TGA ANALYSIS OF SUGARCANE BAGASSE AS A POTENTIAL SOURCE OF BIOFUEL

A

Thesis Submitted

To

Odisha University of Agriculture and Technology, Bhubaneswar

In Partial Fulfillment of The Requirement of The Degree of

MASTER OF SCIENCE IN CHEMISTRY

By

DIPSIKHA CHINARA

Admission No.: 02 CHEM/19

DEPARTMENT OF CHEMISTRY

COLLEGE OF BASIC SCIENCE AND HUMANITIES

ODISHA UNIVERSITY OF AGRICULTURE & TECHNOLOGY

BHUBANESWAR- 751003

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CHINARA D., M.Sc. (CHEMISTRY)THESIS -(2021)

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COLLEGE OF BASIC SCIENCE AND HUMANITIES
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Dr. Pradip Kumar Jena

Assistant Professor Department
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CERTIFICATE – I

This is to certify that the thesis entitled, “TGA analysis of sugarcane bagasse as a potential source of biofuel” submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in **CHEMISTRY** to the Odisha University of Agriculture and Technology, Bhubaneswar, is a faithful record of bonafide research work carried out by **DIPSIKHA CHINARA, Adm No: 02-CHEM/19** under my guidance and supervision and that no part of thesis has been submitted for any degree or diploma or published in any form.

It is further certified that the help and sources of information availed of during the course of study have been duly acknowledged.

Place: Bhubaneswar
Date:

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CERTIFICATE – II

This is to certify that the thesis entitled, **"TGA analysis of sugarcane bagasse as a potential source of biofuel"** submitted by **Dipsikha Chinara** to the Odisha University of Agriculture and Technology, Bhubaneswar, in partial fulfillment of the requirements for the degree of Master of Science in chemistry, has been approved by the students' advisory committee after an oral examination on the same in collaboration with an Examiner.

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Place: Bhubaneswar
Date: Signature

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ABBREVIATIONS AND SYMBOLS USED

1. EBP- Ethanol Blended Petrol
2. LB - Lignocellulosic Biomass
3. TGA- Thermogravimetric Analysis
4. TG – Thermogravimetric
5. DTG– Derivative Thermogravimetric
6. DTA- Differential Thermal analysis
7. FTIR- Fourier Transfer Infrared Spectroscopy
8. NMR- Nuclear Magnetic Resonance
9. DSC- Differential Scanning Calorimetry
10. SCB- Sugarcane Bagasse
11. CA- Cellulose acetate
12. AFM- Atomic force microscopy
13. SEM- Scanning electron microscopy
14. etc- Et cetera
15. Fig.- Figure
16. °C- Degree Centigrade
17. Wt%- Weight percentage
18. mg- Milligram
19. mL- Mililiter

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TGA ANALYSIS OF SUGARCANE BAGASSE AS A POTENTIAL SOURCE OF BIOFUEL

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ABSTRACT

Biofuel is defined as any fuel source derived from biomass, otherwise known as organic matter. Since these types of fuels are continually being replenished naturally by the cycle of life, they are considered as renewable sources of energy. For example, Sugarcane bagasse (SCB) is a renewable, cost-effective, and plentiful source of lignocellulosic biomass for ethanol production. Cellulose, hemicellulose, lignin, extractives, and other inorganic components make up sugarcane bagasse. Sugarcane has been discovered by scientists as a biofuel option for traditional petroleum fuels, which contribute to global warming. Sugar mills can reuse the bagasse (biomass left over after the juice is removed from the stalks) to make ethanol. Sugarcane bagasse is mostly composed of cellulose (32-36%), hemicellulose (28-31%), and lignin (18-24 percent) . It is utilised as a source for the manufacturing of ethanol due to its high starch content, low moisture content, low ash level, and high volatile content. The purpose of this review is to examine the thermogravimetric analysis of sugarcane bagasse at various heating rates in an inert atmosphere in order to determine the degradation temperature of its constituents, which will be necessary for further research into bagasse gasification and pyrolysis. From TGA study of 5 sugarcane bagasse samples it is found that there are mainly four stages of decomposition. Moisture content is evaporated at a range of 80-110°C, hemicellulose is decomposed at a range of 30-200°C, cellulose degrades at a range of 200-380°C and lignin degrades above 330°C.From weight percentages it is found that it has low moisture content and high volatile content which is helpful for pyrolysis and gasification process.

