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Analysis physical parameters of raw biomass to produce waste based briquette: A steps towards waste management in Assam

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ABSTRACT

India mostly relies on domestic coal for energy production and foreign oil for transportation. Most of the energy requirements of rural indigent people are supplied in the least efficient way possible by burning wood and other biomass, which increases greenhouse gas emissions. The population of India increasing day by day which leads to a serious energy requirement in commercial and industrial activities. In industry's main concern today is to minimize by-products, compost organic waste and agro waste. Therefore, the effort is to convert waste collected from industries into briquette which is one of the essential burning materials, which can be used extensively in rural area of Assam as well in industry. The abundance of waste in the industry in Assam, was taken into consideration when choosing the raw materials for biomass. In Assam tea is abundantly available and solid tea waste is generated on a daily basis from the tea estates. The tea industry is eminent for the huge amount of solid waste generated from the withering, rolling, fermenting, drying and grading of raw materials. Solid tea waste, bamboo and sawdust are the materials used. These materials were obtained from tea estate, paper mill and Timber Wood Shop. A proven approach of turning waste into energy is using biomass briquettes. Utilization of waste to prepare biomass fuel, provide eco-friendly and alternate source of energy.

This research examines the characterization of biomass collected from industries which includes solid tea wastes, bamboo and saw dust. The samples undergo Physical, proximate and thermal analysis. The waste product collected from industries had calorific values between 17.24 and 18.5 MJ/kg. The average moisture content was found in tea waste, saw dust, carbonized bamboo is 7.14, 8.65 and 4.2 Percent. The volatile matter of tea waste, saw dust, carbonized bamboo biomass has the value of 70, 76.18, 18.5 per cent. Ash content of tea waste, saw dust, carbonized bamboo has 7.5, 1.60, 5.8 per cent. This study demonstrates that biomass from carbonized bamboo, sawdust, and tea trash may all be used to make fuel briquettes, a source of renewable energy. Compared to fossil fuel, it is more inexpensive, cost-effective, and environmentally benign.

1. Introduction

More than half of the countries, total land dedicated to tea growing is found in Assam. More over half of India's total tea production comes from Assam alone. In Assam, tea is produced on average annually in amounts between 630 and 700 million kg (industries.assam.gov.in). During, tea production process large number of tea residue is dumped as waste .The disposal of tea residue is becoming a major ecological and environmental problem. This not only causes environmental pollution, but also a huge waste of biomass resources (Debnath, Haldar et al. 2022). Waste utilization from the industries is major challenge in developing country. Due to inconsistency data collection method it is difficult to determine the exact quantity of waste disposal from the industries and household (Guerrero, Maas et al. 2013). The waste is generated from the withering, rolling, fermentation,

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drying and grading of raw materials. Due to the ineffective or, in some cases, nonexistent usage of these trash materials, environmental contamination grows in the vicinity of these industries (Mussatto, Ballesteros et al. 2012). The population of India increasing day by day which leads to a serious energy requirement in commercial and industrial activities. In industry's main concern today is to minimize by-products, compost organic waste, and agro waste(Thomas, Soren et al. 2017). Therefore, the effort is to convert the tea waste, into briquette which is one of the essential burning materials, which can be used extensively in rural area of north-east as well in industry. Utilization of tea residue to prepare biomass fuel, provide eco-friendly and alternate source of energy. In Assam tea is abundantly available and solid tea waste is generated on a daily basis from the tea estates. Biomass briquetting is the process of compaction of raw biomass by using required pressure to get the desired shape and size. Briquetting is an effective way of utilizing the industrial residue, agro waste and compost organic waste(Yadav, Krishnan et al. 2021). It is an effective, efficient and alternative energy source for rural and sub-urban communities and industry as a substitute of coal. The briquetting technology in the India still needs to undergo several improvements. Solid waste management in industry is an important challenge in developing and emerging countries. In India population is growing rapidly, the necessity of energy is also increasing .In rural and semi urban area of Northeast, Tree/ wood based Charcoal are one of the essential burning materials used extensively in north east(Bhatt and Sachan 2004). However, making of charcoal is a big environmental issue as it directly leads to deforestation of forest land as well as climate change effect. Due to the continuous use of traditional fuel may cause respiratory problem as it emits smoke. It is necessary to motivate the community to use of briquette for domestic cooking since it is smoke-free(Shrestha 2014). Production of biomass briquette from waste has increased the economic level of many local by giving incentives for the supply of waste and it also creates employment in the process of briquette production center as well as revenue generation from final product (Romallosa and Kraft 2017). Briquette can burns with a small flame and with less smoke, and cook with even heat and is long-lasting. It does not require chopping. It is clean, smokeless, odourless, sparkles, and thus more suitable for slow cooking. It has less crack and better strength. It will help in generating job opportunity in rural areas of developing countries. This technology is comparatively pollution-free and eco-friendly. Indirectly it is a way to utilize the total energy available on a farm to generate electricity/thermal heat. Therefore, briquetting of biomass after carbonization would be a promising option (Khobragade, 2015).

