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Briquette Production from Teak and Neem Twigs Biochar with Selective Binding Materials

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Biochar is the solid residual material obtained after carbonisation or slow pyrolysis of biomass in a controlled condition, typically at a temperature range of 450°C to 510°C in the absence of oxygen to remove water and other volatile constituents from the parent biomass in a closed vessel. The Agricultural Engineering College and Research Institute (AEC & RI), Trichy campus premises has more than 1500 teak trees and neem trees. Pruned twigs of these trees are collected and converted into biochar briquettes through pyrolysis and briquetting technology. The fixed carbon content was found to be 11.5% for teak twigs and 12.5% for neem twigs biomass. Pyrolysis of raw materials is carried out at a temperature range from 450°C to 510°C in a 100 kg capacity pyrolysis reactor. An average biochar yield of 25.7 % and 31.6 % were obtained for teak and neem twigs respectively. The fixed carbon content of 65 % and 68.20% is obtained for the biochar produced from teak and neem twigs respectively. Cow dung and rice gruel starch were used as binders for making biochar briquettes. Cow dung and rice gruel starch were mixed with the biochar with different proportions at 30%, 40%, 50% and 60%. Biochar briquettes were analysed for their thermal and physical properties. The biochar to cow dung ratio of 1:0.3 for both teak and neem twigs gives stable briquettes of 13 cm in length. The fixed carbon content of teak twig biochar briquette and neem twig biochar briquette is 71.96% and 73.47% respectively by using cow dung as binder whereas it was 71.30% and 70.60% respectively with rice gruel starch as binding material.

1. Introduction

Biomass has very high potential and naturally abundant domestic energy source. It is the most promising energy alternative to mitigate greenhouse gas emissions. Agricultural waste materials include timbering residues, tree pruning twigs, oil seeds shells, rise husks and straws, cotton wastes, cassava peels, sugarcane bagasse etc. As an energy resource, biomass may be used directly as solid fuel for cooking, or converted into liquid or gaseous fuels via variety of technologies such as pyrolysis, gasification and combustion. The world's population is increasing, so the energy demand is also increasing. Energy is required for industrial, agricultural, and transportation development, power generation, and many more different sectors (Jelonek et al., 2020).Waste agricultural biomass is often under- utilized, more also there is a rapid increase in the volume and types of waste agricultural biomass produced worldwide due to intensive agricultural activities in the wake of population growth and improved living standards (Awuluet al., 2015). Most of these problems are associated with the low bulk density of agro-residues. One approach to checkmate these setbacks and efficiently utilize agricultural wastes as fuel is by their densification to produce charcoal briquettes (Bianca et al., 2014). The quality of charcoal depends on both the biomass source used as a raw material and the proper application of the carbonization technology (Sunu et al., 2023). The best binder for a given application depends on the locality and the kind of biomass being briquettes as well as the purpose for which the briquette is finally intended (Davies and Davies, 2013). The production of Biochar briquettes is a way to transform agricultural waste materials into a valuable fuel. This work aims to use the ubiquitous agro-wastes: teak and neem twigs to produce biochar briquettes with selective binders

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2. Materials and Methods

The Agricultural Engineering College and Research Institute, Trichy campus premises has more than 1500 Teak trees and Neem Trees. Pruned twigs of these trees were collected and converted into biochar briquettes through slow pyrolysis and briquetting technology.

