Design of Biogas Stove for Frying Chips and Effective Utilization of Cashew Nut Shell for Gasification

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***Abstract*— This study mainly focuses on the waste minimization, the effective utilization of biogas that is generated from anaerobic digestion of banana peel waste and the effective utilization of cashew nut shell for gasification. The OS Chips company located in Selvapuram, Coimbatore has been selected for the study. The company has installed a biogas plant utilizing banana peel waste as a feed material. In order to use the biogas for thermal applications like frying chips, normal stoves cannot be used. Hence a stove utilizing biogas as fuel has been designed. The cashew nut shell that is used as a fuel in the company has been tested for its effectiveness in gasification process. The cashew nut shell contains a large proportion of volatile content (78%) and low ash content (2%) which proved its effectiveness in the gasification process.**

Keywords*— Biogas Stove, Banana Peel waste, Anaerobic Digestion, Chips, Gasification

I. INTRODUCTION (*Heading 1*)

The Economic growth and Human development of a country are the outcome of its energy source. With 15 percent increase of the world's population and an economic growth rate, India has a voracious appetite for energy. But the country lacks sufficient domestic energy resources, particularly of petroleum and natural gas, and much of its growing requirements are met by the imports. Currently, about 35 percent of India's commercial energy needs are imported [1]. The Government of India's Planning Commission predicts dramatic demand increases for coal and oil over the next 20 years. India's total energy requirement for the year 2011-12 is 546 MTOE which would raise up to 729 MTOE in the year 2016-17 (IEP report, 2010).

The energy requirement can be balanced by utilizing renewable energy sources like solar, wind, bioenergy etc. Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas. The OS chips company produces a huge amount of banana peel waste and they are utilizing it as a feedstock for biogas production in the biogas plant that they have installed already. The biogas can be utilized for both the thermal and electrical applications. The main influencing factors in using biogas as a combustible gas are gas/air mixing rate, flame speed, ignition temperature and gas pressure. Compared to liquefied petroleum gas, biogas needs less air per cubic metre for combustion [6]. By considering all the factors a stove utilizing biogas has been designed.

Gasification is an advanced thermo-chemical process. In this process, the fuel is ignited by partial supply of oxidant (30-40 % of the stoichiometric requirement). Different processes and operations occurring in the gasifier reactor are mainly in four reaction zones (i.e., oxidation, reduction, pyrolysis and drying). The sequence of reaction zones in a gasifier depends on the type of gasifier and direction of flow of fuel and air or gas. When air is used as an oxidant, the product is referred to as producer gas. It consists of CO (20-22%), H_2 (10-12%), CH_4 (1-2%), N_2 (50-55%), CO_2 (10%). Char and Tar also produced in gasification [2]. Though India is rich in biomass, the most efficient utilization and the introduction of appropriate conversion technologies in the rural areas assume greater importance. Cashew (Anacardium occidentale) tree grows widely in warm and humid climatic regions of the world. India is leading producer and processor of cashew nuts [3]. The Company that is selected for the study has been utilizing cashew nut shell as a fuel for their thermal requirement. In order to study the potential of cashew nut shell as a fuel, investigations were carried out to assess the properties and use it as a feedstock by combustion or gasification. The physical and chemical properties of the shell were determined in the laboratory.

II. MATERIALS AND METHODS

A. *About the company:*

The OS chips company located in Selvapuram, Coimbatore has been selected for the study. The main commercial product in the company is banana chips. Their total production is about 3000 kg chips per day. The palm oil and seven frying vessels shown in the figure 1 are used to fry the chips and they are consuming about 75 tins of oil per day. Each tin is estimated to contain about 15 kg of oil. Presently the cashew nut shell that has been shown in the Fig. 2 is used as a fuel for frying chips. Total fuel consumption has been estimated to be around 2800 kg per day. As their main product is banana chips they are producing a large quantity of banana peel waste and they are utilizing it in a biogas plant that has been installed long back. They have already constructed a balloon type biogas plant with digester depth 18 feet and diameter 14 feet. The balloon type biogas plant installed has been shown in the Fig. 3.