This study focuses on a comprehensive sustainability assessment of the management of solid waste in Assam. In Today's world we are facing environmental issue which is a global crisis as well as hike of fossil fuel; renewable energy source is a crucial matter. It is time to realize green energy objectives and the Government of India's efforts towards a carbon – neutral economy (Balasubramani, Anbumalar et al. 2016). Alternative source of energy production and utilization may lead to the economic development of country. Development of country is not possible without requisite and reasonable supply of energy. Utilization of the solid waste in order to obtain valuable products several effort has been made. It was able to make biomass briquettes from tannery solid wastes (TSWs) and characterize them (Onukak, Mohammed-Dabo et al. 2017). The enormous amount of poisonous solid and liquid waste produced by the cleaning, fleshing, splitting, tanning, shaving, and polishing of raw materials is well-known in the tannery industry. TSWs were gathered from a tannery in Kano, Nigeria, and included hair, flesh, chrome shavings, and polishing dust. These materials were used to create and characterize six briquettes. Designed and fabricated dually operated screw press briquette machine and performance was evaluated for 30 mins of an interval of 5 mins (Fadeyibi and Adebayo 2021). The efficiency of the briquette machine increased with an increase in the resident time. Characteristics of briquette from forest waste such as Jatropha seed shell and Eucalyptus Camaldulensis wood shaving with binder agent Acacia Senegal (Fadele, Amusan et al. 2021). The mixture proportion was 0:100, 25:75, 50:50, 75:25 and 100:0 while the binder was varied from 50, 60, 70, 80 to 90 g and optimized the physical properties by using the response surface methodology at mixture proportion (Carnaje, Talagon et al. 2018).Many stack holders are giving huge effort to produce briquette and investment to remove the waste (water hyacinth) for conserving the water resource. On the other hand Tree/ wood based Charcoal is one of the essential burning materials used extensively in Assam. However, making of charcoal is a big environmental issue as it directly leads to deforestation of forest land. Objectives of the research work is to study of different properties of the raw biomass and to evaluate the performance of briquetting machine(Wu, Zhang et al. 2018).

2. Materials and Methods

The biomass waste collected from anindustries located in local area (Assam, India). In lab, series of experiment carried out in the Department of Agricultural Engineering to check the physical parameter like percentage of moisture content, volatile matter, ash content, fixed carbon, bulk density and calorific value.

2.1Procedure for the production of briquette

2.1.1Selection of raw material

The abundance of waste in the industry in Silchar, Assam, was taken into consideration when choosing the raw materials for biomass briquettes. These wastes include sawdust, solid tea waste and bamboo. A particular species of acacia tree (*Acacia denticulosa L*) is utilized as waste, specifically for sawdust, because it grows quickly and is extensively marketed in the market as wood for use as a construction related preconstruction materials. Solid tea waste, bamboo and sawdust are the materials used. These materials were obtained from tea estate, paper mill and timber wood shop.

2.1.2 Collection of sample

Biomass are abundantly available in the valley parts of Assam. Effort has been made to collect the waste biomass. Local people are allowed to collect waste in large scale and allowed to transport to the manufacturing place and providing them with incentives nominal incentive were given to them. These processes make the local individual not only the opportunity increase their economy as well as indirectly helped to clean the environment.

2.1.3 Procedure

Biomass was dried and briquetting was accomplished by compressing the grinded biomass in to potential energy source under a pressure of 5000 kg/m^3 using hydraulic press in a compression cylinder in which piston is attached directly to hydraulic press. The dry grinded sample was fed through hopper and extruder to convey the mixture of biomass and the binder materials. The entire briquetting will be accomplished in the developed and fabricated machine.

