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Combustion of groundnut shell/rice straw/ragi straw in a mini hot water generator

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Abstract
The world presently relies heavily on conventional fuel sources like coal, natural gas and oil. Likewise, the world's concern about global warming, civic smog and acid rain caused by these sources has caused the world to consider indispensable sources of energy. Biomass is one of the foremost sources of energy with veritably specific properties and can reduce carbon emissions by 80 and shift to renewable energy resources that are less environmentally dangerous. In this analysis, several aspects that are related to burning biomass in boilers have to be investigated, similar as the composition of biomass, estimating the advanced heating value of biomass, comparing biomass to other energies, and the combustion of biomass. The boiler has to be designed, and a performance analysis also has to be made on the boiler by using different biomass, similar as groundnut shells, ragi straw, and rice straw. The emissions of different biomasses were also examined during the analysis.

Keywords: Combustion, ragi straw, rice straw, hot water generator, efficiency, emission

Introduction
After China, Russia, and the United States, India was the world's fourth-largest energy consumer. India produces 450 to 500 million tons of biomass a year. Currently, more that 30% of the nation's primary energy comes from biomass. It's estimated that the potential in the short term for power from biomass in India varies from about 18,000 MW, when the compass of biomass is as rationally defined, to maximum of roughly 50,000 MW, if the definition of biomass were broadened. Although biodiesel is not currently sold on the Indian fuel market, the government intends to use it to satisfy 20% the diesel requirements in the nation by 2020. The unauthorized sources of biodiesel in India are thought to be shops that sell wild plants like mahua, neem, and jatropha. Nearly 40 million of the 63 acres of wasteland in the nation may be developed by cultivating jatropha. India employs a number of incitement strategies to get towns to restore wastelands by embracing, jatropha culture. The Indian government is targeting a jatropha colony area of 11.2 million by 2012.
Bagasse cogeneration and grid-connected biomass power systems are examples of biomass power technology that has been implemented in India. Further, the most generally used biomass power technology is combustion technology, which accounts for nearly 95 of the capacity installed, as the type of combustion technology employs a conventional Rankine cycle, where the biomass is incinerated in a high-pressure boiler to produce steam, which is also used to spin a turbine to produce electricity.
Patel and B. Gami *et al.* explained about as the power assiduity is defying challenges with putatively clashing pretensions. They give the frugality of scale demanded to minimize the cost of product. Consumers, including industry, calculate on affordable, reliable electrical energy. It's an important part of our economy and our diurnal life. A resource that can be used in different amounts to replace coal in pulverized coal plants is biomass. New, large power plants are being designed to use biomass as the primary fuel [1].
M. Kulkarni *et al.* explained that Petroleum grounded fuels play a vital role in the rapid-fire depletion of conventional energy sources along with adding demand and are also major contributors of air pollutants. Fossil fuels currently supply a significant amount of India's energy needs. Therefore, it is imperative that engines use alternative fuels that come from domestic sources a more common single-cylinder, water-cooled engine is used for the trails [2]. According to Chaney *et al.*, wood is becoming a limited resource in many emerging nations. Particularly in pastoral settings, biomass briquettes made from discarded agricultural residues can provide an essential household solid fuel.

Biomass briquettes are distinct from wood in that they allow for the management of fuel viscosity, humidity content, size, and shape during the manufacturing process. It has been demonstrated that all of these elements, in addition to the material characteristics, significantly impact biomass burn rates [3].

Patil and S. Shinde *et al.* explained that In India, the pastoral population substantially uses biomass feedstock as a fuel for cooking and heating purposes. They conventionally use traditional three-gravestone chulhas (cook cook stove) and modified Indian traditional chulhas. We carried out trials on two kinds of chulhas, batch (packed bed) and nonstop (nonstop feeding) operation mode. The effect of variations in fuel size for packed bed combustion, secondary air's volume and its locales of preface, and radiation losses through the fuel entry opening (nonstop feeding) were studied collectively [4]. A lucrative engineering analysis of a biomass pelleting process was conducted for north americasin conditions, according to Sokhansanj *et al.*

The pelletization of biomass consists of a series of unit operations drying, size reduction, ennobling, cooling, screening, and warehousing. Still, environmental impacts due to the combustion of these energies bear farther investigation to control implicit emissions [5]. P. Maran *et al.*, the performance ofmini-boilers and the situations of exhaust emigrations from colourful vegetable oil mixtures were examined by varying ranging from 0 to 50 with diesel [6, 10]. Pepplow *et al.* explained about as Energy and environmental safety are problems of the first greatness faced by our global economy. It's possible to operate necessary differences in the world energetic matrix to minimize the global heating in the short, medium, or long period [7]. Numerous social, economic, and environmental advantages can be obtained by using biomass in boilers, including reduced CO_2 and NOx emissions, employment possibilities, fuel property maintenance, and net cost reductions [8].

