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Abstract. High fertile soil and optimum sunlight lead to steady increasing sugarcane production in India. It directs second place in sugarcane production. At the same time, the sugarcane-based industries are facing a huge hurdle of disposal of solid residual called biowaste. It is a major issue in a fast-developing country like India. Pyro-oil from biowaste is one of the favourable resources for alternate energy. In this paper, a solar concentrator was designed and fabricated for torrefying the biowaste to improve the bio-oil yield from pyrolysis reaction. The biowaste form sugarcane was characteristic by the thermal-degradation analysis and internal composition analysis. The biowaste was torrefied at various temperature 160 °C, 170 °C, 180 °C, 190 °C. The optimum temperature for the torrefaction was 180 °C at 1hour. The pyro-oil yield was 25.8% and 22.1% for torrefied biowaste and wet biowaste respectively.

1. Introduction

Relic-based carbon fuels fulfil 80% of energy needs for the world. Report from the department of economic and social affairs from UN states that every year 83 million people were newly added in the inhabitants [1]. Due to the exponential growth in inhabitants directs to high utilization of energy. It has been reported that a surge of 24% in energy demand by 2040 results depletion and up-market in crude oil [2]. Another reports from BP energy economic states that the estimated lifetime for fossil fuel was 40-60 years and coal will sustain for another 100 years [3]. Therefore, the upcoming trend in the energy sector was using economic fuel such as coal instead of crude oil. Our current technology to create electricity was burning coal or fossil fuels in power plant and it was the major contributor for greenhouse gas like carbon-di-oxide, methane and Sulphur-di-oxide [4]. These gases are a major contributor to the chance of climate variation and surface temperature. The most of the country's in the world face the global warming effect such as irregular weather pattern, typhoons and el-Nino [5]. The situation guides to avoid relic-based fuels and recommends to find a suitable environmentally viable fuel.

Bio-waste from sugarcane is one of the most capable substitute resources for fuels [6]. Due to its extravagant production in nature and high-level carbon content. India is the leading cultivator of sugarcane in the world. India cultivates almost 290 million tons of sugarcane per year. It is equal to 25% of sugar for the entire world. From one ton of sugarcane, nearly 305 kgs of bio-waste can be collected. In India, around 435 sugar mills have a steam boiler. Bio-waste is used as a fuel for the boiler due to its cheap availability. The direct burning of bio-waste from sugarcane will produce roughly about 2.5 kgs of steam for one kilo of biowaste. The evidence from the sugar mill association from India reports that 35.7 million tons of sugar are manufactured at 2018-2019 years [7]. It is 4 million tons greater than in

previous years. Due to the instant progress in the sugarcane sector will generate a large amount of bio-waste. Therefore, special consideration is necessary to manage the bio-waste of sugarcane. Traditionally, the bio-waste from sugarcane has been an open fire in the fields. It causes air contamination and heads to asthma, eye irritation and even lunges cancer. To overcome these hindrances, people are using the bio-waste as an additive for green brick, natural acoustic damper, producing ceramic, glass material and biofuel like ethanol [8] & bio-oil.

Pyrolysis is the most suitable process to converted biowaste into bio-fuels. In pyrolysis, bio-waste is warm up to 350 °C to 550 °C in the passive atmosphere [9]. Due to that hemicellulose, lignin and cellulose will rupture apart into small molecular. Its results, discharge of flammable gases such as H2 and CH4. In additional pyro-gas can convert into bio-oil by reducing the entropy. The left-over biochar is promptly used to water distillation and soil amendment [10]. To improve the pyrolysis efficiency of biowaste, moisture content should be diminished. It has been reported that biowaste from sugarcane has 45% - 51% of water content [11]. Torrefaction process is required to eradicate the bound moister. To minimize the power consumption for the torrefaction process. The solar collector is used to power the device for the desired amount. Effect of torrefaction in biowaste from sugarcane conducted in temperature 150 to 170 °C for residence time one hour. It's led to improvements in properties homogeneous configuration of biomass, higher bulk energy capacity, high porous structure, water repulsion capacity and eradicate the rotting small from the biowaste [12].

In this study, a solar collector was designed and fabricated, the optimum time and temperature were tested for torrefaction, Composition analysis and TGA/DTG analysis was tested for biowaste. Pyrolysis was performed for wet and dry biowaste from sugarcane.