2.2 Experimental design and briquette preparation

The different processing steps are shown in Figure1. Biomass briquetting is the process of compaction of raw biomass by using required pressure to get the desired shape and size. Briquetting is an effective way of utilizing the industrial residue, agro waste and compost organic waste. As they are made from garbage, briquettes are incredibly affordable. It is an effective, efficient and alternative energy source for rural and sub urban communities and industry as a substitute of coal.

2.3 Biomass preparation (carbonization of bamboo)

Bamboo waste was collected from industries. Portable charring kiln was a simple unit for converting bamboo to a charred mass. The collected bamboo was placed and packed inside the cylindrical metal drum. The drum which was accommodates about 80 kg of biomass. The drum size was about 750 mm height and 550 mm diameter made out by 16 gauge mild steel sheets. The negligible amount of air was considered for carbonization process. A kiln was closed with metal lid after loading with biomass is shown in Figure 2. Due to absence of air heat spread over the biomass and carbonized samples were obtained.

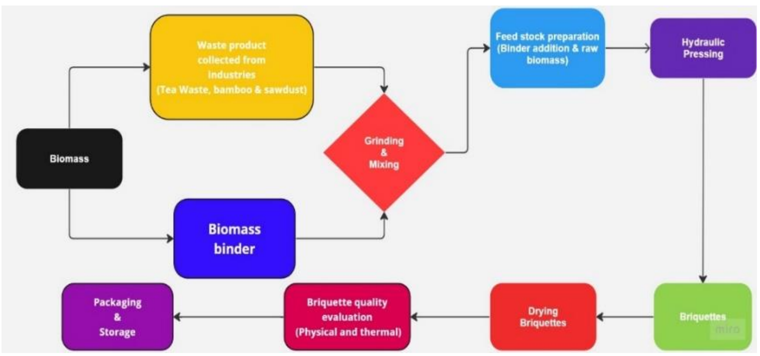

Figure 1. Overview of the utilization of the waste from the industries to briquette development.

Figure 2. Process of carbonization of bamboo

2.4 Proximate Analysis

Proximate Analysis of the raw biomass was carried out to determine percentage volatile matter, percentage moisture content, percentage ash content and percentage fixed carbon.

2.4.1 Percentage moisture content:

The recommended oven-drying technique was used for both organic and inorganic materials. On an analytical balance, the samples (weighing between 1.0 and 1.5 g) were weighed at least three times. The samples were put into a drying oven after being weighed. The temperature was set at 105°C for inorganic materials and 85°C for organic compounds (Suman 2021). Drying was done until constant weight was attained for both inorganic and organic materials (difference 1 mg). The drying procedure has to be completed in between 8 and 60 hours. It should be noted that prolonged drying intervals may cause some volatile non-water components to lose noticeably. These components will begin to evaporate even at shorter drying times and will affect the outcome. After that, a desiccators was used to chill the samples to room temperature. The samples were routinely weighed back (more than three times) once they had reached room temperature, which took around 0.5 hours (Vogl and Ostermann 2006) .

$$MC\ (\%) = \frac{W2-W3}{W2-W1} \times 100 \qquad ....1$$

Where,

W_1= weight of empty crucible,

W_2 = weight of empty crucible + sample,

W_3 = weight of empty crucible + sample after heated.

2.4.2 Percentage volatile matter (VM):

The standard procedure ASTM D-3175 was used to calculate the percentage of volatile matter (VM). The amount of substances lost when the biomass sample is cooked in a muffle furnace at a temperature of 900 °C for seven minutes is known as the volatile matter (VM) (%). It's the gaseous phase that results from the materials' heat deterioration. This equation 2 was used to classify weight loss as volatile matter (Suryaningsih, Nurhilal et al. 2017).

$$VM\ (\%) = \frac{W3-W4}{W2-W1} \times 100 \qquad ….....2$$

Where,

W_1 = weight of empty crucible

W_2 = weight of empty crucible + sample,

W_3 =weight of empty crucible + sample after taken from the stage (I),

W_4 = weight of empty crucible + sample after cooling.