Figure 1 Teak twigs

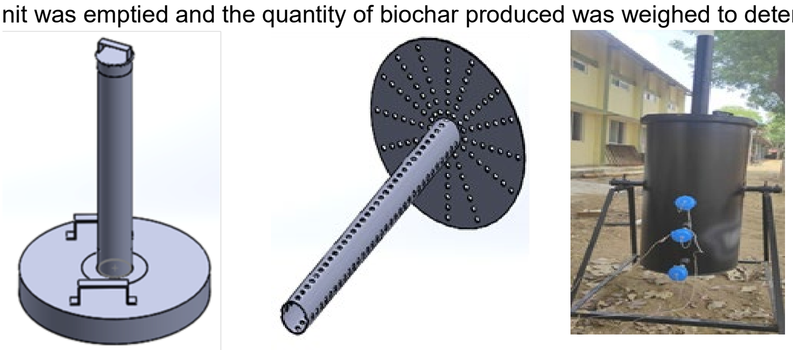
Figure 2 Neem twigs

2.1. Characterization of biomass

The proximate composition of selected biomass and its biochar was analyzed based on ASTM E1755-56. The ultimate composition was calculated by using the correlation equation proposed by Shen et al., 2010 for each element. $C = 0.635FC + 0.460VM - 0.095ASH$ (wt%), $H = 0.059FC + 0.060VM + 0.010ASH$ (wt%)
$O = 0.340FC + 0.469VM - 0.023ASH$ (wt%). Thermo gravimetric analysis of teak twigs was carried out in Themys one TG – DSC1200°C unit available at AEC & RI, Trichy. The sample was heated up to 900°C in an inert atmosphere at a rate of 10°C per minute. The thermogram obtained by plotting per cent weight loss per °C as a function of temperature was analysed to know the temperature at which the pyrolysis gets initiated, reaches its peak and terminates. The higher calorific value of biomass and biochar briquette is determined by using Bomb calorimeter.

2.2. Pyrolysis unit

A double-walled pyrolyser of 50 kg capacity as shown in Figure 3 is used for the production of biochar from teak and neem twigs. The specification of the Pyrolysis unit is presented in Table 1.
The teak and neem twigs were dried, size reduced to length of 3-4 inches. Red hot charcoal was fed into the pyrolyzer before the addition of selected biomass. The temperature of the pyrolysis process is monitored with a thermometer by inserting into the holes provided in the pyrolyser. A blower is used to blow the air inside the pyrolyser unit initially to maintain the temperature of red-hot charcoal. After feeding the raw biomass, the lid is closed and the chimney is placed over it for allowing the volatiles to escape. The chimney was replaced with a lid when the volatiles release gets ceased. The unit is kept undisturbed for nearly 8 hours. Then the pyrolyser unit was emptied and the quantity of biochar produced was weighed to determine the yield of biochar.



Lid with chimney *Grate with central pipe* *Pyrolyser*

Figure 3 Double walled pyrolyser

Table 1 Specifications of Double walled pyrolyser

Details	**Units**
Pyrolyser type	Batch type
Capacity	50 kg
Material	Mild Steel
Outside cylinder (dia)	43cm (10G M.S. Sheet)
Inner cylinder (dia)	36cm (16 G)
Bottom plate (dia)	43.2 cm (10 G)
Top lid (dia)	43.5 cm (10 G)
Grate (dia)	35.5 cm (10 G)
Chimney height	45 cm
Insulating material	Glass wool
Thermocouples	3 nos.

Pyrolysis - start up *Biomass loading* *Biochar*

Figure 4 Biochar production process

2.3. Biochar briquette Production

The biochar obtained from the pyrolyser was powdered into fine particles and then sieved using a 100×10^{-6} sieve. The sieved pulverized biochar was taken and used for briquette production. Cow dung and rice gruel starch were used as binders for making biochar briquettes. Starch and cow dung were mixed with the biochar with different proportions of 30%, 40%, 50% and 60%. The mixture was then stirred until it was blended with binders. Then the mixture was fed into the briquetting machine and briquettes were produced at 29.4 MPa. The produced cylindrical briquettes were shade dried. During drying, the bio-briquettes were flipped so that they would dry evenly. The biochar briquettes were tested for its durability and water resistance. The briquettes were dropped 4 times from 1.85 m height onto a concrete surface. The weight retained by the briquette at the end of 4 drops as the percentage of initial weight was considered as the briquette durability. The briquettes are immersed in water for 5,10,15 and 20 minutes duration. The water resistance was obtained from the percentage of water absorbed by a briquette. Based on the withholding capacity in water, its water resistance was expressed as poor (5 minutes), fair (10 minutes), good (15minutes), and excellent (20 minutes) quality.

Figure 5 Biochar briquettes production

3. Results and Discussion

3.1. Characterization of biomass, biochar and biochar briquette

The Proximate analysis of Teak and Neem twigs, biochar and were presented in the Table 2. The fixed carbon content of Teak twig samples varies from 10.5 % to 12.5% and 11.5 % to 12.5% for Neem twigs. An average biochar yield of 25.7% and 31.6 % were obtained for Teak and Neem twigs respectively.

