Thermal and Chemical Characterization of Co-Blended Coal and Biomass For Energy Applications

A dissertation submitted for the partial fulfilment of the requirements for the degree of

B. Sc. in Chemistry (Paper DSE-603) under Dibrugarh University

Under the Supervision of-

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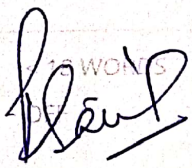

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CERTIFICATE

This is to certify that the dissertation entitled ***"Thermal And Chemical Characterization of Co-Blended Coal And Biomass For Energy Applications "*** *is submitted by* ***Justin Sanga, Roll No.-14720017, Reg.No.-S2205371,*** *a B.Sc. 6th semester student of the Department of Chemistry, N. N. Saikia College, Titabar for the partial fulfillment of B.Sc. degree in Chemistry (Paper: DSE-603), is a record of original research work carried out by her under the supervision of* ***Dr.Prasenjit Saikia.*** *She has fulfilled all the requirements for submitting the dissertation for the B.Sc. degree. The results embodied with this dissertation have not been submitted to any other college or institute for any other degree or diploma to the best of my knowledge.*

29/05/25

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Place: Titabar

(Jayanta Madhab Borah)

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I, here by forwarding the project report entitled **"Thermal and chemical Characterization of Co-blended Coal and Biomass for Energy Application"**, submitted by Justin Sanga, a student of B. Sc. 6th semester, Department of Chemistry, Nanda Nath Saikia College, Titabor, Jorhat, under the Winter Internship Program for the partial fulfilment of the degree of Bachelor of Science, embodies the record of original investigation carried out by him under my supervision during the period from 1/12/2024 to 20/01/2025 at Coal, Energy and Material Science Group, CSIR-NEIST, Jorhat.

It is also certified that no part of the project has not been submitted for any purpose to any other institute/university for the award of any research degree.

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FORWARDING

I, here by forwarding the project report entitled **"Thermal and chemical Characterization of Co-blended Coal and Biomass for Energy Application"**, submitted by Justin Sanga, a student of B. Sc. 6th semester, Department of Chemistry, Nanda Nath Saikia College, Titabor, Jorhat, under the Winter Internship Program for the partial fulfilment of the degree of Bachelor of Science, under the guidance of Dr. Prasenjit Saikia, Principal Scientist, Coal, Energy and Material Science Division, MSTD, CSIR-NEIST, Jorhat

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ACKNOWLEDGEMENT

I, the student of the B.Sc. 6th semester at Nanda Nath Saikia College, Titabor under Dibrugarh University, have conducted a project titled ***"Thermal and Chemical Characterization of Co-Blended Coal and Biomass for Energy Applications"*** *under the guidance of* ***Dr. Prasenjit Saikia****, Scientist at CSIR-NEIST, Jorhat. I would like to express my appreciation to several individuals who played a role in this project and thank them for the guidance they provided to help me achieve this goal. First and foremost, I wish to convey my sincere thanks to my supervisor,* ***Dr. Prasenjit Saikia****, for giving me the chance to work under his mentorship; without his support, this project would not have been feasible.*

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Justin Sanga

Justin Sanga

DECLARATION BY CANDIDATE

I hereby declare that the project report titled ***"Thermal and chemical Characterization of Co-Blended Coal and Biomass for Energy Applications"*** submitted to the Department of Chemistry, Nanda Nath Saikia College, Titabor in partial fulfillment of the requirement of the award of the Bachelor Degree of Science in a record of Bonafide work carried out under the supervision of ***Dr. Prasenjit Saikia***, Scientist, CSIR-NEIST, Jorhat. The matter embodied in this project has not been submitted by us for the award of any other degree.

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ABSTRACT

The present work explores the thermo chemical properties of coal, biomass, and their blends to evaluate their suitability as green energy sources. Thermal decomposition was analyzed using thermo gravimetric analysis (TGA) from 0–1000°C and through Fourier Transform Infrared Spectroscopy (FTIR) from 500–4000 cm^{-1}. Coal exhibited gradual weight loss with high carbon content, and significant decomposition at temperatures above 400°C along with substantial char residue. Biomass broke down quickly in the range of 200–400°C as hemicellulose, cellulose, and lignin decomposed with minimal ash. Combining coal and biomass at 25–75%, 34–66%, 50–50%, and 40–60% blends exhibited synergistic effects by enhancing combustion efficiency and lowering emissions. Derivative thermo gravimetric (DTG) curves indicated characteristic peaks for the blends, suggesting better thermal behavior. Findings indicate that blends of coal-biomass have the potential to increase energy generation and reduce CO_2 emissions in comparison to using coal alone. The work highlights optimizing mix ratios to meet a balance of energy production and sustainability, presenting important implications for renewable energy policies.

Keywords: Coal, biomass, coal-biomass blends, Thermo gravimetric Analysis (TGA), Fourier Transform Infrared Spectroscopy (FTIR), thermal decomposition, combustion efficiency, synergistic effects, derivative thermo gravimetric (DTG) analysis, char residue, CO_2 emissions reduction.

1) INTRODUCTION

1.1) Coal: - Coal is an organic sedimentary rock that has been an important source of energy around the world. The process of coal formation takes about 10-350 million years and also depends on physical conditions. The carbon content increases with the release of carbon oxide and water from organic matter, and the higher the rank of the coal, the higher are its carbon content, aromatic character and higher calorific value [8]. Coal is the world's most abundant fossil fuel. The existing accessible stock of gas and oil will last for approximately another 50 years while the coal resources will be able to supply power at least for three centuries. The world demand for coal with low ash and low sulphur is due mainly to environmental pressure and is already changing the value of coals.

High-sulphur coals have a deleterious effect on the environment especially when these are used as a fuel. There are vast deposits of high-sulphur coals throughout the world, i.e., in countries where coals have been found. In India although we have coal reserves that are likely to last for 200 years at the present rate of consumption, the present thermal power plants are able to achieve only 38-40% efficiency since nearly 71% of Indian coals contain high ash and high sulfur. Inefficient use of these coals is also unacceptable to our present environmentally conscious society. The high-sulphur Indian coals occur in the North Eastern part of the country; the reserve of Assam coals predominates over the others. Sulphur is an important raw material in industry and it is presently imported because India does not have native deposits of sulphur. Therefore, if an efficient method of desulphurization of Assam coal can be developed [1]. Coals are divided into several types according to the coalification age, carbon content, volatile matter, total moisture, oxygen or hydrogen content, and calorific values. The main types are low rank coals: lignite (sometimes defined as brown coal), bituminous coal sometimes defined as steam

coal), and anthracite. The main difference between the three types of coal macromolecules is the fact that lignite contains a large percentage of aliphatic C-H bonds and is low in the aromatic nature and hydrogen and oxygen contents as well as the water content is high. Bituminous coal contains a much higher aromatic C-H character and no intrinsic water, and anthracite contains only aromatic carbon with very low hydrogen and water contents [8].

The different types of coal are:-

TYPES OF COAL:-

Coal is divided into four ranks-

1) Anthracite coal
2) Bituminous coal
3) Sub-bituminous coal
4) Lignite coal
5) Peat

Anthracite coal: - It is also called hard coal. It is formed from the bituminous coal when great pressure developed in folded rock strata during the creation of mountain ranges. This occurs only in limited Geographic areas.

Anthracite has the highest energy content of all coals and is used for making coke, a fuel used in steel foundry ovens. It is dense, hard rock with a jet black color and metallic luster. It contains between 86% and 98% carbon by weight and it burns slowly with a pale blue flame and very little smoke.

Fig 1: Lump of an anthracite coal.

Bituminous coal:- Great pressure results in the creation of bituminous or soft coal. This is the type most commonly used for electric power generation in the U.S. It has a higher heating value than either lignite or sub-bituminous but less than that of anthracite bituminous coal is formed chiefly in the Midwest and Appalachia. It contains between 69% and 86% carbon by weight.

Fig 2: Lump of a bituminous coal.

Sub-Bituminous coal: - Sub–Bituminous coal is a lower grade coal that is used as a fuel for steam electric power generation. It's a transitional type of coal between lignite, the lowest grade and bituminous coal, the second highest grade. It can be dark dull brown to black or bright jet-black. It contains 35-45% carbon. It is soft and crumbly at the lower end of the range and hard and relatively strong at the upper end. It's none cooking, meaning it undergoes little swelling

when heated. It is found in many places around the world including Australia, Brazil, Canada, China, Germany, Russia, Ukraine and the U.S.

It contains less carbon, more water and is less efficient source of heat.

Fig 3: Lump of a sub-bituminous coal.

Lignite coal: - Lignite coal is also known as brown coal. It is soft, brown, combustible sedimentary rock formed from naturally compressed peat. It has carbon content around 25-35% and is considered the lowest rank of coal due to its relatively low heat content. When removed from ground it contains a very high amount of moisture, which partially explains its low carbon content. Lignite is mined all around the world and is used almost exclusively as a fuel for steam-electric power generation. Lignite coal is most harmful to health when burned [16].

Fig 4: Lump of a Lignite coal.

Peat: - Peat is a soft, crumbly, dark brown substance that is formed from generations of dead and partly decaying organic matter. It is the first step in the formation of coal and slowly becomes lignite after pressure and temperature increases as sediment is piled on top of the partially decaying organic matter. In order to be turned into coal the peat must be buried from 4-10 km deep by sediment. Since, peat becomes coal over time; it is classified as fossil product.