2.4.3 Percentage ash content (AC):

Ash in biomass naturally has an alkaline pH, which indicates the mineral concentration. The ASTMD-3174 is used to measure the ash value. Biomass are cooked in the muffle furnace for three hours at a temperature of 800 C to determine the ash content AC (%). The samples are then withdrawn from the furnace once the furnace has been switched off and the temperature has dropped below 400 C. If it is really cold, samples will be weighed and the results determined using the Equation 3 (Suryaningsih, Nurhilal et al. 2017).

$$AC\ (\%) = \frac{W5-W1}{W2-W1} \times 100 \qquad ....3$$

Where,

W_1= weight of empty crucible,

W_2 = weight of empty crucible + sample taken from stage (II),

W_5 = weight of empty crucible + ash left in the cup.

2.4.4 Percentage fixed carbon:

The percentage fixed carbon (FC) was computed by subtracting the sum of VM, AC and MC from 100.

Fixed Carbon = 100% — (VM + AC + MC) 4

2.5 Thermal analysis

2.5.1 Calorific Value

One of the key quality aspects of a fuel is the calorific value (CV), in effect the amount of potential energy the fuel contains which can become available, upon combustion, as heat. This known as the calorific value. To measure calorific value, we use a calorimeter in accordance with CEN/TS 14918 Standard Method. The calorific values of samples were calculated by the equation 4. The fuel is first combusted with oxygen, under pressure in sealed bomb. The heat of the subsequent reaction is measured from the temperature rise of a surrounding water bath (Onukak, Mohammed-Dabo et al. 2017).

$$Qv = \frac{C(Q1-Q2)}{Wb} \qquad ....5$$

Where,

Q_v = Heating/Calorific Value (kJ/kg),

C = Calibration of constant for biomass acid (0.6188),

Q_1 = Galvanometer deflection without sample,

Q_2 = Galvanometer deflection due to test sample, and

W_b = Weight of sample

2.6 Physical properties of biomass

2.6.1Bulk Density

The Standard Method CEN/TS 15103 was used to measure the bulk densities of the industry-collected biomass. The mass of biomass was divided by the total volume the sample occupied to get the bulk density (dry basis)which is expressed in equation 5 (Onukak, Mohammed-Dabo et al. 2017).

$$\rho = \frac{m}{v} \quad ....6$$

Where,

ρ = density of biomass sample.

m = mass of biomass sample.

v = volume of the vessel.

3. Results and Discussion

The current energy policy in Assam, aims to replace the energy obtained from fossil fuels with that from renewable energy sources. One of the main sectors of concentration is the power sector by the Government of Assam in order to promote sustained industrial growth. A new, alternate heating source that is widely accessible, has a low price while still having a high energy value is needed. One of the potential solutions is the investing on briquette technology.

3.1.Carbonization of bamboo

The directly utilization of bamboo for making briquettes was difficult. The biomass was carbonized in metallic kiln. The extraction of oil it was very difficult and costly process. The size reduction of cashew shell for directly used for briquetting its required lot of electrical, mechanical and man power because firstly it's converted into powder form.

3.2 Average temperature recorded during the carbonization of rice husk

Bamboo waste was carbonized for obtained char and ash. The average temperature of the rice husk was varied 90.2 °C to 257.8 °C at the upper zone of the kiln. The average temperature at the lower zone of the kiln was varied 42.5 °C to 209.2 °C. The average kiln surface temperature was varied from 69.5 °C to 199.1 °C. It was also observed that the kiln surface temperature was less than the inside temperature of the kiln. The time required for carbonization of bamboo was 5 hours but the time required for the kiln to cool down and removal of char was about 8 to 10 hours.

3.3 Analysis of carbonized biomass

The char percentage, oil percentage and ash percentage obtained during the carbonization process.