1.0 INTRODUCTION

The world is leaning towards modernity these days. As a result, the number of vehicles and engines on the road is fast expanding. However, the sources of energy utilised in all of these engines are finite and dwindling. As a result, this issue has prompted the search for an alternate fuel. Transportation is becoming a fundamental component of human life as civility grows. The most serious issue is the expanding population and the use of fossil fuels. About a century ago, the primary energy source shifted from solar-to-fossil-fuel conversions in recent years (hydrocarbons).In general, technology leads to a significant utilisation of fossil fuels.

This necessitates the hunt for an alternative to oil as a source of energy. Air pollution is a typical occurrence in many parts of the world. Air pollution is a major problem all around the world. As a result, it has become necessary to be thoroughly knowledgeable on an important aspect of the topic. Air pollution is a problem for the environment as well as for human health. As a result, even the most vulnerable organisms, such as plants, birds, fish, and mammals, are harmed by air pollution. Humans are not immune to these impacts. The United States, along with other countries, has recently began to investigate and utilise other forms of fuel in order to limit the amount of pollution produced by the combustion of fossil fuels.

Ethanol, biodiesel, natural gas, propane, and hydrogen are among the recently produced fuels. All of these fuels have advantages over fossil fuels, and they all burn entirely. A better health and air quality could be just around the corner if the globe can begin to rely less on fossil fuels and more on alternative energy sources. It is necessary to focus on use of alternative fuels for the sake of following reasons-

1. Traditional fuels are going to dismiss: Finding a new way or solution for finding different countries to design new fuels will help to alleviate the challenges and conflicts caused by the world's reliance on fuel supplies.

2. To reduce pollution: Using alternative fuels reduces hazardous emissions (such as carbon monoxide, carbon dioxide, particulates, and sulphur dioxide) as well as ozone-producing pollutants significantly.

3. To combat global warming: The combustion of fossil fuels promotes people all throughout the world to trust that in finding cleaner burning fuel sources is a key step toward enhancing the condition of our environment, according to a widely recognised scientific theory.

4. In order to save money: Using alternative fuels can be less expensive., both in terms of the fuel and the life in service they provide. As a result, long-term investments turn into a valuable asset for someone else.

5. Farmers' assistance: Farmers can be rewarded for their devotion and hard work by using biofuels derived from locally grown and processed products. Ethanol and biodiesel cooperatives are the results of massive, defunct farmer cooperatives, allowing people to retake their authority.

Ethanol is a clear, colourless alcohol fuel produced by fermenting sugars present in sugarcane and wheat, as well as wastes of potato, cheese whey, corn fibre, rice straw, urban wastes, and yard clippings. Alcohol (ethanol) can be made in a variety of methods from biomass. The most extensively used techniques for producing ethanol presently involve yeast to ferment the sugars and starch in the feedstock. Enzymes are being utilised in a new to decompose cellulose in woody fibres, allowing ethanol to be made from trees, grasses, and crop waste.

1.1 BIOFUELS

Biofuel is a type of renewable energy derived from microorganisms, plants, or animals. Biofuel is a sort of fuel , that produces bioenergy and it generated directly obtained from animal or plant stuff, often called as biomass. Because it is not generated by a geopolitics process as fossil fuels, the term "bio" refers to the organic character of this fuel source. (petroleum and coal). Ethanol (usually obtained from corn in the US and sugarcane from Brazil), biodiesel (made from liquid animal fats and vegetable oils), green diesel (produce from algae and other plant resources), and the biogas are all examples of biofuels (methane generated from animal dung and other organic material that has been digested).

Biofuels offer a lot of benefits and can be generated from a range of sources, including commercial, industrial, agricultural and household waste. The fuel is comparable to fossil fuels. There are three states of fossil fuels: solid, liquid, and gas. (see Figure 1).