Table 2. Proximate analysis of teak and neem twigs and biochar

Biomass	Moisture content (%)	Volatile Matter, VM (%)	Fixed Carbon, FC (%)	Ash content (%)
Teak twigs	6.50	78.40	11.50	3.60
Neem twigs	6.20	78.30	12.50	3.00
Teak twig biochar	4.00	28.00	65.00	3.00
Neem twig biochar	3.50	25.80	68.20	2.50

The suitability of Teak twigs and Neem twigs for the pyrolysis process was confirmed using thermo gravimetric analysis. The TGA was performed in TG (Make and Model) and the result was depicted in Figure 6 and 7.

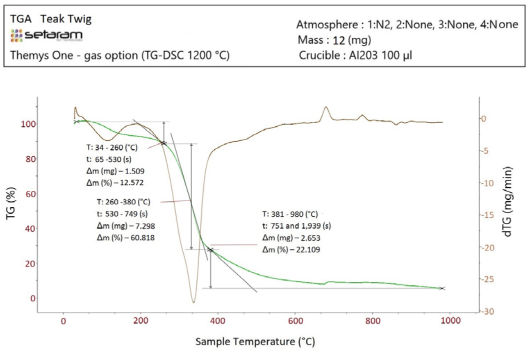


Figure 7 TGA of Neem Twig

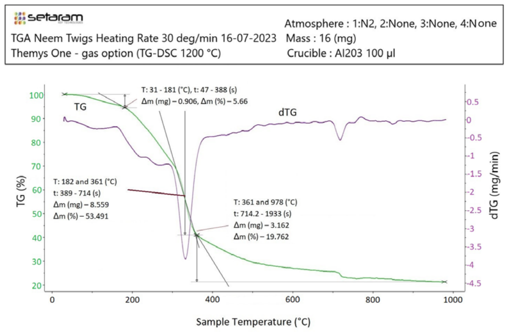


Figure 6 TGA of Teak Twig

From the figure, it was confirmed that the feedstock undergoes the degradation process in three different phases namely, moisture evaporation, main devolatilization, and continuous devolatilization. Initially, the weight reduction or moisture evaporation range was found to be at the very lesser rate of around 6 to 15 % per C up to 200 °C and afterwards till 380 °C it was at a higher rate of 50 to 60 % per °C and finally till 980 °C it was at a lesser rate as 18 to 20 % per °C. It was also observed that till 260 °C, there was a linear reduction rate, then from 260 to 380 °C have strategic change with increasing rate and gradually it tended to linear curve with a low reduction rate till 980 °C. It was confirmed that the volatile release was higher and char can be obtained as a product from teak and neem twigs by setting this as reaction temperature in pyrolyzer. The thermal decomposition of the biomass samples can be achieved by one reaction stage (Adetoyese et al., 2014).The values of proximate analysis were used to determine the elemental composition (C, H and O) for biomass through the correlation equation proposed by Shen et al., 2010.It was observed that the moisture content was low and ranged from 6.2 to 6.5% for teak and neem twigs and 3.5 to 4 % for teak twigs and neem twigs biochar respectively. Lower moisture content can produce high heat values and will produce briquettes that are easy to ignite or initially burn. Lower the water content, higher the heating rate and combustion power. Ash content is the non-combustible component of a biomass and higher the fuel's ash content, the lower is its calorific value (Mencarelli et al., 2022). The result of the ash content of teak and neem twigs were found to be 3.6 to 3.0% respectively. Ash content was influenced by the quality of biomass used. Ash content can affect the calorific value of briquettes. Lower ash content is valuable and higher ash content trouble burning. The ash is capable of blocking air from penetrating into the stove, thereby retarding the burning rate (Emerhi, E. A., 2011). Volatile content of raw biomass and biochar is significantly noticed. The volatile matter is much influenced by chemical component of biochar such as presence of extractive substance from charcoal raw material (Kaur et al., 2017). The Fixed carbon is normally determined by the difference in the other quantities, such as moisture, volatile matter and ash content, of the total biomass in percentage. The result of the measurement of fixed carbon of raw biomass is in the range of 10 to 13%. Fixed carbon increased of biochar briquettes were in the rage of 65% and 68% for teak and neem twigs. The elemental composition of raw biomass and its bio char is presented in Table 3.