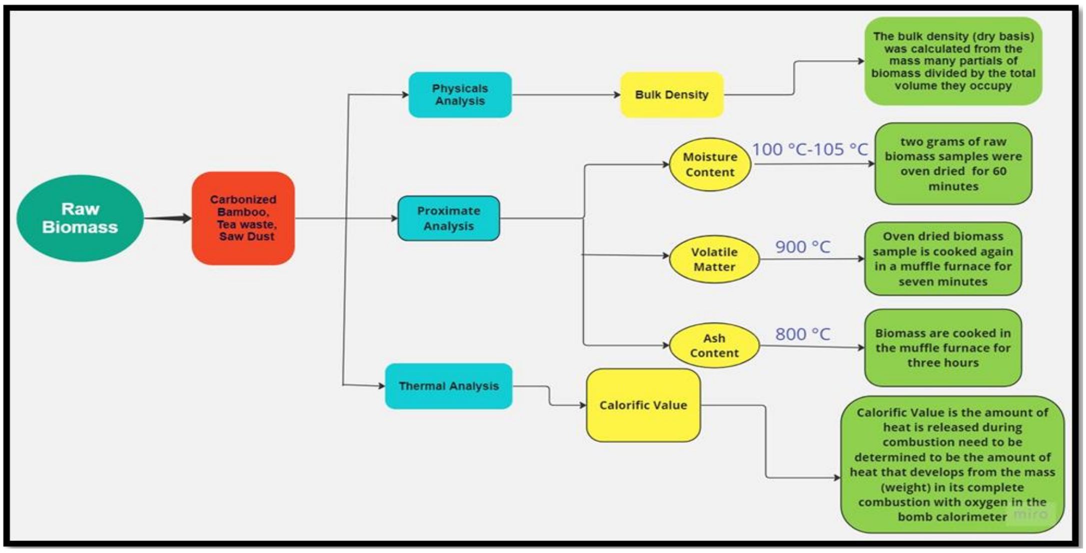

Figure 3. Characterization of physical, proximate and thermal analysis

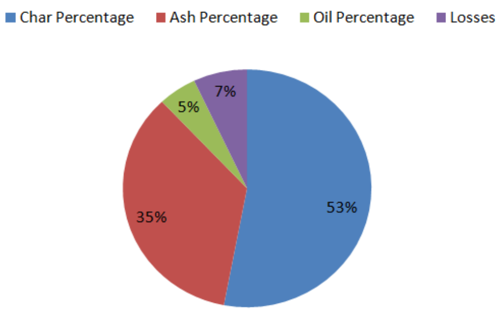

Figure 4. Product obtained after carbonized sample of bamboo.

The char obtained as 53 percentage, oil 5 percentage and the ash percentage 35 per cent from waste bamboo respectively. The observed carbonized material crushed and made into powder form for making the briquettes. The average char, ash content obtained after carbonization are depicted in Figure 4.

3.4 Physical, proximate and thermal analysis of biomass

Physical, proximate and thermal properties of the biomass were shown in Table.1. The basic parameters characterizing the biomass is its moisture content. According to the result the average moisture content was found in tea waste, saw dust, carbonized bamboo is 7.14, 8.65 and 4.2 percent. Sawdust in its fresh form has a high moisture content as compare to other biomass. Smaller value of moisture content in the biomass is better as biomass need to bind for briquette development. The small amount of water content in biomass briquette is better. Excessive water content should be avoided because the briquette will evaporate the water at first. The volatile matter of tea waste, saw dust, carbonized bamboo biomass has the value of 70, 76.18, 18.5 per cent. Ash content of tea waste, saw dust, carbonized bamboo has 7.5, 1.60, 5.8 per cent. In combustion process of fuel ash content plays a vital role, lower the amount of ash content, the greater will be its calorific value. The lower ash is advantageous as it indicates the low contamination of minerals which can be used as fertilizer. The fixed carbon of tea waste, saw dust, carbonized bamboo biomass has a value of 12.5, 13.57 and71.5 percent. The quality of briquette will be better if the value of fixed carbon is higher as fixed carbon acts as major generator of heat during combustion.

Table 1. Physical, Proximate and thermal parameter of biomass

Sl. No.	Biomass	Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Calorific Value (MJ/Kg)	Bulk Density (g/cm^3)
1	Carbonized Bamboo	4.2	18.5	5.8	71.5	18.5	0.18
2	Solid Tea Waste	7.14	70	7.5	12.5	17.24	0.28
3	Saw Dust	8.65	76.18	1.60	13.57	14.53	0.89

Table1. Shows the test results calorific value of biomass. Carbonized bamboo has the highest calorific value is 18.5 MJ/Kg due to lower ash and volatile matter contents and a higher fixed carbon. The average bulk density is displayed in the table1.above, with the carbonized bamboo having the lowest bulk density of 0.18 g/cm^{3}and saw dust having the greatest of 0.89 g/cm^3.