Fig.1 Different states of Biofuel

1.2 Various Types of Biofuel

Various types of biofuel are discussed below**:**

1.2.1. Wood

It is the main basic type of fuel obtained from biological matters. plants and trees offer biomass in the form of sawdust, charcoal, firewood, pellets and chips, which are all used as fuel. As a result, In all parts of the world, wood is one of the most extensively used types of fuel. People frequently harvest these various types of wood to cook food , heat their houses and power tiny household gadgets.

1.2.2 Biogas

This is a kind of gaseous biofuel. Because it combust similarly to the natural gas, it is gradually but slowly displacing it. The anaerobic decomposition of biomass produces biogas, which is mostly constituted of methane gas. Biogas is used in the majority of agricultural businesses, which is currently packed in the gas cylinders for home uses. Since each supplies a specific element this fuel is obtained from a variety of animals and plants. Plants, for example, have a high carbon content and hydrogen content, but mammals have nitrogen content more. The creation of biogas necessitates the use of these components.

1.2.3. Biodiesel

Biofuel is in liquid by nature. It concentrates on plants with energy content is high in order to obtain the pure biodiesel. It's made by blending oils and fats from plants and animals, respectively. Another element is alcohol which is utilised in the manufacturing of biodiesel. As a supplement, plant and animal grease is used.

These oils are abundant in sunflower seeds. The manufacture of biodiesel necessitates several chemical steps, like trans esterification, that requires alcohols and esters like example methanol and ethanol.

1.2.4. Ethanol

Biofuel is naturally liquid and it is made from the plants and animal biomass, with plants accounting for the majority of the biomass. It's an alcoholic beverage, as the name suggests. It is made by fermenting biomass with a greater carbon contents, primarily cellulose and sugars. One of the most popular crops is sugarcane.It is used to reduce carbon emissions when it is combined with other fuels because of its clean nature. In its current state, it can also be used as a car fuel. Vehicles powered purely by ethanol have proved successful in Brazil, a sugarcane-growing country on a huge scale.

1.2.5. Methanol

Methanol, like ethanol, is an alcohol that is utilised as a clean fuel in many regions of the world to power vehicle engines, particularly racing automobiles. Methanol has a chemical structure that is strikingly similar to methane; the major difference is that methane is a gas, in comparision this methanol is a liquid. In the presence of a catalyst and at an extremely higher temperatures , gasification is used to convert biomass to methanol.

1.2.6. Butanol

Yet this is an another example of alcohol that can be used like a biofuel. Since butanol is a liquid that is formed through the process of fermentation and has a greater energy content per unit than that of methanol and ethanol. Furthermore, its efficiency and chemical structure are similar to gasoline, but it is extremely difficult to produce. It obtains from plants, especially those that have high-energy grains like wheat and sorghum. Because of its longer hydrogen chain and high energy content, it may be pumped straight into gasoline engines.

1.3 LIGNOCELLULOSIC BIOMASS (LB)

Plant's dry matter (called biomass), also known as lignocellulosic biomass, is referred to as lignocellulosic. The raw material which is most abundantly available over the planetfor manufacture of biofuels, bioethanol primarily. It consists of polymers of carbohydrates (cellulose and hemicellulose) and an lignin as an aromatic polymer . Figure 2 shows some LB and an approximate chemical composition. These carbohydrate polymers are tightly bound to lignin and it contain different sugar monomers (six and five carbon sugars). There are three types of lignocellulosic biomass: waste biomass, virgin biomass and energy crops. All naturally occurring terrestrial plants, such as bushes, trees and grasses are considered virgin biomass .

Waste biomass is generated in a lowvalued byproduct of the many industrial sectors, agriculture including (sugarcane bagasse, corn stover, straw and so on) and forestry (paper mill and saw mill discards). A high yield of lignocellulosic biomass can be produed by Energy crops to be used as raw material in the production of the secondgeneration biofuels; example involve Elephant grass and switchgrass (Panicum virgatum).