To form peat, the vegetation must fall and be buried in a relatively oxygen poor environment so that it can be incorporated into layers of the soil without completely decomposing. Although the peat used today is older, the material is still being formed today in bags around the world. Peat has low carbon content, less than 60%. [1]

Fig 5: A peat

USES OF A COAL:-

The main utilization of coal is for power generation (steam coal) and also to a lower extent in the metallurgical industry (cracking coal and PCI (pulverized coal injection) to the furnace using a stream of air), and it will remain as a major fuel source for the next decades. Two coal types are used for power generation: lignite and bituminous coals. Depending on the coal type, steam coals are ground to the micrometer size (~10–70μm) to achieve efficient combustion. Also, the grinding process occurs at higher temperatures to reduce the moisture content in lignite

from up to 65 wt% to lower than 30 wt% and in bituminous coal from up to 10 wt% to lower than 2wt%. After drying, the combustion process is composed of two main stages: (i) pyrolysis of the coal particle that involves emission and burning of volatiles (mainly methane and low-molecular-weight organic [14]. Coal is a major fuel for energy and steam production in coal-fired power plants across the globe. "Coal currently supplies around 30 % of primary energy and 41% of global electricity generation. Coal use is forecast to rise over 50 % to 2030, with developing countries responsible for 97% of this increase, primarily to meet improved electrification rates" [2].

The extraction and burning of coal damages the environment, causing premature death and illness, and it is the largest anthropogenic source of carbon dioxide contributing to climate change. Burning of coal produces sulfur dioxide, which contributes to acid rain and nitrogen oxide and particulates to smog [1]. Epidemiological studies have reported associations between multiple public health outcomes and coal mining in general, and MTR in particular persons who live near surface mining operations experience significantly higher rates of morbidity for cardiovascular disease [3].

1.2) Forms of sulphur in coal

Assam coal has three forms of sulphur- sulphate, pyritic and organic sulphur. No elemental sulphur has been reported so far in case of Assam coal. The major portion of sulphur is in the organic form [10] which is about 70-80% of the total sulphur. Moreover, the occurrence of another type of sulphur in high-sulphur Assam coal has recently been established and reported elsewhere. This sulphur has been termed as secondary sulphur containing Fe-S moieties associated with coal organic matter. Combustion of high-sulphur coal forms SO_2, which in

contact with water, forms sulphuric acid. The presence of sulphur in coke beyond a certain limit makes it unsuitable for metallurgical purposes. In weathered coal sulphur percolates with ground water making the water highly acidic and causes the problem of acid mine drainage. The presence of moisture and sulphur are indications of the liability of coal to spontaneous combustion during storage. Other deleterious effects observed are- formation of acid rain, corrosion of boilers, underground pipelines, etc [9].

The presence of sulphur in coal possesses important environmental problems in its usage. The sulphur dioxide (SO_2) emissions produced during coal combustion account for a significant proportion of the total global output of anthropogenic SO_2. The extent of sulphur separation depends on several variables such as the form of sulphur in coal, intimacy of contact between minerals and the products of devolatilization. The total sulphur in coal varies in the range of 0.2-11 wt %, although in most cases it is between 1 and 3 wt %. Sulphur occurs in a variety of both inorganic and organic forms. Inorganic sulphur is found mainly as iron pyrite, marcasite, pyrrhotite, sphalerite, galena, and chalcopyrite and as sulphates. Organic sulphur is found in aromatic rings and aliphatic functionalities usually as mercaptan, aliphatic and aryl sulfides, disulfides and thiophenes. Organic and pyritic sulphur quantities depend on coal rank. Higher rank coals tend to have a high proportion of labile sulphur. All the organic sulphur is bivalent and it is spread throughout the organic coal matrix. Sulphur occurs in all the macerals and the most minerals.

The methods for the removal of sulphur from coal can be divided into: physical, chemical and microbiological. The mineral sulphur component can be removed or reduced by commercial methods of washing, flotation and agglomeration. A number of chemical desulphurization for the removal of both pyritic and organic sulphur has been advocated.

1.3) BIOMASS: - With increasing technology advancement and side by side improvement of social impact, every country is seeking on adequate energy to run their daily lives [4]. Whereas, till present fossil fuel is the major source of energy generation. Noticeably, fossil fuels are dramatically decreasing to fulfill the energy demands of daily life. Unfortunately, remaining limited resources could destabilize the economy of the country, because it is non-renewable. It is worth to note that burning of fossil fuel results a harmful emission of pollutant gasses, such as Carbon monoxide (CO), Carbon Dioxide (CO2), Nitrogen Oxide, Volatile Organic Compounds (VOC), Particulate Matter (PM) etc. can badly impact on the environment. As alternative resources like solar energy, wind energy and water energy are very popular nowadays; however these sources are not available in every geographical context. Interestingly, Biomass Energy (BE) which is based on Hydrocarbon (HC) molecules are very efficient and cost effective for every technological aspect. Therefore, to handle the issues of using fossil fuels, renewable Biomass energy and its development have come into limelight as a renewable energy source, which could be developed repeatedly from animal waste and plant derivatives [18]. In ecological terms, biomass refers to any type of organic matter, when it comes to energy; biomass is any organic matter that can be used to generate energy. Biomass used and combusted for energy can come in a number of different forms, ranging from compressed wood pellets – which are used in power stations that have upgraded from coal – to biogas and biofuels, a liquid fuel that can be used to replace fossil fuels in transport. Biomass can be produced from different sources including forestry residue, agricultural residue, animal waste, wood wastes, industrial wastes, municipal solid wastes and sewage [4]. Biomass can be burned to create heat (direct), or processed into bio-fuel (indirect). Different types of energy are created through several ways

such as: direct firing, co-firing, pyrolysis, gasification and anaerobic decomposition. All this ways involve thermal conversion. Thermal conversion involves heating the biomass feedstock in order to burn, dehydrate, or stabilize it. The most familiar biomass feedstock for thermal conversions is raw materials such as municipal solid waste (MSW) and scraps from paper or lumber mills. Before burning the biomass, it must be dried. The chemical process is called torrefaction. During torrefaction, biomass is heated to about 200°C or more. If the biomass dries out completely it loses about 20% of its original mass, but retains 90% of its energy. Biomass can also be co-fired, or burned with a fossil fuel. Biomass is most often co-fired in coal plants. Co-firing eliminates the need for new factories for processing the biomass. This reduces the amount of carbon dioxide and other greenhouse gases released by burning fossils fuels only [5]. Biomass is more abundantly distributed over the earth and has an advantage over the other renewable sources. Also, biomass is the fourth-most important source of energy after coal, petroleum and natural gas, and presently fulfills 10% of the global energy requirement. It is projected that biomass and different types of waste may contribute one-third of global primary energy demand by 2050 [6].

Advantages: - Biomass is a clean, renewable energy source. Its initial energy comes from the sun, where plants or algae biomass can re-grow in a relatively short amount of time. Trees, crops and municipal solid waste are consistently available and can be managed sustainably. If trees and crops are sustainably farmed, they can offset carbon emissions when they absorb carbon dioxide through respiration. Many biomasses feed stocks, such as switch grass; can be harvested on marginal lands or pastures, where they do not compete with food crops. Unlike other renewable energy sources, such as wind or solar, biomass energy is stored within the organism and can be harvested when it is needed [5]. Biomass can be grown in a sustainable way

through a cyclical process of fixation and release of CO_2, thereby mitigating global warming problems. Biomass fixes CO_2 in the form of lignocelluloses during photosynthesis, and the CO_2 emitted from the combustion of these materials make no net contribution to the accumulation of CO_2 in the atmosphere or to the greenhouse effect [11].

Disadvantages: - If biomass feed stocks are not replenished as quickly as they are used, they become non renewable. A forest, for instance, can take hundreds of years to re-establish it. This is still a much closer time period than a fossil fuel such as peat. It can take 900 years for just a meter (3 feet) of peat to replenish itself. Biomass has a lower "energy density" than fossil fuels. As much as 50% is water, which is lost in the energy conversion process. Burning biomass releases carbon monoxide, carbon dioxide, nitrogen oxides and other pollutants and particulates. If these pollutants are not captured and recycled, burning biomass can create smog and contribute to the pollutants released by fossil fuels [5].

1.4) CO-BLENDING:-

The increasing demand for sustainable energy sources has prompted the exploration of renewable biomass materials as substitutes for fossil fuels such as coal. Co-blending is the process of mixing two or more different types of fuels to create a single, combined fuel source that leverages the strength of each component. Co-blending refers to physically mixing coal with biomass (like agricultural residues, wood chips, or other organic materials) to burn them together in power plants or industrial furnaces. It can be used in a variety of fields, including energy, winemaking, and polymer science. Power stations blend coal to create a consistent fuel supply for power generation. Blending can also help reduce emissions and transportation problems. Biomass and coal are burned together in a coal boiler. The blending of biomass with coal will

reduce coal dependence in thermal power plants. It will also reduce dependency on coal and fossil fuels. This can also reduce fuel costs, greenhouse gas emissions, improve combustion efficiency and utilize renewable waste resources.

Some challenges of co-blending are handling and storage due to its hydroscopic nature, inconsistent biomass quality and seasonal availability. It must need for modification in boiler and combustion system. It has an ash related issues, especially with high-alkali biomass.

Nowadays many operations people in power plants in India accept the concept of utilizing the facilities for blending of indigenous and imported coal because of the shortage of Indian coal [7].

2) MATERIALS AND METHODS:

2.1) SAMPLE COLLECTION:

The sample of coal was collected from the mines of Namchik, Arunachal, whereas, the sample of biomass was prepared from bamboo stalk *(Bambusa tulda Roxb.)* that was collected from Thengal Gaon, Titabor, Assam.

2.2) SAMPLE PREPARATION:-

For sample preparation both the coal and the biomass sample was crushed using mortar and pestle and further crushed in the Rotor Beater mill to a size of 212μm and was sieved in the sieve shaker. The sample was thus prepared then used for further analysis and studies.