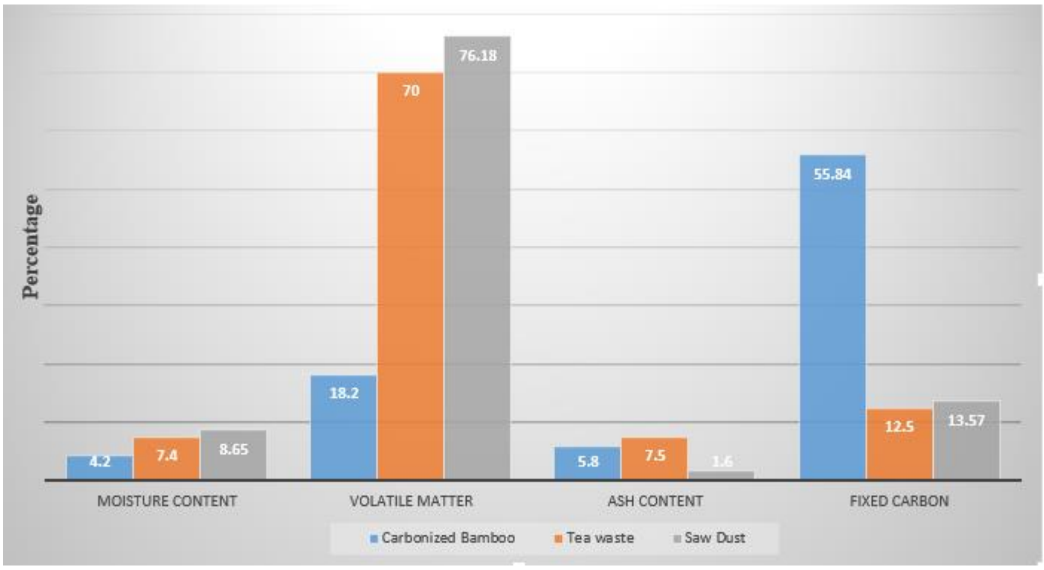

Figure 4. Proximate analysis test results of selected biomass

Figure 5. shows that the calorific value will grow as the percentage of fixed carbon increases. Hence the fixed carbon provides an approximate indication of the briquettes' heating value. As seen in Figure 6. sawdust has high moisture content and low the calorific value.

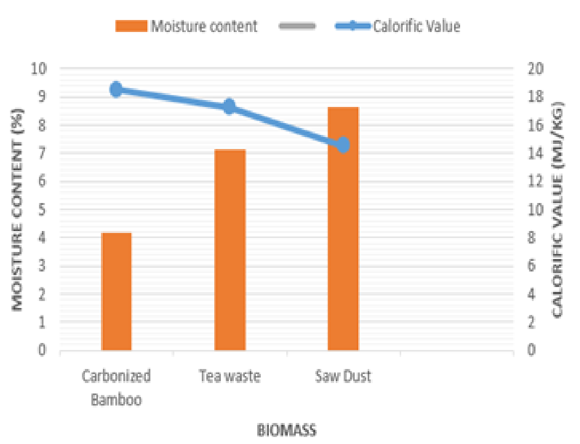

Figure 5. Analysis of Fixed Carbon versus Calorific value

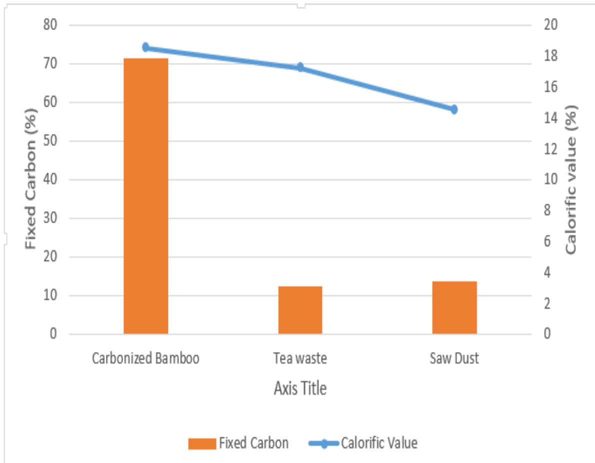

Figure 6. Analysis of Moisture Content versus Calorific value

It was observed from the Figure7.That the amount of volatile material in tea trash is notably high and effective. Methane, hydrocarbons, hydrogen, carbon monoxide, and incombustible gases like carbon dioxide and nitrogen are all components of volatile matter. Depending on the composition, volatile matter may exhibit a high ease of ignition for bio-briquettes or vice versa.