Fig. 1 Palm oil and frying pan

Fig. 2 Cashew nut shell

Fig. 3 Balloon type biogas plant

B. Biogas flow requirement calculation:

Heat Energy required = Heat Input / Heat output

Heat Input = $mc_p\Delta t$
Where
m = Mass of the oil used for frying the chips
c_p = Specific Heat of palm oil
Δt =Temperature required to raise the temperature to frying temperature

Heat Output = Calorific value of biogas

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

One volume of Methane requires 2 volume of oxygen for the efficient combustion of biogas. Methane content in biogas is taken as 55% [4]. Hence 1.82 volume of biogas requires 9.52 volume of air. 1 volume of biogas requires 5.23 volume of air.

% of biogas to be mixed with air = 16.05%

C. Design of Stove: [6]

The schematic diagram of the biogas burner has been given below. The main components of the stove are the injector, the air/gas mixing chamber and the burner. The air/gas mixing chamber opens into the burner head. The combustion of biogas is regulated by moving the injector into and out of the air/gas chamber, which regulates the amount of air that enters into the chamber. If the injector is moved deeper into the air/gas mixing chamber, the drift of oxygen into the burner is reduced thus reducing combustion. On the contrary, when the injector is moved out of the air/gas mixing chamber more oxygen enters into the burner there by increasing combustion. The stove is connected to the gas holding unit of the biogas plant by a rubber hose which convey biogas from the gas holder of the plant to the stove.

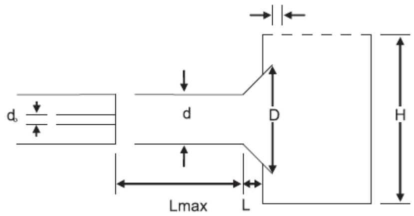

Fig. 4 Schematic diagram of the biogas burner

Design Analysis:
The parameters that are necessary for the design are:
Diameter of the Injector jet (do)
Length of the mixing pipe (L_{max})
Length of the air intake holes measured from the end of the jet (L_{max})
Length of the mixing pipe (L)
Height of the burner head (H)
Jet Diameter:
The jet diameter (do) was estimated from equation given below:

$$do = 2.1\sqrt{(Vf/\sqrt{h})}\ (mm)$$

Where
Vf = fuel flow rate (m^3/hr)
h = prescribed gas pressure which is taken as 0.01 mm of WC

Diameter of the mixing pipe
The diameter of the mixing pipe (d) was determined using the formula

$$d = 6do\ (mm)$$

Length of air intake holes
The length of air intake hole measured from the end of the jet was estimated as.

$$L_{max}\ (mm) = 7d$$
$$L_{min}\ (mm) = 1.35d$$

Diameter of mixing chamber
The diameter of the mixing chamber (D) was determined from

$$D\ (mm) = 1.30d$$

Length of mixing chamber
The length of the mixing chamber (L) was determined from

$$L = 1.50d$$

D. Proximate Analysis:
The Proximate analysis for the cashew-nut fuel sample includes the following:

Moisture Content:

Using hot air oven, moisture content of biomass was determined. By oven method (ASTM, E-871), 3 grams of powdered sample of biomass was taken in a Petri dish and kept inside the oven with a set temperature of 105°C for 24 h. The moisture content was calculated by measuring weight of moisture escaped from sample and original sample. The formula is given below:

Moisture content % = (Loss in wt.of sample / initial wt. of the sample) * 100

Volatile Matter:

After analysis of the moisture content, the volatile matter of the biomass was determined using muffle furnace (ASTM, E-872). To measure the volatile content, known weight of sample was taken in a closed crucible and kept inside the muffle furnace at 650˚C for six minutes and again at 750˚C for another six minutes. The loss in the weight of the sample was found out and the per cent of volatile matter was calculated as

Volatile Matter % = (Loss in wt. of the sample/initial wt. of the sample) * 100

Ash Content:

The ash content of the selected sample was found out (ASTM, E-830) by taking a known quantity of dried sample in an open crucible and keeping it in a muffle furnace at about 750˚C up to reaching a standard weight. The ratio between the remaining weight of materials in the crucible and the sample taken was the fraction of ash content of tested material.