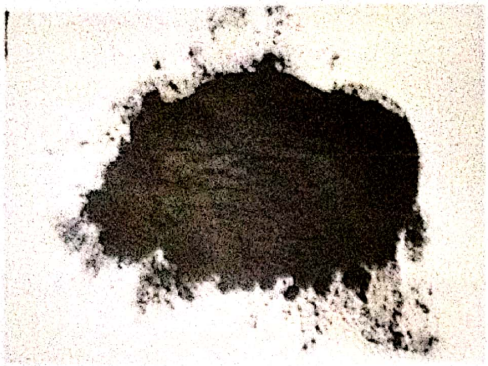

Fig 6: A coal sample of Arunachal, Namchik.

Fig 7: A biomass sample.

3) Thermal behavior of co-blending of coal and biomass

3.1) Property evolution of coal sample:

3.2) Physico-chemical properties of a coal,

3.2.1) PROXIMATE ANALYSIS

Proximate analysis is the most common form of coal evaluation, applied to determine fuel structure, its properties and energy value. It provides information on moisture content, ash content, volatile matter content and fixed carbon content of the material. Fixed carbon other than ash does not vaporize when heated in the absence of air. Fixed carbon is usually determined by subtracting the sum of the first three values that is moisture, ash, and volatile matter. So, it is very important for economic reason to know the moisture and ash contents of the material. They do not contribute to the heating value of a coal. In most cases ash is an undesirable residue also a source of pollution. Mostly heat value of the material comes from after excluding moisture,

volatile matter and fixed carbon content. The proximate analysis was done by IS-1350 (Part 1)-1984 (reaffirmed 2019).

3.2.2) Determination of moisture content:

The moisture content is an important parameter for determining a coal's calorific value and handling properties. To determine the moisture content, a coal sample of 1gm was taken in a silica crucible and heated in a muffle furnace at 105°C-110°C for an hour to measure the mass loss. After that the crucible is taken out and put in desiccators for cooling. Then the coal sample is weighed and the loss of weight is determined. The equation for moisture determination is given by,

$$\text{Moisture percentage (\%)} = 100\left(\frac{M\square - M\square}{M\square - M\square}\right)$$

M_1 = mass in gram of the vessel + cover.

M_2 = mass in gram of the vessel + cover + sample before heating.

M_3 = mass in gram of the vessel + cover + sample after heating.

3.2.3) Determination of ash content:

Ash is the non-combustible impurity left after coal is burnt. It represents the bulk mineral matter after carbon, oxygen, sulphur and water (including from clays) has been driven off during combustion. For determination of ash content, a clean dry empty silica crucible dish is weighed.

Into the dish about 1gram of the sample is weighed accurately. The sample is equally distributed in the dish. The uncovered dish is inserted into the muffle furnace at room temperature. The temperature was raised to 800°C ±10 °C for 2 hours and maintained at this temperature for an hour.

The equation for determination of ash content:

$$\text{Ash percentage (\%)} = 100\left(\frac{M_3 - M_1}{M_2 - M_1}\right)$$

M_1 = mass in gram of the dish

M_2 = mass in gram of the dish and sample

M_3 = mass in gram of dish and ash

M_4 = mass in gram of the dish after brushing out the ash and on reweighting

3.2.4) Determination of volatile matter content:

Volatile matter of coal is considered to be the one of the primary components of coal. This is usually a mixture of methane, hydrogen, carbon monoxide, carbon dioxide and nitrogen, etc. This method consist of heating of 1gm of the coal sample taken in a crucible at a temperature of 900° C ± 10° C for seven minutes. The crucible is then removed from the furnace and cooled and is weighed as soon as it is cooled.

The equation for determination of volatile content:

$$\text{Percentage of volatile content(\%)} = 100\left(\frac{M_2 - M_3}{M_2 - M_1}\right) - M_4$$

M_1 = mass of the empty crucible along with the lid

M_2 = mass of the crucible + lid + sample before heating.

M_3 = mass of the crucible + lid + sample after heating

M_o= percentage of the moisture in the sample on air dried basis.

3.2.5) Determination of fixed carbon:

Fixed carbon is the solid combustible residue that remains after a biomass particle heated and the volatile matter expelled. The fixed carbon content of a biomass is determined by subtracting the percentage of moisture, volatile matter and ash content from the sample, fixed carbon has a relation with calorific value. The equation for determination of fixed carbon:

Fixed carbon content (%): 100 – [moisture (%) + ash (%) + volatile matter (%)]

3.3) ULTIMATE ANALYSIS, (carbon and hydrogen):-

The ultimate analysis is performed to determine the elemental composition of the material. Ultimate analyses are used to determine the carbon, hydrogen, nitrogen sulfur, ash, oxygen contents of the material. For the specific applications, other chemical analysis can be employed. These include organically bound sulfur. Other specific cases the analyses may involve determining the trace elements present which influences the suitability of the material for a particular purpose. This may include methods for reducing environmental pollution and so forth. In the determination of carbon and hydrogen, volatile matter is released from the sample. If the

unit used for the actual burning of the sample is heated too rapidly, volatile matter may be released suddenly and some of it may pass unburned through the entire system and be lost. It is therefore necessary to conduct the analysis at a rate slow enough to allow all combustible products to be burned and converted to carbon dioxide and water [19].

It was carried out using a CHN elements analyzer which provides carbon, hydrogen, nitrogen, sulphur percentage composition. The ASTM standard of D-5373-21 was employed as reference for analysis of hydrogen and carbon in coal and biomass sample.

3.4) Calorific value

The heating value or calorific value of a substance is the amount of heat released during the combustion of a specified amount of it. The calorific value is a characteristic for each substance. It is measured in units of energy per unit of substance, usually mass, such as; kcl/kg, kJ/kg, j/mol, Btu/m^3. Heating value is commonly determined by use of a bomb calorimeter. The heat of combustion for fuel is expressed as HHV, LHV or GHV.

The quantity known as lower heating value (LHV) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any H_2O formed as a vapor. The energy required to vaporize the water therefore is not released as heat. The gross heating value accounts for water in the exhaust leaving as vapor, and includes liquid water in the fuel prior to the combustion. This value is important for fuels like wood or coal, which will usually contain some amount of water prior to burning. Most applications which burn fuel produce water vapor which is not used, and thus wasting its heat content. In such applications, the lower heating value is the applicable measure. This is particularly relevant for natural gas, whose high hydrogen content produces much water. The calorific value is relevant for gas burnt

in condensing boilers which condense the water vapor produced by combustion, recovering heat which would otherwise be wasted.

4) CHEMICAL CHARACTERIZATION OF THE SAMPLE

4.1) FTIR ANALYSIS:

Fourier Transform Infrared spectroscopy (FTIR) is an important analysis technique that detects various characteristic functional groups available in oil. Interaction of an infrared light with oil the chemical bond will stretch. Contract, and absorb infrared radiation in a specific wavelength range in the presence of the rest of the molecules. Based on this, the principle functional groups present in the pyrolytic oil were identified. The FTIR spectra were collected generally in the range of 400-4000 cm^{-1} region with $8cm^{-1}$ resolution. Absorption in the infrared radiation region makes changes in the vibrational and rotational states of the molecules. The absorption frequency depends greatly on the vibrational frequency of the molecules. The absorption intensity depends on how the infrared photon energy can be transferred to the molecule. This depends on the change in the dipole moment that occurs as a result of molecular vibration. A molecule will absorb infrared light only if the absorption causes a change in the dipole moment.

In an FTIR instrument, the monochromator and the slits are replaced by an interferometer of Michelson type. A beam of radiation is divided into two beams by means of a beam splitter. A path difference between the beams is also introduced whereupon it is allowed to recombine. In this way, interference between the beams is obtained. The intensity of the output beams from the interferometer is monitored as a function of path difference using an approximate detector.

4.2) THERMO-GRAVIMETRIC ANALYSIS (TGA)

Thermo gravimetric analysis or thermal gravimetric analysis is mainly considered as a type of testing on samples which determines changes in weight to a temperature program in a controlled atmosphere. It relies on a high degree of precision in two basic aspects which are weight and temperature. As most weight loss curves look more or less similar, the weight loss curve may require keen analysis before results may be interpreted. A derivative weight loss curve can identify the point where weight loss is most prominent. Interpretation is limited without further modification of the overlapping peaks. For the determination of the composition and purity, one must take the mass of the substance in the mixture by using thermal gravimetric analysis.

Polymers generally exhibit mass loss, although mass gain may be observed prior to degradation at slow heating rates in an oxidizing atmosphere. Mass loss may be categorized as volatile components such as absorbed moisture, residual solvents, or low-molecular-mass additives or oligomers that generally evaporate between ambient and 300°C; reaction products, such as water and formaldehyde from the cure of phenolic and amino resins, which generally form 100°C and 200°C; and generation of volatile degradation products resulting from chain scission that generally require temperatures above 200°C but not more than 800C°. All of this mass loss process may be characterized by TGA to yield information such as composition, extent of cure, and thermal stability.

4.2.1) Factors affecting Thermo gravimetric Analysis

In thermo gravimetric analysis buoyancy is the upward force on the sample produced by the surrounding atmosphere, which will affect the apparent mass during a TGA experiment. Disturbance in the measurement arises from three general sources; atmosphere effect, secondary reactions and electrical consideration. The buoyancy phenomenon occurs as the density of the atmosphere in the balance decreases with increasing temperature, resulting in an apparent mass gain. Consequently, it depends on the volume of the sample and its support, and the density of the atmosphere. Both may vary with temperature and rate of temperature increase, so any buoyancy correction may change during the course of the experiment. Effects of buoyancy can be quite apparent at the start of a heating segment, and when an atmosphere is deliberately switched, such as from nitrogen to air, owing to differences in gas properties such as density and flow rate. Modern thermo balances have design features that minimize or compensate for these affects. In general no corrections are required, except for the most sensitive experiments involving very small changes in mass [12].