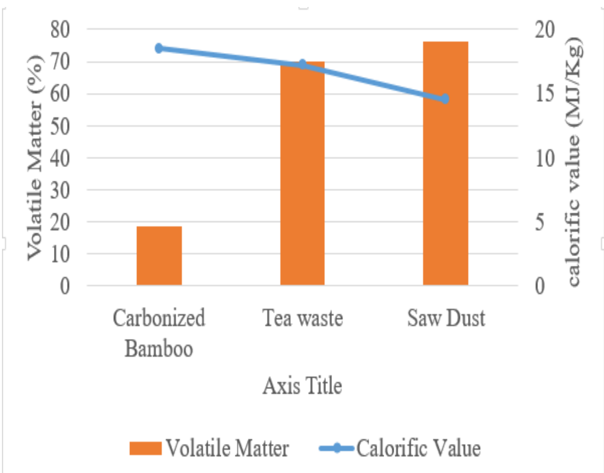

Figure 7. Analysis of Volatile Matter versus Calorific Value

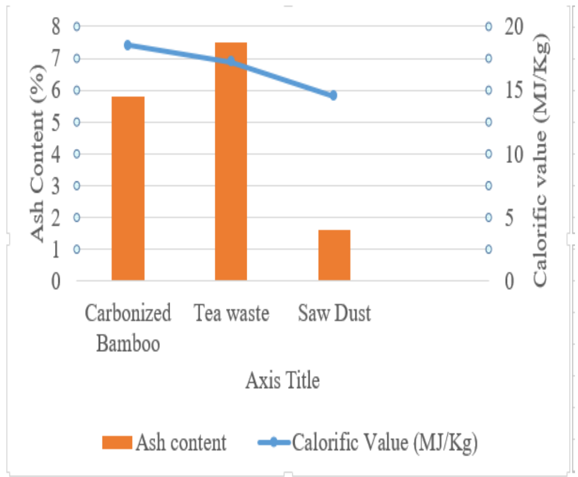

Figure 8. Analysis of Ash Content versus Calorific Value

4. Conclusion

Utilizing industrial waste is crucial for the globe since it integrates science and technology, economy, and sustainability (use of residues). A large volume of industrial by products is dumped as waste and which constitute environmental hazards. The effort is to convert the waste collected from industries into briquette which is one of the essential burning materials which can be used extensively in rural area of North-east as well in industry. A series of experiment carried out to check the physical parameter i.e. moisture content, volatile matter, ash content, fixed carbon and calorific value. The tea waste, carbonized bamboo, saw dust has appropriate physical parameters. It is evident by this experimentation that the time required for carbonization of bamboo was 8 hours .After carbonization of bamboo char had moisture content 4.2%, volatile matter 18.5%, and ash content 5.8% and fixed carbon 71.5% respectively. The bulk density of bamboo char were found to be 0.8 g/cm^3 after carbonization. According to the result the average moisture content was found in tea waste, saw dust, carbonized bamboo is 7.14, 8.65 and 4.2 per cent. The volatile matter of tea waste, saw dust, carbonized bamboo biomass has the value of 70, 76.18, 18.5 per cent. Ash content of tea waste, saw dust, carbonized bamboo has 7.5, 1.60, 5.8 per cent. The fixed carbon of tea waste, saw dust, carbonized bamboo biomass has a value of 12.5, 13.57 and 71.5 per cent. Carbonized bamboo has the highest calorific value is 18.5 MJ/Kg due to lower ash and volatile matter contents and a higher fixed carbon. Carbonized bamboo having the lowest bulk density of 0.18 g/cm^3 and with saw dust having the greatest of 0.89 g/cm^3.Thus, this study established that tea waste, carbonized bamboo and saw dust has potential to be converted to biomass briquettes for use as an alternative energy source. Production of biomass briquette from waste collection will increase the economic level of many local by giving employment as well as revenue generation from the final product and indirectly manages the waste from the industry

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