2. Biomass

Any organic substance that comes from plants that develop in the sun is referred to as biomass. Burning the biomass releases the energy it contains, which may be used to generate power or heat. All carbon, hydrogen, and oxygen-based materials created by biological processes is referred to as biomass. An estimated 146 billion tons of biomass are produced year worldwide, primarily from wild plant growth. Six different energy sources are used to generate biomass energy: waste, wood, plants, landfill gasses, alcohol fuels, and trash. Using lignocellulose biomass (second generation biofuels) as fuel yields wood energy. This involves either gathering from wood waste streams or utilizing gathered wood directly as fuel. Pulping liquor, sometimes known as "black liquor", is a waste product from the pulp, paper, and paperboard industries and is the main source of energy from wood.

2.1 Type of Biomass

Straw with wood, etc. wood, etc. Grass, hemp, straw, seeds, wood and wood industry waste, sawdust, wood chips, bark, pellets, shavings, agricultural waste, fast-growing trees (willows, poplars), and co-fired fuels (sludge, coal, peat, etc.) are a few examples of biofuels. Aside from that, straw with wood, etc.

Table 1: Calorific values of different biomass

Fuels	Mass (kg)	Calorific value of fuel (kcal/kg)	Ash produces for kg of fuel (%)	% of carbon content
Groundnut shell	1	4008	2.8	19.1
Rice straw	1	3420	2.6	36.4
Ragi straw	2.5	4024	2.7	38.2

2.2 Fuels and properties

Fuel gas is the term used to describe any of a fuel that is normally gaseous. Hydrocarbons (such methane or propane), hydrogen, carbon monoxide, or combinations of these make up a large number of fuel gasses. These gases are potential thermal energy sources that are easily transported and dispersed via pipelines from the site of direct consumption to the point of consumption.

Fuel gases are different from solid and liquid fuels, even if some are liquefied for storage or transit. Their gaseous state provides benefits, such as avoiding the challenges associated with moving solid fuel and the potential for spills that come with liquid fuels, but it also has drawbacks. A fuel gas could go unnoticed and gather in specific locations, increasing the possibility of a gas explosion. To make them detectable by a unique smell, odorizers are added to the majority of fuel gasses.

3. Experimental Setup

A boiler is a closed vessel that transfers heat from combustion into water, turning it into heated water or steam. The hot water or steam under pressure is than usable for transferring the heat for the steam requirements of process industries or for power generation. Combustion boilers are designed to use the chemical energy in fuel to boost the energy content of water so that it can be used for heating and power applications. Boilers use a variety of fossil and non-fossil fuels, with coal, oil, and natural gas being the most widely used fuels. During combustion, oxygen reacts with the fuel's carbon, hydrogen, and other constituents to produce a flame and hot combustion gases. These gasses cool as heat is transmitted to the water as they pass through the boiler. The gasses eventually enter the atmosphere after passing via a stack.

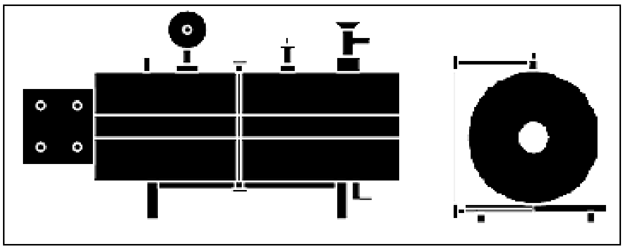

Fig 1: Layout of boiler front view & side view

In order to move air forward, air blowers often employ centrifugal force. Inside a centrifugal air blower is a wheel with tiny blades on the circumference and a casing to guide the flow of air into the centre of the wheel and out toward the edge. The design of the blades will determine how

efficient the air blower is. Air blower blade designs can be categorized as radial, air foil, forward-curved, backward-curved, and backward-inclined. Only a few weeks at the start of a project, during the revision phase, is the boiler available for examination and research.
The boiler's unique design is known as a heat transmission tube. Here, the boiler bed-zone of the furnace receives another injection of the circulating fluidization sand. During the course of the research, no further significant reconstruction has been completed. The boiler's fuel types are usually a combination of various biomass and wood recycling materials. Common biomass fuels include peanut shell, bagasse, bean and cotton layers, rice straw, and grass. Using a soot-blowing system with high-pressure steam is the standard procedure to decrease the quantity of deposits that form from the boiler running and thermometer during the periodic review periods. This increases the heat transfer rate and boiler efficiency.