MASS	TEMPERATURE
Buoyancy and thermal expansion	Hating rate
Atmospheric turbulence	Thermal conductivity
Condensation and reaction	Enthalpy of the processes
Electrostatic and magnetic forces	Sample-furnace-sensor arrangement
Electronic drift	Electronic drift

Table 1: Major Factors Affecting TGA Results

5) RESULTS AND DISCUSSIONS

5.1) PROXIMATE ANALYSIS:

TABLE 2: The proximate analysis of Biomass and coal sample of Arunachal Pradesh, Namchik is presented below in the table;

Sample	Moisture Content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
1.CA (Coal Arunachal)	45.15%	45.31%	3.54%	49.65%
2. Biomass (*Bambusa tulda Roxb.)*	8.54%	71.20%	3.24%	17.02%

5.2) ULTIMATE ANALYSIS

TABLE 3: The ultimate analysis of biomass and coal sample of Arunachal Pradesh, Namchik is presented below in the table;

Sample	Carbon (%)	Hydrogen (%)	Average Carbon (%)	Average Hydrogen (%)
1.CA (Coal Arunachal)	79.9%	5.31%	79.3%	5.38%
2. CA (Coal Arunachal)	78.8%	5.45%		
3. Biomass (*Bambusa tulda Roxb.)*	45.5%	5.82%	45.9%	5.84%
4. Biomass (*Bambusa tulda Roxb.)*	46.3%	5.86%		

5.3) FOURIER TRANSFORM INFRARED RADIATION (FTIR) OF COAL

In order to determine the functional group present in the sample, Fourier Transform Infrared Spectroscopy of the sample is being analyzed in the Perkin – Elmer Infrared Spectrometer. The FTIR Analysis of coal sample of Arunachal, Namchik is given below:

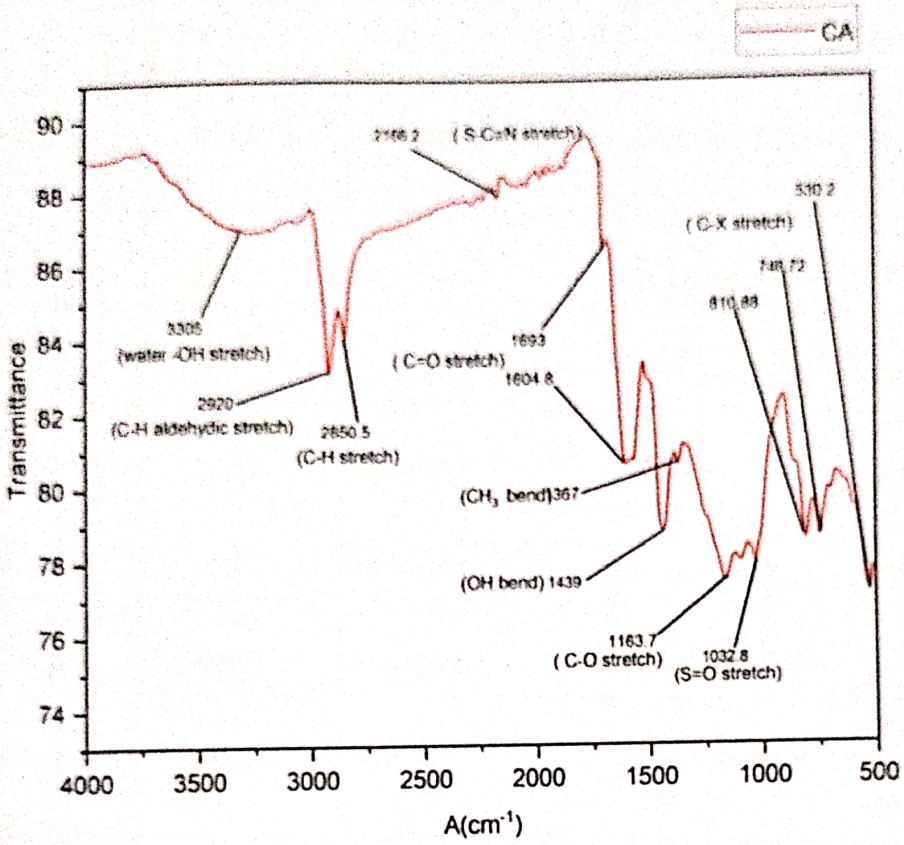

Fig 8: FTIR Analysis of coal sample of Arunachal Pradesh, Namchik

TABLE 4: Functional groups analysis and its quantified frequencies of the FTIR Analysis of a coal.

SAMPLE CODE	ABSORPTION (cm-1)		APPEARANCE	GROUP	COMPOUND GLASS
CA	750-500	530.2	STRONG	(C-X stretching)	HALO COMPOUND

CA	750-500	746.72	STRONG	(C-X stretching)	HALO COMPOUND
	850-550	810.88	STRONG	(C-X stretching)	HALO COMPOUND
	1070-1030	1032.8	STRONG	(S=O stretching)	SULFOXIDE
	1210-1163	1163.7	STRONG	(C-O stretching)	ESTER
	1420-1330	1367	MEDIUM	(CH_3- bending)	ALCOHOL
	1440-1395	1439	MEDIUM	(O-H bending)	ALCOHOL
	1650-1600	1604.8	MEDIUM	(C=C stretching)	AROMATIC/CARBONYL
	1710-1680	1693	STRONG	(C=O stretching)	CARBONYL (KETONE/ALDEHYDE)
	2000-2500	2166.2	STRONG	S-C≡N stretching)	THIOCYANATE
	2865-2845	2850.5	MEDIUM	(C-H stretching)	ALKANE
	3000-2800	2920	STRONG	(C-H stretching)	ALDEHYDE
	3550-3200	3305	STRONG	(O-H stretching)	ALCOHOL

FTIR analysis of coal sample and its identification gained from the above discussion.

In relation to the number of peaks, there are over five peaks, advising that the sample analyzed is not a mere chemical. The FTIR spectrum displays multiple absorption peaks corresponding to several functional groups prevalent in coal such as aliphatic and aromatic hydrocarbons, oxygen groups, and sulfur groups. The peaks with labels are described as follows- The peaks have single bond area between (2500-4000 cm^{-1}). A wide band of absorption between 2500-4000 cm^{-1} is observed representing hydrogen bond. This band proves the presence of hydrate (H2O), hydroxyl (-OH), ammonium or amino. A sharp band less than 3000 cm^{-1} is observed indicating aliphatic compounds. For instance, long-chain linear aliphatic compound's absorption band is seen at 3000-2800 cm-1. This shows the presence of aldehydic C-H stretching, which may be due to oxygenated functional groups that form during coal oxidation or weathering. The bond will be trailed by peaks between 1470-750 cm^{-1}. There was a distinct peak for methylene at between 2865 and 2845 cm-1, which is the aliphatic C-H stretching vibration (e.g.-CH2 or –CH3) which is usually of alkyl groups in the organic structure of the coal. Triple bond area (2000-2500 cm-1) was identified. 2166 cm-1 peak indicates thiocyanate, representing trace sulfur organic compounds, which are either from coal and impurities or processing. Double bond area can be found between 1710-1680. Double bond may be of (C=C), imino (C=N), and azo (N=N) groups. Conjugated carbonyls are indicated by the 1693 cm-1 peak. Strong intensity at between 1650 and 1600 cm-1 was

observed, which indicated double bonds or aromatic compounds. The 1604.6 cm-1 may indicate aromatic C=O or hydrogen-bonded groups, which are typical in oxidized coal.

Fingerprint Region:-

A sharp peak is noted between 1440-1395, which indicates single bond of alcohol or phenol group. Few of the peaks are seen in fingerprint region between (500-1500 cm-1). The region is normally specific and individualistic. However, there can be more than one identification present. Alcohol (O-H bend) is at 1439 cm-1. It will also overlap with CH_2 or CH_3 bending. Because it is accompanied with strong broad O-H stretch at 3305 cm-1, it will fit the compound to have alcoholic O-H group. Since, 530.2 cm-1, 746.72 cm-1 and 810 cm-1 (C-X stretch) peaks fall in fingerprint region, it most probably represents C-X (halogen) stretching vibrations, likely suggesting minor halogenated impurities or preparation artifacts.

5.4) FOURIER TRANSFORM INFRARED RADIATION (FTIR) OF BIOMASS

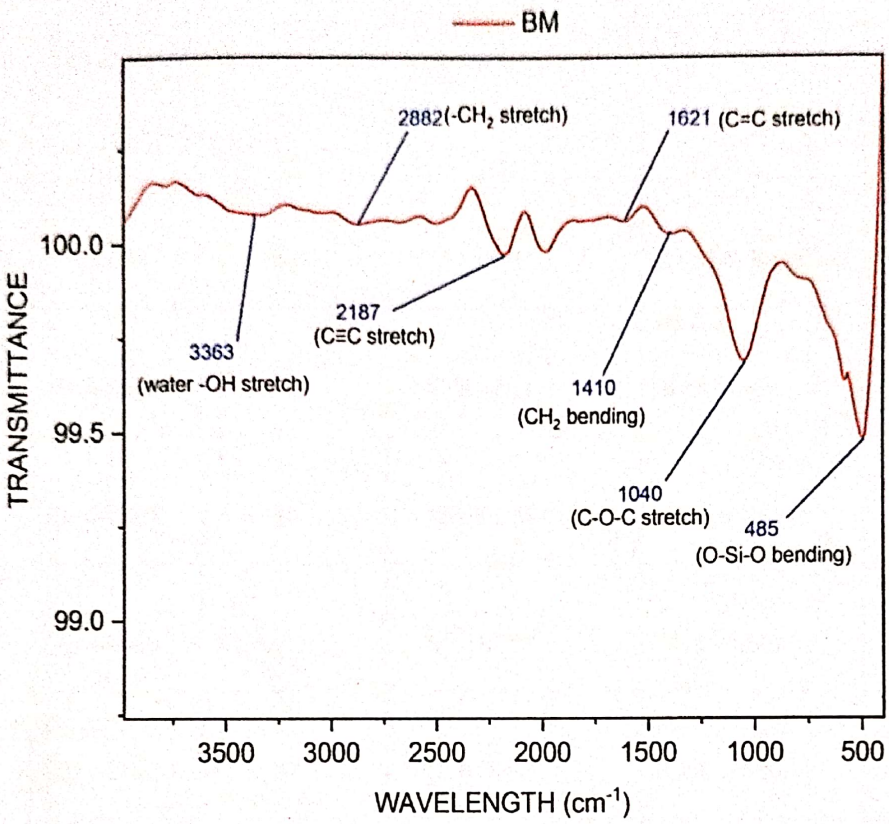

Fig 9: FTIR analysis of a Biomass sample

TABLE 5: Functional groups analysis and its quantified frequencies of the FTIR Analysis of a Biomass.

