisture = 7.07% Volatile matter = 73.84% Ash = 4.75% Fixed Carbon = 14.34%

Table 2: Raw material and Pellet comparison.

Wood Chips (Raw Biomass)	Compressed pellets
% Sulfur = 1.359%	% Sulfur = 0.0265%
% Chlorine = 5.64%	% Chlorine = 4.650%
% Nitrogen = 2.75%	% Nitrogen = 3.158%

Table 3: Comparison in terms of sulfur, chlorine and nitrogen.

Raw Material	Bulk Density (Kg/m³)	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	
Prosopis	185.55	14.04	76.20	4.01	5.75	100%
Cotton Stalk	241.46	10.42	65.11	7.02	17.44	100%
Wood Strips	161.06	10.67	78.78	10.67	4.06	100%
	Average Bulk Density	Avg. MS	Avg. VM	Avg. Ash	Avg. Fixed Carbon	
Total	196.02 Kg/m³	**11.71%**	**73.36%**	**7.23%**	**9.08%**	**100%**

Table 4: Quality combination I using three different biomass materials.

Raw Material	Bulk Density (Kg/m³)	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	
Wood Waste	176.16	11.34	70.69	9.38	5.24	100%
Sawdust	152.89	12.95	58.23	6.98	21.84	100%
Wood Strips	161.06	10.67	78.78	10.67	4.06	100%
	Average BD	Avg. MS	Avg. VM	Avg. Ash	Avg. Fixed Carbon	
Total	163.37 Kg/m³	**11.65%**	**69.23%**	**9.01%**	**10.38%**	**100%**

Table 5: Quality combination II using three different biomass materials.

Raw Material	Bulk Density (Kg/m³)	Moisture(%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	
Prosopis	185.55	14.04	76.20	4.01	5.75	100%
Wood Waste	176.16	11.34	70.69	9.38	5.24	100%
Wood Strips	161.06	10.67	78.78	10.67	4.06	100%
	Average Bulk Density	Avg. MS	Avg. VM	Avg. Ash	Avg. Fixed Carbon	
Total	174.25 Kg/m³	**12.01%**	**75.22%**	**8.02%**	**5.01%**	**100%**

Table 6: Quality combination III for the raw biomass material.

Raw Material	Bulk Density (Kg/m³)	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	
Cotton Stalk	241.46	10.42	65.11	7.02	17.44	100%
Wood Waste	176.16	11.34	70.69	9.38	5.24	100%
Wood Chips	176.16	11.34	70.28	5.05	13.33	100%
	Average Bulk Density	Avg. MS	Avg. VM	Avg. Ash	Avg. Fixed Carbon	
Total	197.92 Kg/m³	**11.03%**	**68.69%**	**7.13%**	**12.01%**	**100%**

plants and these pellets will have other heating application as well, hence lower flue gas emission altogether. The global population stand around seven billion people and predicted to rise to more than nine billion by 2050, as reliance on fossil fuels will start to drop, increase in the share of renewables should increase, to contribute to energy security of each nation. Renewable energy, though intermittent in nature is humanity's best chance to combat global warming, climate change and rising energy demands [5]. Present energy scenario demands a comprehensive rethink of the existing model of production and consumption, where one's output is another's input, and obsession with ownership of material goods is moderated. Doing this would help us have healthier food, more efficiently managed resources, a cleaner environment, and a safer, more resilient and equitable world.

References

1. Beck F, Martinot E (2004) Renewable Energy Policies & Barriers. Encyclopedia of energy 5:365-383.

2. State-wise potential of various renewable energy technologies.

3. http://pmindia.gov.in/report_to_people/2012-2013/report_PMO_English.pdf

4. Meisen P, Quéneudec E (2006) Overview of sustainable renewable energy potential of India. Global Energy Network Institute 1-26.

5. World Population to EXCEED 9 billion by 2050: Developing Countries to Add 2.3 Billion Inhabitants with 1.1 Billion Aged Over 60 and 1.2 Billion of Working Age (2009) Press Release.