3.1 Specification of integrated furnace with hot water generator

Diameter of hot water generator (D)=0.26m
Diameter of furnace (d)=0.065m
Length of the hot water generator (L)=0.8m
Volume of the hot water generator (V)=$\frac{\pi}{4}L(D^2-d^2)$=39.8 liters

4. Results and Discussions

4.1 Calorific Value

The total amount of heat released occurs when a unit mass or volume of fuel is burned completely; the total amount of heat produced occurs when a unit mass or volume of fuel is burned completely and the combustion products have cooled to room temperature; and the net heat produced occurs when a unit mass or volume of fuel is burned completely and the products are allowed to escape.

LCV

=HCV-latent heat of water vapour formed
=HCV-(mass of hydrogen×9×latent heat of steam)

Where, Latent heat of steam=587kcal/kg

Theoretical calorific value (TCV)

$$TCV=\frac{W(T_2-T_1)}{V}$$

Where,
W-Mass of water in the hot water generator
V-Mass in kg of fuel sample taken in the grate
T_1-Initial temperature of water in the hot water generator
T_2-Final temperature of water in the hot water generator

4.2 Calorific value of fuel constituents

The following table represents the high calorific value on various constituents.

Table 2: Calorific value of fuel constituents

Constituents	Hydrogen	Carbon	Sulphur
HCV(kcal/kg)	144249	33,823	9418

The oxygen, if present in the fuel is assumed to be present in combined form with hydrogen, i.e. in the form of fined hydrogen. So, the amount of hydrogen available for combustion.

=Total mass of hydrogen in fuel-fixed hydrogen
=Total mass of hydrogen in fuel-1/8 mass of oxygen in the fuel

Prabir Basu's formula for computing the calorific value depe nding on the fuel's composition of chemicals is (approximat e value).

$$HCV=\frac{1}{100}(33{,}823\ C+144249(H-O/8) + 9418)\ kJ/kg$$

$$LCV=\frac{1}{100}(HHV-22604H-2581)\ kJ/kg$$

This table shows various compositions such as Carbon, Hydrogen, Sulphur and various other contents on biomasses

Table 3: Composition of fuels

S. No.	Content	Groundnut	Rice straw	Ragi straw
1	Carbon	45.72	36.4	46.3
2	Hydrogen	5.96	6.0	6.02
3	Sulphur	0.06	0.05	2.01
4	Oxygen	43.41	44	42.4
5	Nitrogen	0.9	0.6	0.26
6	Ash	2.8	2.6	2.7

Table 4: Calorific values and efficiency

Biomass	HCV (kJ/kg)	LCV (kJ/kg)	TCV (kJ/kg)	Efficiency %
Groundnut	16239.455	14918.067	10998.4	73
Rice straw	13126.99	12507.8	10498.48	83
Ragi straw	16887.9	1217.69	2126.99	57.2

4.5 Theoretical amount of oxygen required for the complete combustion of 1kg of fuel

$$=\left(\frac{32}{12}\times C+8\left(H-\frac{O}{8}\right)+S\right)\ kg$$

4.6 Amount of air required theoretically for combustion of 1kg of fuel

$$=\left(\frac{100}{23}\left(\frac{32}{12}\times C+8\left(H-\frac{O}{8}\right)+S\right)kg\right.$$

Table 4: Theoretical oxygen/air required

SL. No.	Biomass	Theoretical oxygen required/kg of fuel	Theoretical air required/kg of fuel
1	Groundnut	124.65	541.95
2.	Rice straw	101.11	438.81
3.	Ragi straw	131.4	571.3

Now, For Groundnut (Shell)

Total oxygen required=541.95 kg
Oxygen already present in100 kg fuel (given)=0.7 kg
Additional oxygen required=541.95-0.7=541.25 kg
Therefore quantity of dry air needed=(541.25) / 0.23
(Air contains 23%oxygen by weight)=2353.26 kg of air
Theoretical air required=2353.26 / 10=23.53 kg of air / kg of fuel

Therefore, in this example, for each kg of groundnut shell, 23.53 kg of air is required.