SAMPLE CODE	ABSORPTION (cm^{-1})		APPEARANCE	GROUP	COMPOUND GLASS
BM	1000-400	485	STRONG	(O-Si-O Bending)	SILICON-OXYGEN
	1070-1030	1040	STRONG	(C-O-C Stretching)	ANHYDRIDE
	1440-1395	1410	MEDIUM	(CH_2-bending)	ALKANES
	1650-1600	1621	MEDIUM	(C=C stretch)	CONJUGATED ALKENE
	2260-2100	2187	STRONG	(C≡C stretch)	THIOCYANATE
	2950-2840	2882	MEDIUM	(-C-H stretch)	ALKANE
	3550-3200	3363	STRONG	(-OH stretch)	ALCOHOL

FTIR analysis of Biomass sample and its identification gained from the above discussion.

The FTIR spectrum of the biomass sample (BM) is presented in **Figure 9**, with transmittance (%) plotted against wave number (cm^{-1}) from 3500 to 500 cm^{-1}. The spectrum shows

important functional groups and molecular bonds typical of biomass, which generally contains elements such as cellulose, hemicellulose, lignin, and other organic substances. At 3363 cm^{-1} (O-H Stretch, Water): A wide peak at 3363 cm^{-1} suggests the occurrence of O-H stretching vibrations, mainly due to water molecules trapped by the biomass or hydroxyl groups in polysaccharides such as cellulose and hemicellulose. The wide nature of this peak indicates hydrogen bonding, common in biomass materials with high water content or hydroxyl-rich structures.2882 cm^{-1} (C-H Stretch): The 2882 cm^{-1} peak is due to C-H stretching vibrations, probably from aliphatic chains in the biomass, e.g., cellulose, hemicellulose, or lipids. This peak indicates the natural character of the sample with a prevalence of hydrocarbon frameworks.2187 cm^{-1} (C≡C Stretch): A minor peak at 2187 cm^{-1} corresponds to C≡C stretching and could suggest the existence of alkynes groups. This is less frequent in normal biomass but may indicate small contributions from individual organic compounds or impurities in the sample.1621 cm^{-1} (C=C Stretch): The band at 1621 cm^{-1} is attributed to C=C stretching vibrations, usually indicative of aromatic structures in lignin or unsaturated bonds in other biomass structures. This confirms the presence of lignin, a major structural element of biomass, with aromatic rings.1410 cm^{-1} (CH_2 Bending): The 1410 cm^{-1} peak is due to CH_2 bending vibrations, characteristic of the polysaccharide backbone of cellulose and hemicellulose. This again supports the prevalence of carbohydrate structures in the biomass.1040 cm^{-1} (C-O-C Stretch): An intense band at 1040 cm^{-1} is an indication of C-O-C stretching, specific for glycosidic linkages present in cellulose and hemicellulose. This peak indicates the polysaccharide-rich composition of the biomass since these ether linkages are central to the structure of these carbohydrates.485 cm^{-1} (O-Si-O Bending): The 485 cm^{-1} peak indicates O-Si-O bending vibrations, which can be indicative of the occurrence of silica or silicates in the

biomass. This may be caused by ash content or inorganic impurities, usually present in biomass from plant sources depending on the source and treatment.

Overall, the FTIR spectrum indicates that the biomass sample is mainly made up of polysaccharides (hemicellulose and cellulose) and lignin, with the other contributions being water, lipids, and possibly inorganic. The determined functional groups correspond to the normal content of lignocellulosic biomass, thus the sample can be utilized in processes like the production of biofuel, the development of biocomposites, or other valorization processes of biomass

5.5) Thermo gravimetric Analysis (TGA) of a Coal Sample

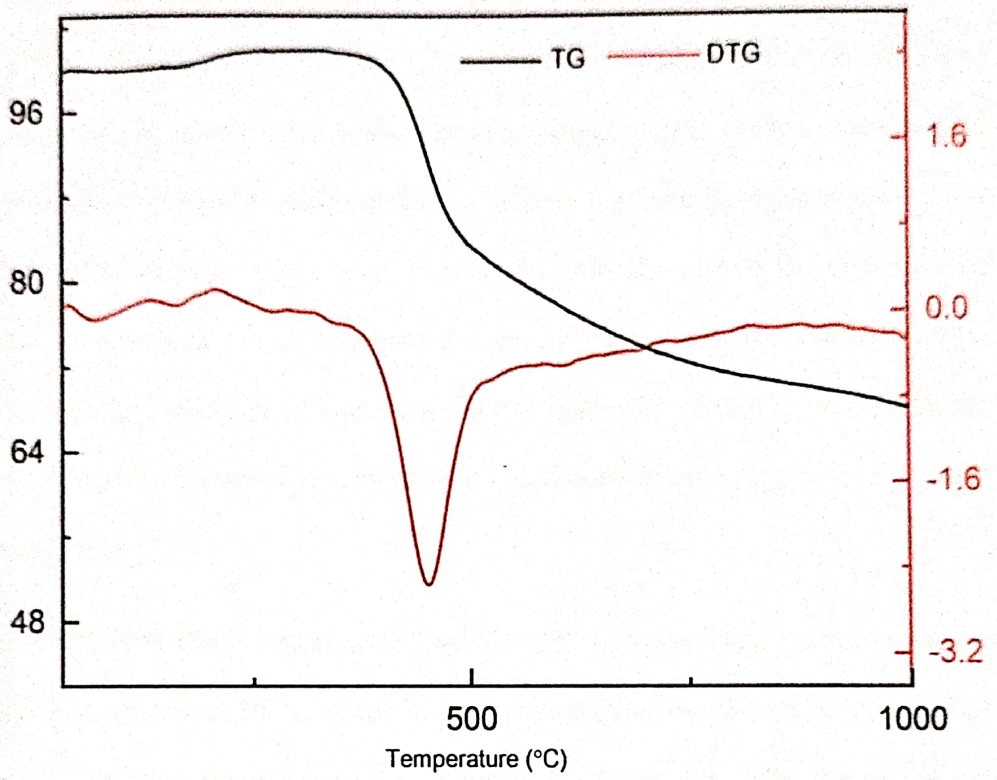

Fig 10 : Thermo Gravimetric Analysis of coal sample of Arunachal Pradesh

The TGA (Thermo gravimetric Analysis) of coal sample graph shows the thermal stability and decomposition behavior of a material as a function of temperature. The material is heated from room temperature to about 1000°C along x-axis. The left y-axis represents the percentage of mass remaining, ranging from 48 to 96 and the right y-axis indicates the rate at

which mass is lost ranging from -3.2 to 1.6. The –TG curve shows percentage weight (%), indicating how the sample mass changes with respect to temperature. The –DTG (Derivative Thermo gravimetric) curve shows the rate of weight change (%/°C), showing how quickly the material is losing mass. The –TG graph starts nearly 100%, meaning the initial weight is considered 100%. Around 300-500% there is a significant weight loss, which indicates decomposition or loss of volatile components. The curve stabilizes after ~600°C, indicating no further significant loss of mass. The curve remains relatively flat, with the mass stabilization at around 50-60% of the original weight up to 1000°C. This indicates that no further significant decomposition occur, and the sample has reached a thermally residual mass. A point of graph from (~300°C-600°C) where the graph starts degrading or sloping downward to the point before it gets linear is the second stage of the process and this process is called pyrolysis or thermal decomposition [15].

The –DTG curve shows a clear peak at around ~430°C, representing the maximum rate of mass loss or decomposition. This peak confirms the main thermal decomposition event in that range. After that, the curve returns near zero, indicating no further significant decomposition. This is consistent with the sharp drop seen in the –TG curve and confirms a single-step or dominant decomposition phase. Both the –TGA and –DTG graph reveals a single-step thermal degradation, beginning around 300°C and peaking near 430°C, with nearly half the mass retained at high temperatures. The two-stage decomposition observed is consistent with materials that contain both volatile and stable components, such as polymers, biomass, or organic-inorganic composites. For example, the initial mass loss up to 200°C could be attributed to the evaporation of adsorbed water or solvents, while the first major decomposition stage (200°C-400°C) might correspond to the thermal degradation of organic polymers or cellulosic

materials. The second stage (400°C to 600°C) could involve the oxidation of carbonaceous residues or the decomposition of inorganic additives, with the final stable mass indicating the presence of non-combustible inorganic fillers or ash.