2. Material and Experimental methods

Biowaste of sugarcane was collected from juice shop inside the VIT, Vellore campus. The wet and dry biomass was chopped and ground into small pieces, then it fed into a multistage sieve machine to segregate the desired particle size. The wet and dry biowaste were subjected to ultimate and proximate analysis. On the other hand, wet biowaste was dried using the solar collector. The solar dryer consists of a frame with parabolic shape, reflect material, a small reactor made up of copper tube (figure 1).
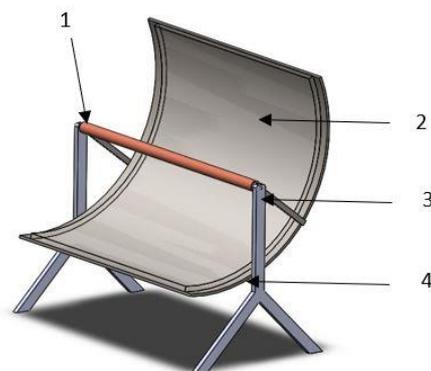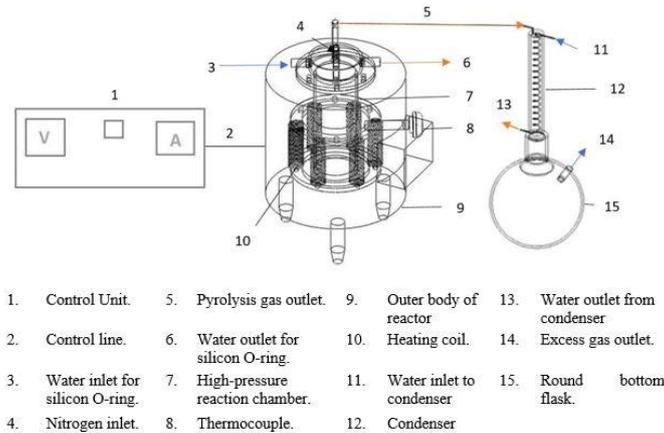

1. Copper Tube   3. Stand for solar collector
2. Reflecting surface   4. Parabolic frame

Figure 1. Solar collector for torrefaction

The space occupied by the solar collector was 1m × 1m × 1m. A steel frame is used to make an outer skeleton for the parabolic shape, where all the glass mirrors can fit in as a reflector. All reflector was focused on a single point to increase the temperature of the copper tube. All biowaste is kept inside the copper tube and kept on the focal point of the collector. The bio-oil were extracted from wet and dry

biowaste by pyrolysis reaction. The reactor consists of a furnace, biomass chamber, condenser unit, vacuum pump (figure 2).

1.	Control Unit.	5. Pyrolysis gas outlet.	9. Outer body of reactor	13. Water outlet from condenser
2.	Control line.	6. Water outlet for silicon O-ring.	10. Heating coil.	14. Excess gas outlet.
3.	Water inlet for silicon O-ring.	7. High-pressure reaction chamber.	11. Water inlet to condenser	15. Round bottom flask.
4.	Nitrogen inlet.	8. Thermocouple.	12. Condenser	

Figure 2. Fixed bed pyrolysis reactor for Sugarcane waste

Three-dimension measurement of the reactor is 0.25 m × 0.095 m × 0.005 m. The biomass chamber was constructed by 309 (S) stainless steel to resist high temperature. The furnace was covered by ceramic wool to prevent the heat loss. The total condenser unit was designed by the glass for easy visibility of oil flow. The vacuum pump is to suck the pyro-gas through the condenser column. Initially, wet biowaste of sugarcane was fed into the copper chamber and closed both the ends. The copper chamber was placed in the focal point of the parabolic solar collector. Due to the increases in temperature all unbound moisture will remove. Then the dried biowaste was tested ultimate and proximate analysis. On other hand, the dried biowaste was directly fed into the pyrolysis chamber. The temperature of 450 °C was set based on the thermogravimetric analysis and derivative gravimetric analysis. Finally, the pyro-oil yield was measured separately for wet and dry biowaste.