Ash content, % = (Weight of ash formed / Weight of dried sample) * 100

Fixed Carbon:

Fixed carbon of dried materials has been determined by the following formula.

Fixed carbon, % = 100 – (volatile content (%) + ash content (%))

Calorific Value:

Calorific value of biomass was determined by using the Bomb calorimeter. The efficiency of a fuel can be understood by its calorific value. The calorific value of a fuel is defined as "the amount of heat liberated, when a unit mass of fuel is burnt completely". The procedure for using Bomb calorimeter and calculation is given below

Description of Apparatus:

The bomb calorimeter consists of a strong stainless steel bomb inside of which the fuel sample is burnt. The bomb is provided with an oxygen inlet valve and two stainless steel electrodes.

To one of the electrodes, a small ring is attached. In this ring, a stainless steel crucible is placed. The bomb is placed in a copper calorimeter which contains three fourth of water. The copper calorimeter is provided with a Beckmann thermometer and a stirrer for stirring water. The copper calorimeter is surrounded by an air jacket and water jacket.

Working of Bomb Calorimeter

A known weight of sample was taken in the crucible. A fine magnesium wire, touching the fuel sample, was then stretched across the electrodes. The bomb lit was tightly screwed. The bomb was filled with oxygen at 25 atm. The bomb was kept in a copper calorimeter containing three fourth of water. Initial temperature of water in the calorimeter was noted after thorough stirring. The electrodes were then connected to 6V battery. The current was switched on and the fuel sample in the crucible burnt with the evolution of heat. The heat liberated raised the temperature of water in the calorimeter. The final maximum temperature of water was noted. The calorific value of the fuel was calculated as follows.

CV, Cal / g = (W * T) / M

Where, CV– calorific value Cal / g

W – water equivalent of calorimeter assembly, Cal / °C

T – rise in temperature, °C

M – mass of sample burnt, g

III. Results and Discussion

Biogas Requirement:

1 tin contains about 15 kg of palm oil. 1 tin of palm oil can fry around 40 kg of chips/day

Total Oil Consumption = 3000*15/40
= 75 * 15
= 1125 kg of oil

Mass of palm oil used = 75/7= 11 tin / vessel
= 11 *15
= 165 kg / vessel

Specific Heat of Palm oil = 5.25 kJ/kg°C [4]

Heat Energy Required = $mC_p\Delta t$
= 165 * 5.26 * (573 – 301)
= 236068.8 kJ/day
= 21460.8 kJ/hr

Heat Energy Available in Biogas = 21500 kJ/m^3

Heat requirement = $\frac{21460.8 \text{ kJ/hr}}{21500 \text{ kJ/m}^3}$
= 0.998 m^3/hr

Biogas required = 1 m^3/hr (Approx)

Design of Stove:

The stove which is working through the biogas has been designed based on the above mentioned formula and the specifications have been given in the Table. 1.

TABLE 1 Specification of biogas stove

S. No.	Parameters	Specifications (in cm)
1.	Diameter of the Jet	1.6
2.	Diameter of the mixing pipe	9.7
3.	Length of the mixing pipe	67.9
4.	Diameter of the Mixing chamber	12.6
5.	Length of the Mixing Chamber	14.6

Proximate Analysis of the cashew nut shell sample:

The proximate analysis of the sample that is taken from the OS chips company have been found out to investigate the gasification potential.

Parameters	Value
Moisture Content (%)	10
Volatile Matter (%)	78.08
Ash Content (%)	2.04
Fixed Carbon (%)	9.88
Calorific Value	5163.2 kCal/kg

The volatile matter was found to be higher (78%) and the ash content was low (2%) which proves the gasification potential of the cashew nut shell. It is also evident from the results of previous researches that the volatile matter of 73.2% and the ash content up to 26% is optimum for gasification process [7].

IV. CONCLUSION

In this research the biogas required for the efficient frying of chips has been calculated and the stove has been designed based on the requirement. Also the gasification potential of the cashew nut shell has been studied and found that the can be significantly utilized for gasification process as it contains large volatile content and low ash content.

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