5.6) Thermo gravimetric Analysis (TGA) analysis of a Biomass sample

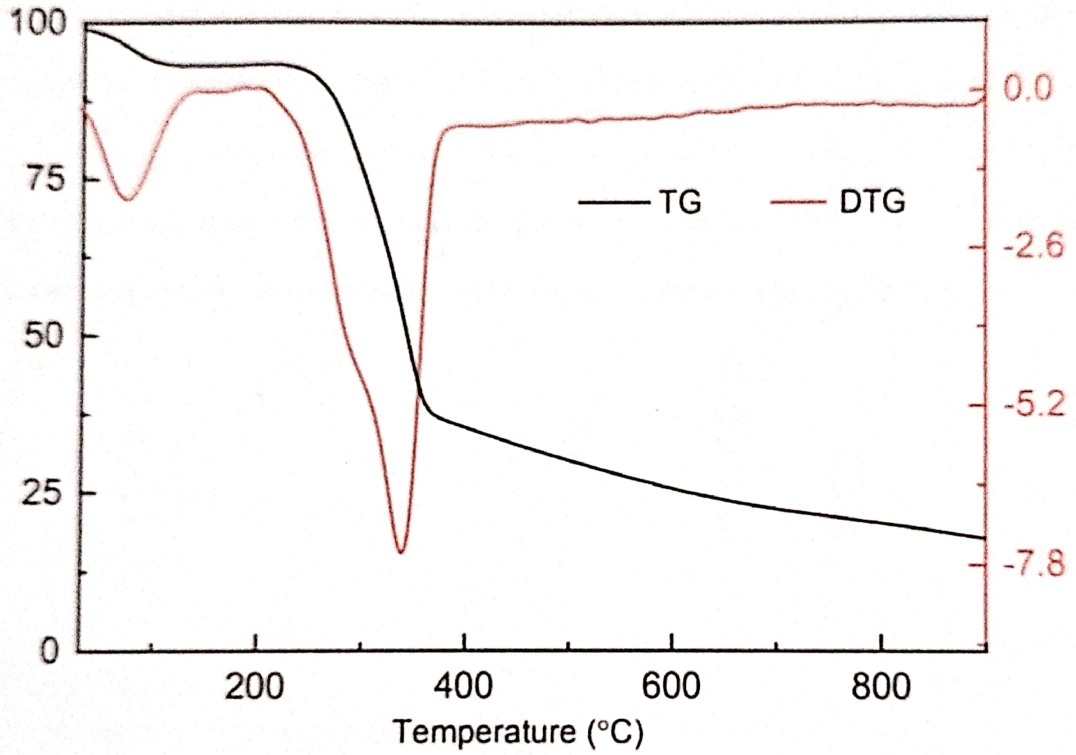

Fig 11: TGA Analysis of sample of biomass.

The Thermo gravimetric analysis graph represents the –TG curve and –DTG curve of a sample of biomass, representing the percentage of mass remaining and rate of weight loss. The –TG curve starts at ~100% and shows a steady decline with increasing temperature. A slight

weight loss (~2-3%) is observed below 100°C, indicating the loss of surface moisture or physically adsorbed water. The corresponding -DTG peak confirms this with a shallow dip, indicating a low-rate mass loss. The major loss occurs between (~250°C- 400°C), indicating the decomposition or volatilization of a major component in the biomass sample. This is the primary decomposition stage, likely due to the breakdown of organic components or volatile substance. The total mass loss in this stage is substantial, dropping to nearly 50% of the initial mass. After the volatilization of a sample at ~400°C, the weight decreases more gradually, indicating slower decomposition or residual ash. The residual material remains thermally stable up to 900°C. This sample shows two main decomposition steps. The initial weight loss below 100°C corresponds to moisture loss and the major thermal degradation occurs between 250°C-400°C. This thermal behavior suggests the sample contains volatile organic materials with suitable inorganic residue or char.

5.7) TGA analysis of Co-Blending of Coal and Biomass

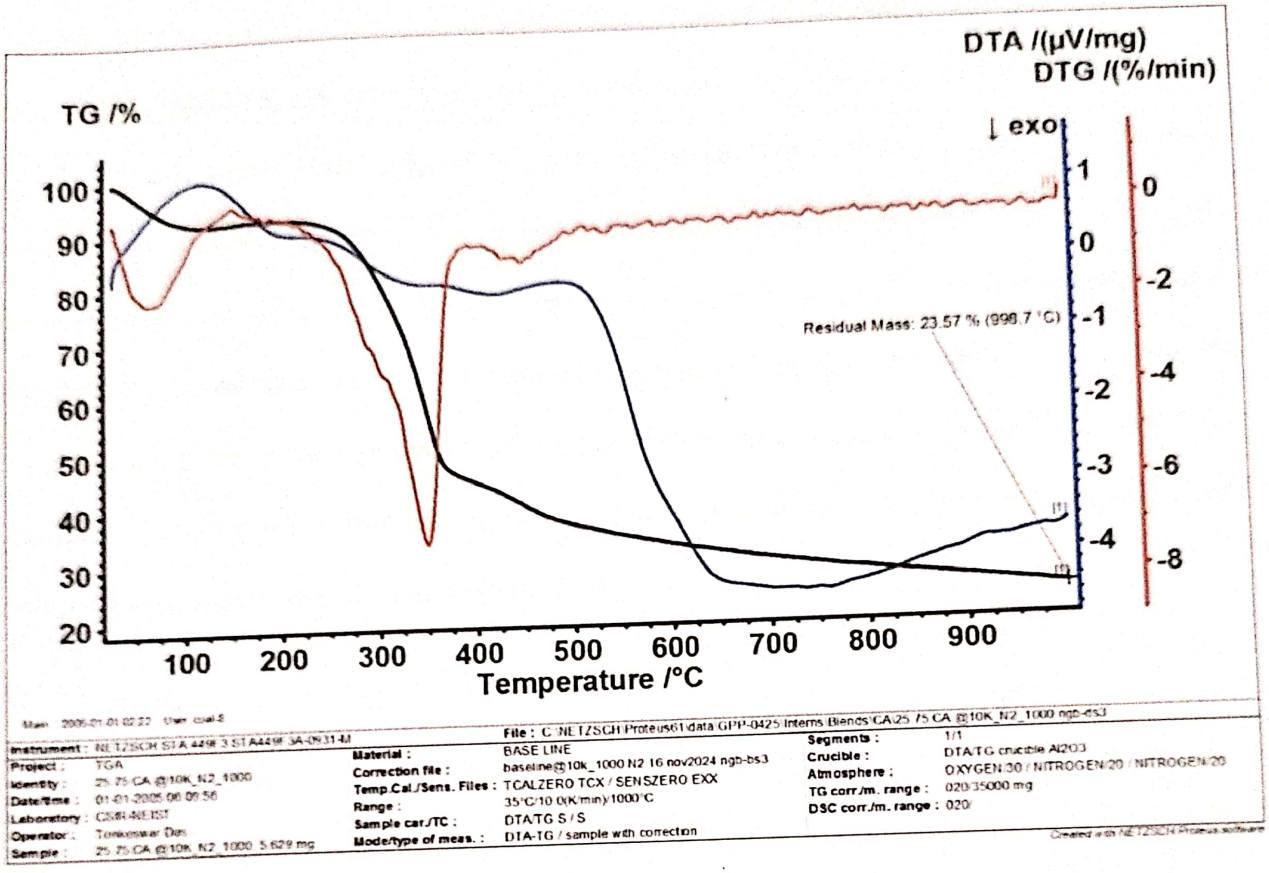

Fig 12: TGA Analysis of Co-blending of coal and biomass of (25-75%) blend.

The thermogravimetric analysis (TGA), combined with differential thermal analysis (DTA) and derivative thermogravimetric (DTG) data of Co-blending of coal and biomass at (25-75%) blend reveals the thermal behavior of co-blended coal and biomass as temperatures rise from 0°C to 1000°C. The analysis was conducted using a NETZSCH STA 449F3 STA449F3A-0931-M instrument. The black TGA curve shows a gradual decrease in mass, with significant weight loss between 300°C and 500°C, likely due to volatile components decomposing in both materials. At 998.7°C, the residual mass is approximately 23.57%, representing ash and non-volatile content.The red DTG curve, measuring the rate of mass loss, peaks between 300°C and

400°C, indicating maximum decomposition rates as volatile matter is released from coal and biomass.The blue –DTA curve, tracking heat flow, displays an exothermic peak between 400°C and 500°C, signaling heat release during combustion or decomposition. Additional peaks and baseline shifts suggest phase changes or reactions.The analysis indicates a synergistic effect in co-blending, with biomass promoting earlier devolatilization of coal at lower temperatures. The residual mass and –DTA peaks point to char formation and ash content, with biomass driving earlier weight loss compared to coal alone. Synergistic effects are the combined effects of at least two drugs that have a greater influence than either of them could have had individually. It happens when chemical substances or biological structures interact, resulting in a larger overall effect than the sum of their separate effects [17].