3. Theoretical Calculation
The volume of the solar power collector and the energy desired for torrefaction was computed. The equation is exploited to determine the complete energy for torrefaction [13].

$$Q_{total} = Q_{drying} + Q_{torr} \qquad (1)$$

Total energy essential for dry out was computed by the equation.

$$Q_{drying} = [(1-m)/100\ C_{pb}\ (T_{finial} - T_{initial})] + [m_w C_{pw}\ (T_{finial} - T_{initial})] + L \qquad (2)$$

The maximum and minimum energy required for torrefaction was 600 - 1000 kJ/kg. Assumed the torrefaction required 800 kJ/kg for 1 kg od biowaste.

$$Q_{torr} = [(1-m)\ C_p\ (T_{finial} - T_{initial}) + 800] \qquad (3)$$

Solar energy should be equal to the total energy for the drying and torrefaction. The total energy is the minimum energy for drying and torrefaction process. To obtain the desired total energy, area and length of the solar collector play the crucial role. The area of the solar collector was evaluated by the equation.

Average of the collector = (Q_{total} * 1000)/Average solar radiation * Collector efficiency   (4)

The diameter and the focal length were denoted as d and f respectively. Length of the solar collector was evaluated by the equation.

$$\text{Length of the collector} = \text{Area} / [(d/2) + (1 + (d^2/16f^2))^2 + 2f \ln (d/4f) + (1 + (d^2/16f^2))^2] \qquad (5)$$

4. Results and analysis

4.1. Feedstock analysis

The TGA/DTG graph denotes thermal degradation with regard to temperature. The TGA/DTG analysis was handled at 5 °C/min in an inactive environment. The TGA/DTG graph exposed in figure 3.
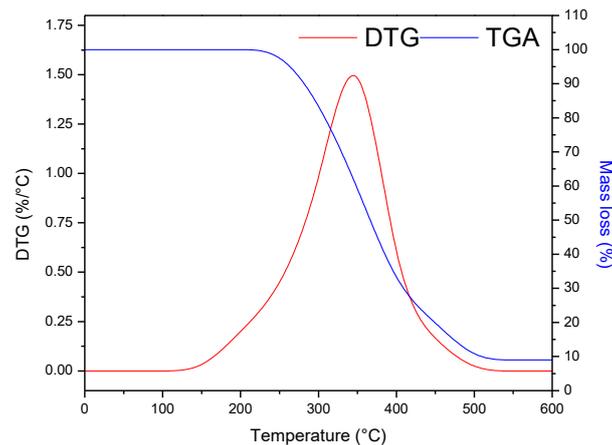
Figure 3. DSC/TGA analysis of sugarcane waste

The total degradation occurs between 0 °C - 600 °C. The TGA curve can separate into four areas. The first area denotes that removing of moisture and it occurs at 0 °C - 180 °C. In the second area, all cellulose and hemicellulose will rupture at 200 °C - 450 °C and it emit the combustible and non-combustible gases like H2, CO, CO2, CH4 and C_xY_x. The final area also called char formation area. It occurs at 450 °C – 600 °C. After 600 °C are called inactive area in that no mass loss occurs.

The proximate analysis shows 45.1% of moisture content, 69.5% of volatile content, 2.2% of ash content and 11.2% of fixed carbon content. Biowaste is more suitable for pyrolysis process due to its high volatile content and low ash content. These two parameters were more significant for high yield at low temperature. The proximate, ultimate analysis was revealed in Table 1.

Table 1. Psychochemical analysis of sugarcane biowaste

Proximate Analysis		Ultimate Analysis		Chemical Composition	
Moisture (%)	45.1	C (%)	42.98	Cellulose	43.3
Volatile (%)	69.5	H (%)	4.6	Hemi-Cellulose	31.5
Ash (%)	2.2	O (%)	22.18	Lignin	12.9
Fixed carbond (%)	11.2	N (%)	39.12	-	-
Q_{net} (KJ/kg)	1875	S (%)	-	-	-

The ultimate analysis shows 42.98%, 4.6%, 22.18% and 39.12% for carbon, hydrogen, oxygen and nitrogen respectively. The oxygen content was considerably lesser than wood biomass (40% to 45%). The quality and oxidational stability of pyro-oil will boost by the lesser oxygen content. Biowaste contains zero percentage of sulphur content. It means fuel taking out from biowaste is suitable for BS-VI norms. The energy value of biowaste was 18.75 MJ/kg It is roughly equivalent to brown coal. The chemical composition indicates 43.3% of cellulose content, 31.5% of hemicellulose content and 12.9% lignin content. Cellulose and hemicellulose content were much higher than the typical wood. High lignin

was unfavourable substance for incineration process but biowaste from sugarcane shows much lower than the other biomass. It is a more positive approach to the pyrolysis method.