4.7 Calculation of theoretical CO_2 content in flue gases-groundnut shell

It is necessary to also calculate the CO_2 content in the flue gases, which then can be used to calculate the excess air in the flue gases. A certain amount of excess air is needed for complete combustion of bagasse. However, too much excess air points to heat losses and too little excess air point's incomplete combustion. The CO_2 in flue gases can be calculated as follows:

Nitrogen in flue gas=2353.26-541.25=1812.01 kg

Theoretical CO_2 % in dry flue das by volume is calculate as below:

Moles of CO_2 in flue gas=161.02 / 44=3.65
Moles of N_2 in flue gas=1812.01 / 28=64.71
Moles of O_2 in flue gas=124.65 / 32=3.89
Moles of SO_2 in flue gas=43.47 / 64=0.67

Theoretical CO_2% by volume

=(Moles of CO_2 ×100) / Total moles (dry)
=(3.65 ×100) / (3.65+64.71+3.89+0.67)=5.04%

4.8 Calculation of constituents of flue gas with excess air-groundnut shell

Now we know the theoretical air requirements and the theoretical CO_2 content of flue gases. The next step is to measure the actual CO_2 % in the flue gases. In the calculation below it is assumed that the measured CO_2% in the flue gas is 6%.

% excess air=[(theoretical CO_2% / actual CO_2)-1] × 100
=[(5.04 / 6)-1] × 100
=16%

Theoretical air required for 100 kg of fuel burnt=2353.26 kg
Total quantity of air supply required with 16% excess air=2353.26 kg ×0.16=376.52kg

Excess air quantity (theoretical excess air-actual)
=2353.26-376.52=1976.74 kg
O_2 (23%)=1976.74 × 0.23=454.6 kg
N_2 (77%)=1976.74 × 0.77=1522.08kg

The final constituents of flue gas with 16% excess air for every 100 kg fuel is as follows

Table 5: emission constituents

SL. No	Biomasses	CO_2 (kg)	H_2O (kg)	SO_2 (kg)	O_2 (kg)	N_2 (kg)
1.	Groundnut	161.02	353.24	43.47	996.55	3334.09
2.	Rice straw	153.88	358	44.05	622.12	2082.72
3.	Ragi straw	159.5	345.22	44.41	1019.89	3414.42

5. Conclusion

These days, burning biomass makes a substantial contribution to the world's energy supply. It is a proven technology and widely applied in the size range from a few kW for household heating to several MW for district heating and up to more than one hundred MW for power stations based on steam cycles. Although the procedures for full combustion are well - known in concept, future efforts for development are needed to implement adequate gas mixing in commercial furnaces and to assure correct functioning in practice.

We infer from the aforementioned research and tests that Figure 2. Different Biomasses and Emissions According to this investigation, ragi-straw gross has a greater calorific value than groundnut shell and rice straw. However, groundnuts have a greater ash content than rice and ragi-straw. Emissions from groundnuts and ragi-straw are about comparable to or higher than those from rice-straw. Groundnut is more effective than ragi straw, while rice straw is more effective than groundnut. Three biomasses, including rice straw, ragi straw, and groundnuts, were sampled. A number of these biomasses still need further study but may be used in the future to cut emissions and the usage of fossil fuels.

Biomass combustion can still be enhanced and has the potential to improve the economy, lessen its impact on the environment, and spread more widely if these research and development demands are met and the information that is already accessible is put into reality. In addition to the woody fuels that are currently widely utilized, other biofuels, such as peanut shell, rice husk, rice straw, etc., are being exploited as a future energy source.

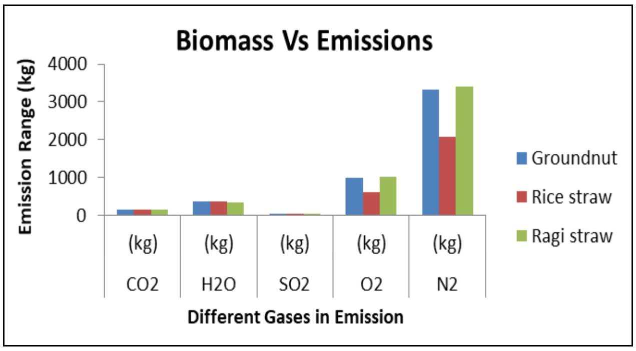

Fig 2: Different biomasses and emissions

In this analysis it was observed that ragi-straw gross calorific is higher when compared with rice straw & groundnut shell. But the content of ash is higher on groundnut as compared with rice and ragi-straw. Groundnuts and ragi-straw have emissions that are almost equal and greater than rice-straw. Rice straw is more efficient than groundnut and groundnut is more efficient than ragi straw. a sample of three biomasses was taken, such as groundnuts, ragi straw and rice straw, and several biomasses still require research and can be utilized in the future to reduce the use of fossil fuels and thereby emissions.

By following these needs for research and development and by introducing available knowledge in practice, biomass combustion can still signification be improved and has a potential for better economy, reduced environmental impact, and increased propagation. Beside woody fuels widely used nowadays, further bio fuels such as Groundnut shell, Rice straw and ragi straw etc., as future energy supply. Additional challenges related to fuel constituents such as increased emission and corrosion needs to be overcome for these types of fuels.

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