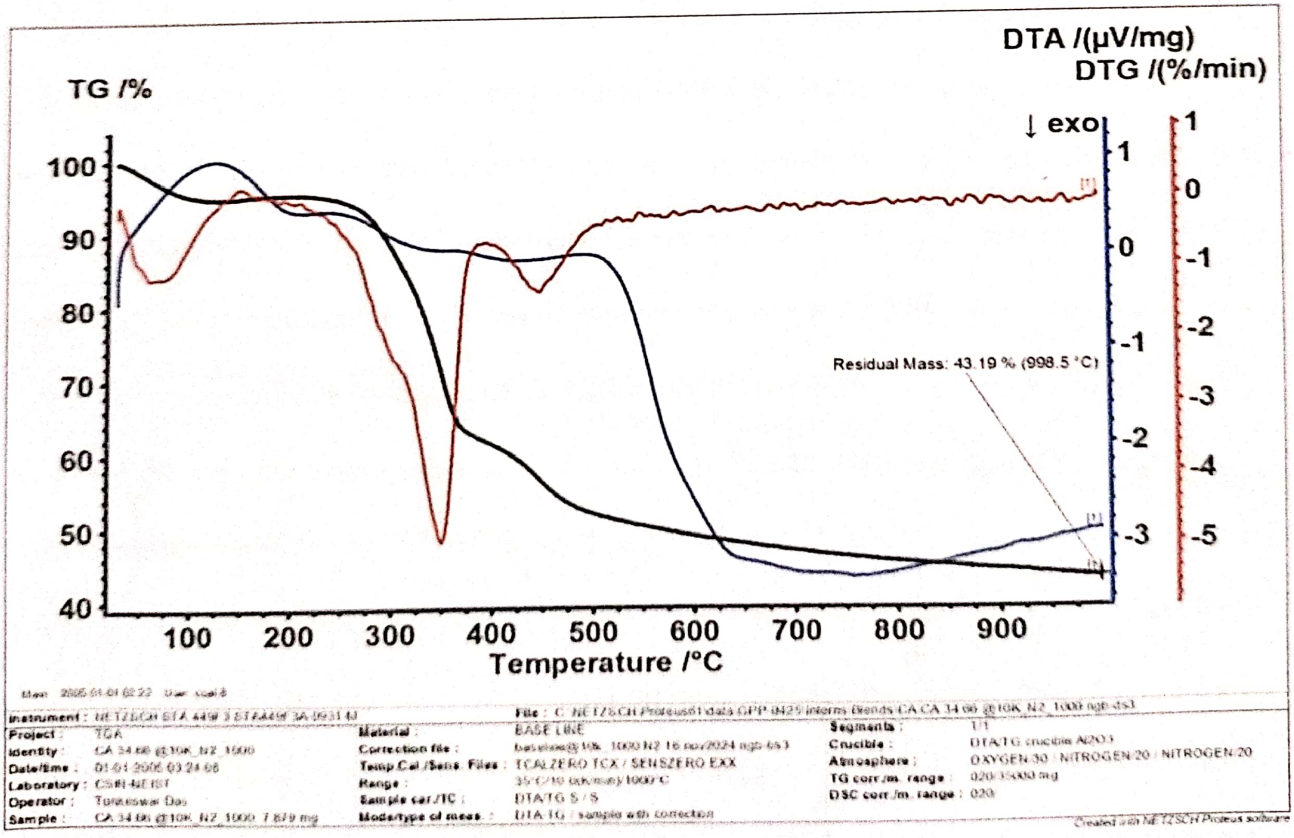

Fig 13: TGA Analysis of Co-blending of coal and biomass of (34-66%) blend.

The thermogravimetric analysis (TGA), combined with differential thermal analysis (DTA) and derivative thermogravimetric (DTG) data of Co-blending of coal and biomass at (34-66%) blend reveals the thermal behavior of co-blended coal and biomass as temperatures rise from 0°C to 1000°C. The analysis was conducted using a NETZSCH STA 449F3 STA449F3A-0931-M instrument in nitrogen atmosphere. The initial mass of the TG curve (black line) is normalized to 100%. A major weight loss occurs between approximately 300°C and 500°C, indicating significant thermal degradation, likely due to degradation of biomass and devolatilization of coal components. Beyond 500°C, the rate of mass loss decrases and the curve plateaus, indicating the formation of stable char residue. The residual mass is approximately 43.19% at 998.5°C, representing the no volatile mineral content, likely from coal ash and fixed carbon residue. The –DTG curve (blue line) exhibits distinct peaks corresponding to the maximum rate of mass loss. A major peak around ~350°C indicates the active pyrolysis phase of biomass and volatile coal matter. A smaller peak around ~600-700°C may be associated with the decomposition of more thermally stable coal decomposition or lignin in biomass. The –DTA curve (red line) represents an exothermic peak in the range of 300-400°C, associated with combustion of volatiles or oxidation of char. The thermal degradation occurs in multiple stages, reflecting the complex combustion of coal – biomass blends. Biomass typically degrades at lower temperatures (200-400°C), while coal degrades over a broader and higher temerature range. The residue percentage is relatively high due to presence of ash and fixed carbon from coal. The presence the distinct –DTG peaks implies synergistic effects between coal and biomass during thermal degradation. The TGA analysis of the coal and biomass co-blend reveals a multi-stage degradation process. The blend shows significant mass loss at moderate

temperatures due to biomass volatiles and early coal decomposition, followed by a stabilization period with residual mass retention. This suggests potential for energy recovery and manageable ash content, which is crucial for thermochemical applications such as co-firing and gasification.

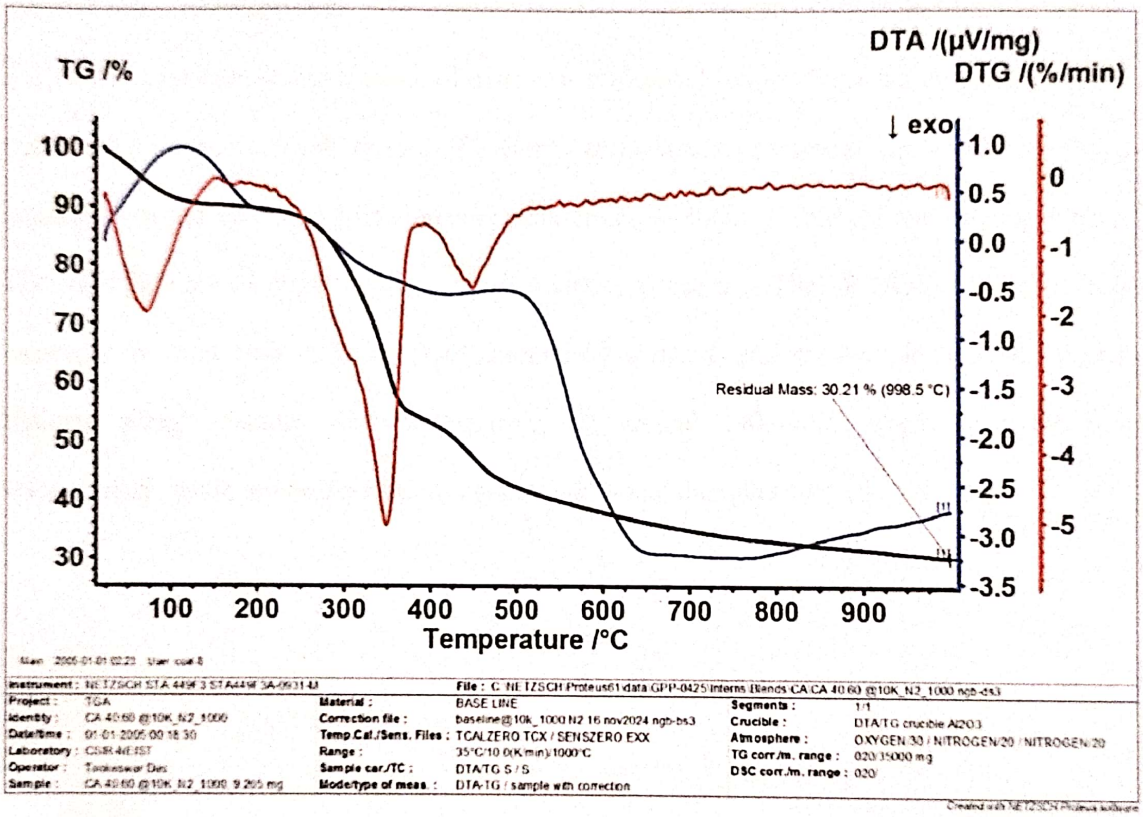

Fig 14: TGA Analysis of Co-blending of coal and biomass of (40-60%) blend.

The thermogravimetric analysis (TGA), combined with differential thermal analysis (DTA) and derivative thermogravimetric (DTG) data of Co-blending of coal and biomass at (40-60%) blend reveals the thermal behavior of co-blended coal and biomass as temperatures rise

from 0°C to 1000°C. The analysis was conducted using a NETZSCH STA 449F3 STA449F3A-0931-M instrument in nitrogen atmosphere. The initial mass of the TG curve (black line) is normalized to 100%. A minor mass loss (~5-10%) is likely observed due to the evaporation of moisture and volatile compounds at around 0-200°C. Around 200-400°C, a significant mass loss (~30-40%), indicating devolatilization and primary decomosition of biomass components. A gradual loss of mass around 600-900°C is observed suggesting the decomposition of coal and residual biomass components. The residual mass is approximately 30.21% at 998.5°C. The –DTG curve (red line) shows the rate of mass loss (%/min). Peaks indicate major decomposition stages. The prominent peak around 300-400°C corresponds to biomass decomposition (e.g., hemicelluloses, cellulose), while a broader peak around 400-600°C reflects coal decomposition. The multiple peaks suggest overlapping degradation processes. The –DTA Curve (blue line) measures the heat flow (µV/mg). Endothermic (downward) and exothermic (upward) peaks indicate energy changes. The endothermic dip around 300-400°C aligns with biomass volatilization, while minor fluctuations suggest additional thermal events.