Table 3 Elemental composition for biomass and biochar using Shen equation

Biomass (wt.%)	Carbon (%)	Hydrogen (%)	Oxygen (%)
Teak twig	43.02	5.42	40.60
Neem twig	43.67	5.46	40.90
Teak twig biochar	53.87	5.54	35.16
Neem twig biochar	54.93	5.59	35.23

The biochar obtained from teak and neem twigs were mixed with semi solid rice gruel which is obtained from the student's hostel mess in the proportions of 30%, 40% and 50%. The mixture was fed to the briquetting machine. Stable length of 10 cm to 14 cm biochar briquette is obtained from the 30% rice gruel mixture. It is observed that the 40% and 50% rice gruel mixture led to collapsible briquette, even when it is coming out of the screw extruder itself. Water oozes out was observed for 40% and 50% rice gruel mixture. The biochar obtained from teak and neem twigs were mixed with wet cow dung as received from the cattle shed, in the ratio of 30%, 40 % and 50% proportions. It is observed that for all the proportions, briquette with a stable length of 13.5 to 15.0 cm was attained. Hence, for economic usage of cow dung, biochar and cow dung proportion of 1:0.3 was considered for making biochar briquettes. The characteristics of biochar briquettes are presented in Table 4.

Table 4 Characteristic analysis of biochar briquettes

Proximate analysis	Biochar briquettes (BB) using rice gruel starch as binder		Biochar briquettes (BB) using cow dung as binder	
	Teak twigs BB	Neem twigs BB	Teak twigs BB	Neem twigs BB
Moisture content (%)	05.30	5.70	5.91	05.18
Volatile content (%)	20.50	21.6	18.93	18.25
Ash content (%)	02.90	2.10	03.20	03.10
Fixed carbon (%)	71.30	70.6	71.96	73.47
Elemental analysis using Shen Equation for Briquette Samples using Rice gruel as binder (1:0.4)				
	Teak twigs BB		Neem twigs BB	
Carbon (%)	45.54		54.56	
Hydrogen (%)	5.51		5.48	
Oxygen (%)	40.34		34.08	
Elemental analysis using Shen Equation for Briquette Samples using cow dung as binder (1:0.3)				
	Teak twigs BB		Neem twigs BB	
Carbon (%)	44.81		45.09	
Hydrogen (%)	05.46		05.51	
Oxygen (%)	40.11		40.59	

From the above results, neem twigs biochar briquette using cow dung binder has high fixed carbon content of 73.47% than the starch. The ash content ranged between 2.1-3.1% for neem and teak twig biochar briquettes. The values of proximate analysis were used to determine the elemental composition for biomass through the correlation equation proposed by Shen et al., 2010. The raw biomass and biochar briquettes were tested for its calorific value using Bomb calorimerter, durability and water resistance and the results were presented in Table 5.

Table 5. Calorific value of biomass briquettes

Biomass		Calorific value (kJ/kg)	Durability, %	Water resistance
Teak twigs		30902	-	-
Neem Twigs		29827	-	-
Rice gruel starch binder	Teak twigs BB	33287	94.2	Good
	Neem twigs BB	32850	93.5	Good
Cow dung binder	Teak twigs BB	35767	95.5	Fair
	Neem twigs BB	35666	94.3	Fair

The calorific values for the teak twigs biochar briquette was found to be 33287 kJ/kg (starch as binder) and 35767 kJ/kg (cow dung as binder). The calorific value of the briquettes was found to be high when compared to biomass. Cow dung binder gives the higher calorific value than starch. It is similar to the results found by Olorunnisola, 2007 and Pallavi *et al.,* 2013. Usage of briquettes as a fuel gives best result in terms of calorific value when compared to the usage of raw biomass as a fuel (Nicholas, 2012).

4. Conclusion

In this study, briquettes were produced teak and neem twigs with rice gruel starch and cow dung as binding materials. The raw materials and its briquettes were analysed for proximate composition, elemental composition and calorific values. The biochar yield of 25.7% and 31.6 % were obtained for teak and neem twig respectively. Briquettes were produced with 1:0.3 (biochar: cow dung) ratio and 1: 0.4 (biochar: rice gruel starch) gives good water resistance and more than 90% durability. In general, the production of briquettes from these residues and binding materials helps us to provide renewable, clean, and sustainable energy and a substitute for fuel wood and charcoal.

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