4.2. Experiment
From equation (1) to (5) is used to calculate the basic parameters for the collector (table 2).

Table 2. Calculate value for the solar collector

Parameters	Value
Q_{total}	1.59 MJ/kg
Area	1.052 m^2
Length	0.91 m
Diameter	1 m
Focal	0.25 m
Rim angle	90°

Torrefaction is a pre-processing method used to shrink the unbound moisture and intensify the energy value of the biowaste. It further diminishes the unsaturated group and promotes the hydrogen bonds. In torrefaction, mass loss occurs and volatile gas rises by converting the cellulose component into hemicellulose. One kilogram of biowaste from sugarcane was packed into the copper tube. To avoid heat environmental contact both side of the tube was sealed by a copper cap. The copper tube was placed at the focal point of the parabolic collector. The parabolic collector guides the sun radiation to the focal point to increases the temperature (Figure 4).


Figure 4. Parabolic solar collector

The experimentation was carried out at four different temperature (160 °C, 170 °C, 180 °C and 190 °C) for one hour to estimate the unbound moisture (table 3). The moisture content was degraded from 45% to 7.56% at 190 °C but few biomasses started the carbonization process. It clearly shows 190 °C was not suitable for the pyrolysis process. The next least moisture content was 190 °C. It reduces 45% moisture to 8.01%. The least moisture without carbonization process is better for the pyrolysis. After torrified, the biowaste was sent to the grinding machine to convert in the form of powder.

Table 3. Moisture content after torrefaction of sugarcane biowaste

Temperature (°C)	Moisture (%)

160	9.56
170	8.72
180	8.01
190	7.56

Then, the powder was filled in the biomass chamber and sealed to prevent the contact from the atmosphere. The experiment was performed in three different temperature 450 °C, 500 °C, 550 °C. The highest yield was attained from 500 °C. On the other hand, an identical experiment was conducted for wet biowaste (Figure 4.).
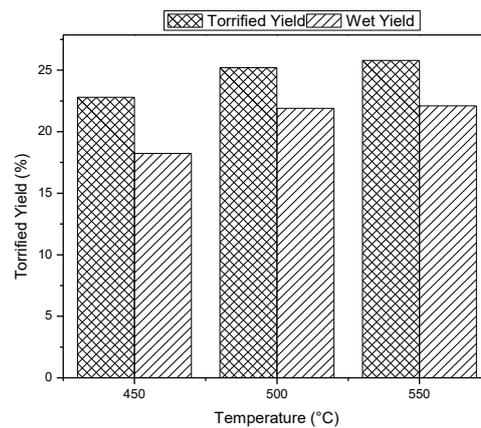
Figure 5. Pyro-oil yield for torrified and wet biomass

The graph shows that the pyro-oil yield for torrefed biomass was slightly higher than the wet biomass. It is due to the conversion of hemicellulose to cellulose component by limiting the OH group. It makes the biowaste into a high energy source. Torrefaction process leads the biowaste to a brittle material. Due to that, biowaste can convert into a fine particle which enhances the heat conduction property for the biowaste. This property plays a vital role in the pyrolysis yield.

5. Conclusion
Biowaste from sugarcane has high unbound moisture and it is the major hindrance for the pyrolysis process. To rectify this drawback a solar collector was designed and manufactured for the torrefaction. The research was conducted to find the optimum temperature for the torrefaction process and a higher yield on bio-oil.
1. Four different temperature (160 °C, 170 °C, 180 °C and 190 °C) were studied on torrefaction process. From that, 180 °C showed low unbound moisture without starting of carbonization process.
2. Pyrolysis was conducted for wet and torrefed biowaste. Wet biowaste produced less pyro-oil and high-water content. On the other hand, torrefed biowaste produces less water content and more pyro-oil. The highest yield for pyro-oil was 25.8% and 22.1% for torrefed biowaste and wet biomass respectively.

The inferences of this project confirm that the torrefed process diminishes the unbound moisture with the help of free solar energy and indicates that torrified biowaste at 500 °C produces extreme pyro-oil yield.

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