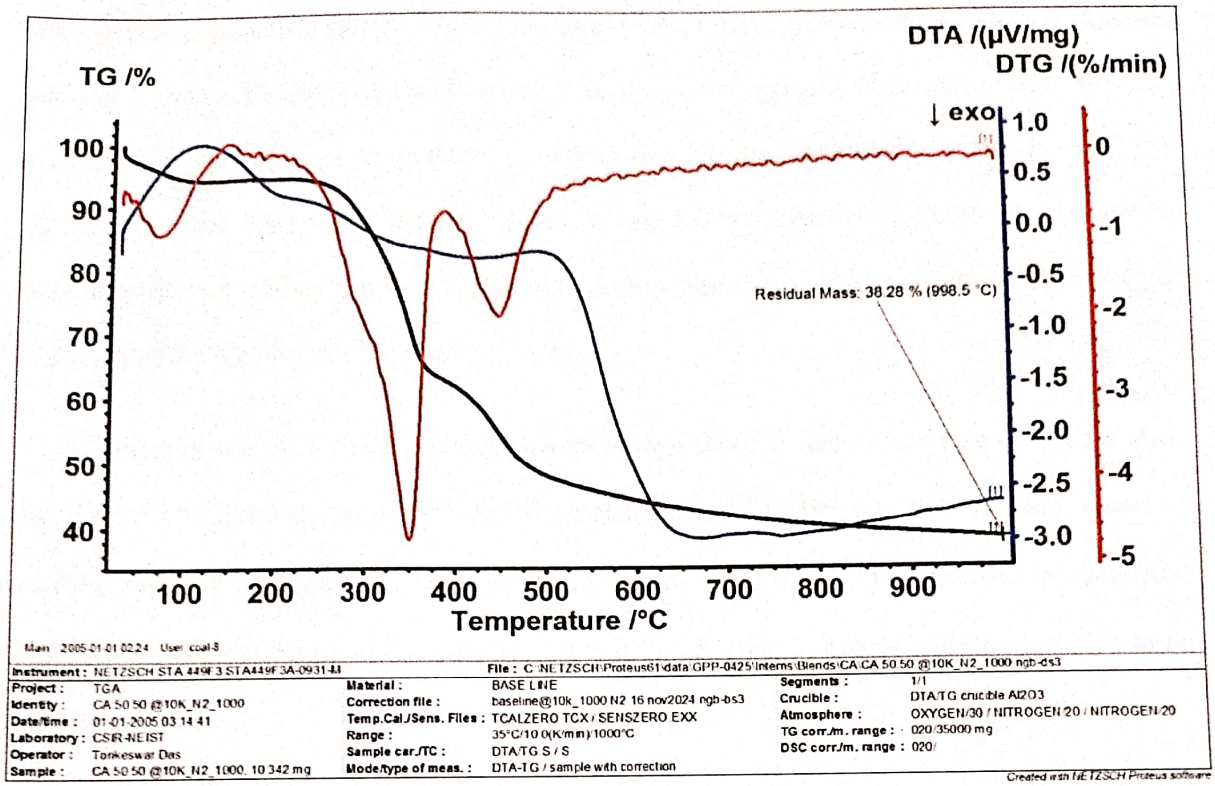

Fig 15: TGA Analysis of Co-blending of coal and biomass of (50-50%) blend.

The thermogravimetric analysis (TGA), combined with differential thermal analysis (DTA) and derivative thermogravimetric (DTG) data of Co-blending of coal and biomass at (50-50%) blend reveals the thermal behavior of co-blended coal and biomass as temperatures rise from 0°C to 1000°C. The analysis was conducted using a NETZSCH STA 449F3 STA449F3A-0931-M instrument in nitrogen atmosphere. The initial mass of the TG curve (black line) is normalized to 100%. The –TG curve shows shows the percentage of residual mass. A significant weight loss occurs between 200°C and 500°C, reflecting decomposition of volatile matter. The reflecting mass stabilizes at approximately 38.28% at 998.5°C, indicating a lower clear yield

compared to similar blends. The –DTA curve (blue line) indicates heat flows (µV/mg). Around 300-400°C, an exothermic peak is observed, indicating decomposition of organic components. A minor fluctuation at higher temperatures suggests slow thermal reactions or phase changes. The –DTG curve (red line) shows the rate of weight loss (%/min). Around 300-400°C a prominent peak is observed, indicating the maximum decomposition rate. The rate diminishes beyond 500°C, marking the end of major volatile release.

The coal-biomass blend undergoes a two-stage thermal decomposition; initial moisture loss (<200°C) followed by significant devolatilization (200-500°C). The residual mass of 38.28% suggests a moderate char yield, influencd by the blend composition and inert atmosphere. The exothermic –DTA peak at 300-400°C highlights energy release during volatile matter breakdown.

CONCLUSION

The detailed examination of the thermal and chemical characteristics of co-blended coal from Arunachal Pradesh (Namchik) and biomass (Bambusa tulda Roxb.) identifies their potential for energy utilization, especially in thermo chemical processes like co-firing and gasification. The proximate and ultimate analyses indicate compositional differences: coal has high fixed carbon (49.65%) and moisture (45.15%) content with high carbon (79.3% average), whereas biomass has low moisture (8.54%), high volatile matter (71.20%), and average carbon (45.9% average). These characteristics show that coal gives a consistent, high-energy fuel matrix, while biomass adds to increased volatility and reactivity, so that their mixtures are well suited for effective combustion. Fourier Transform Infrared (FTIR) spectroscopy also reveals the chemical complexity of the two materials. The coal sample has a rich variety of functional groups such as aliphatic and aromatic hydrocarbons, carbonyls, alcohols, and minor sulfur and halogen compounds, corresponding to its heterogeneous organic composition. Conversely, the biomass is characterized by polysaccharide-derived groups such as C-O-C, O-H, and CH□ and lignin-associated aromatic structures, in keeping with its lignocellulosic origin. The occurrence of silica in biomass indicates trace amounts of inorganic impurities, which can affect ash behavior when combusted.TGA, in combination with differential thermal analysis (DTA) and derivative thermo gravimetric (DTG) information, exhibits the thermal decomposition characteristics of single and co-blended samples. Coal degrades in a single-step at maximum ~430°C, having ~30-60% residual mass, characteristic of its high fixed carbon and ash content. Biomass follows two-stage decomposition with extensive mass loss in 250-400°C range by loss of volatile organic content, and leaving behind ~50% residual mass. Samples co-blended (25-75%, 34-66%, 40-60%, and 50-50%) show synergistic thermal properties where biomass catalytically supports

pre-maturation of coal devolatilization at low temperatures (200-500°C). The residual mass ranges from 23.57% to 43.19%, indicating the effect of blend composition on char and ash yield. Exothermic DTA peaks at 300-500°C validate energy release upon volatile combustion, while DTG peaks identify multi-stage degradation, especially in blends with more biomass content.

The synergistic effects in co-blending improve thermal reactivity and lower the decomposition temperature, enhancing energy efficiency in combustion processes. The moderate char yields and limited ash content of the blends indicate their potential for energy recovery in uses such as co-firing, where biomass can displace coal's environmental impact by mitigating net carbon emissions. Nonetheless, the high ash content of coal and possible silica in biomass require proper ash management to avoid slagging and fouling in industrial furnaces. Overall, co-blending coal and biomass provides a viable strategy for sustainable energy generation. The complementary chemical and thermal characteristics of these materials facilitate efficient combustion, with biomass increasing reactivity and coal offering thermal stability. Optimization of blend ratios, e.g., 34-66% or 40-60%, can balance energy yield, char production, and ash content, making these blends suitable for large-scale energy applications while facilitating the shift to cleaner, renewable fuel sources. Additional research on combustion kinetics and emission profiles is suggested to further optimize their practical application.

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Photograph Gallery:

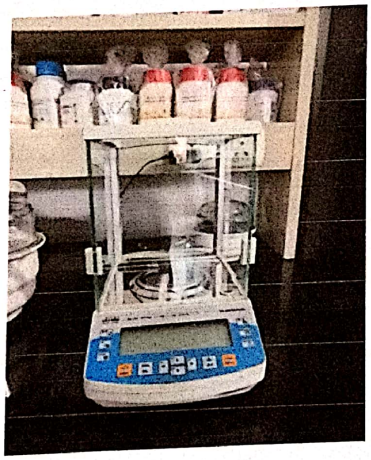
Photos of major instrument used during the experiment:-

(1): Hot Air Oven (Model No. PID 702)

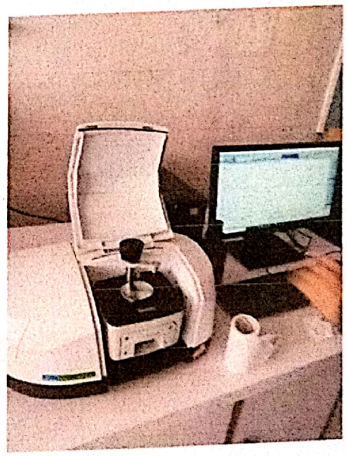
(2): MuffleFurnace (Okay Model: 60F6)

(3): A Rotor Beater

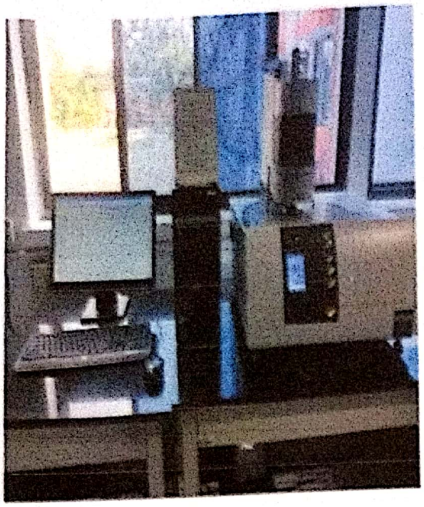
(4): Sieve Shaker



(5): Digital Analytical Balance



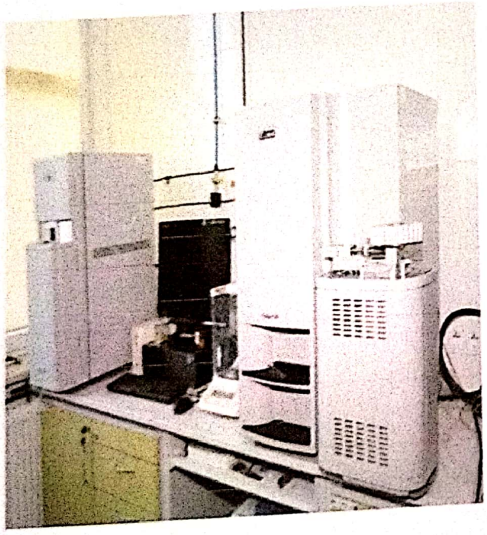
(6): Perkin-Elmer Infrared Spectrometer



(7): TG –DTA/DSC Apparatus (Model: STA 449 F3Jupiter)

(8): Ash content Analysis

(9): Moisture content analysis



(10): Leco Truspec-CHN Elemental Analyzer (630-300-100)

(11): Mortar pestle