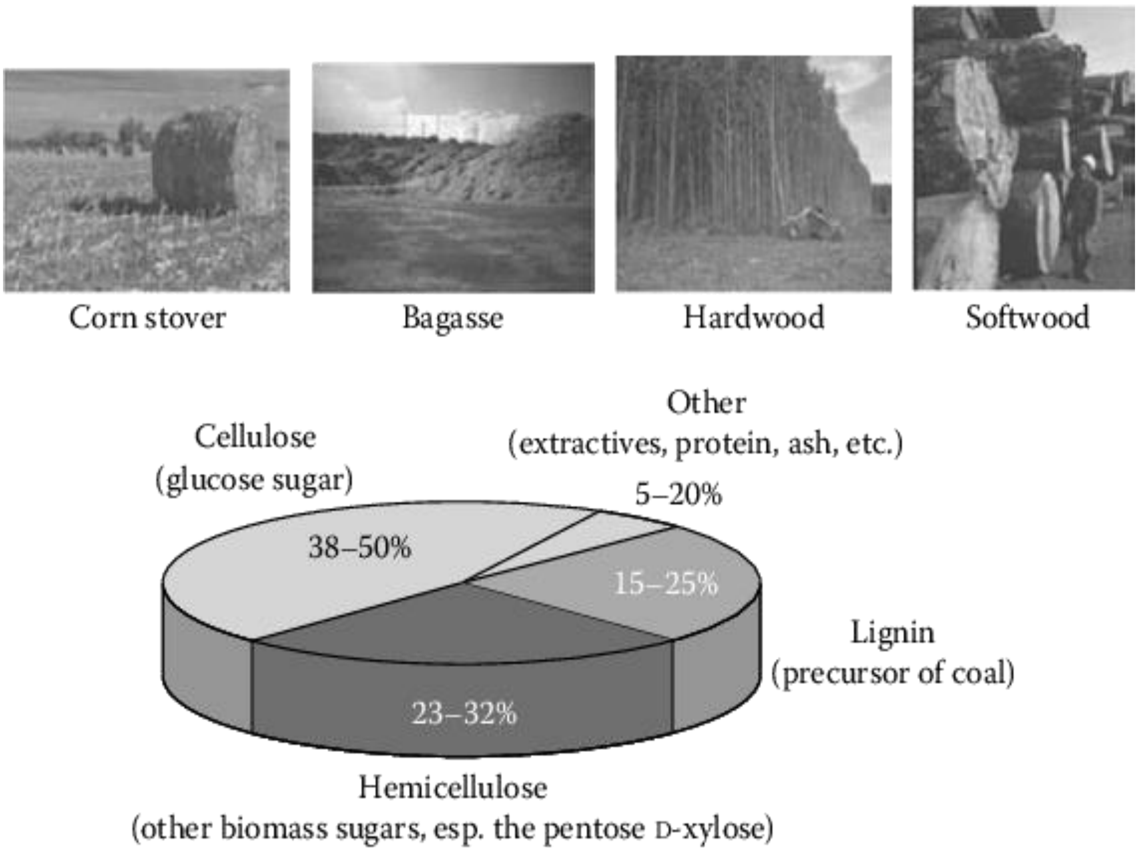


Fig.2 Lignocellulosic Biomass and it’s chemical composition

The most abundant biopolymer on the world is lignocellulosic complex. It is evaluated that lignocellulosic matters account for approximately 55% of biomass of the globe (15–55 billion t/year). Most of the lignocellulosic matters have been tested for the production of bioethanol and can be divided into the following categories:

1. Crop waste (sugarcane bagasse(SB), straws of the cereals, the barley straw and sweet sorghum bagasse etc.)

2. Timber (softwood, hardwood)

Herbaceous biomass is a type of biomass that is found in plants (switchgrass, alfalfa hay, reed canary grass)

4. Agro industrial by products (i.e sawdust, wood chips, olive kernels and pulp)

5.Cellulosic wastes are a type of waste that is made up of cellulosic (i.e waste office paper, recycled paper sludge, newsprint etc.)

Different sources of LB and the structures of constituents present in it have been shown in fig.3 and fig.4 respectively.

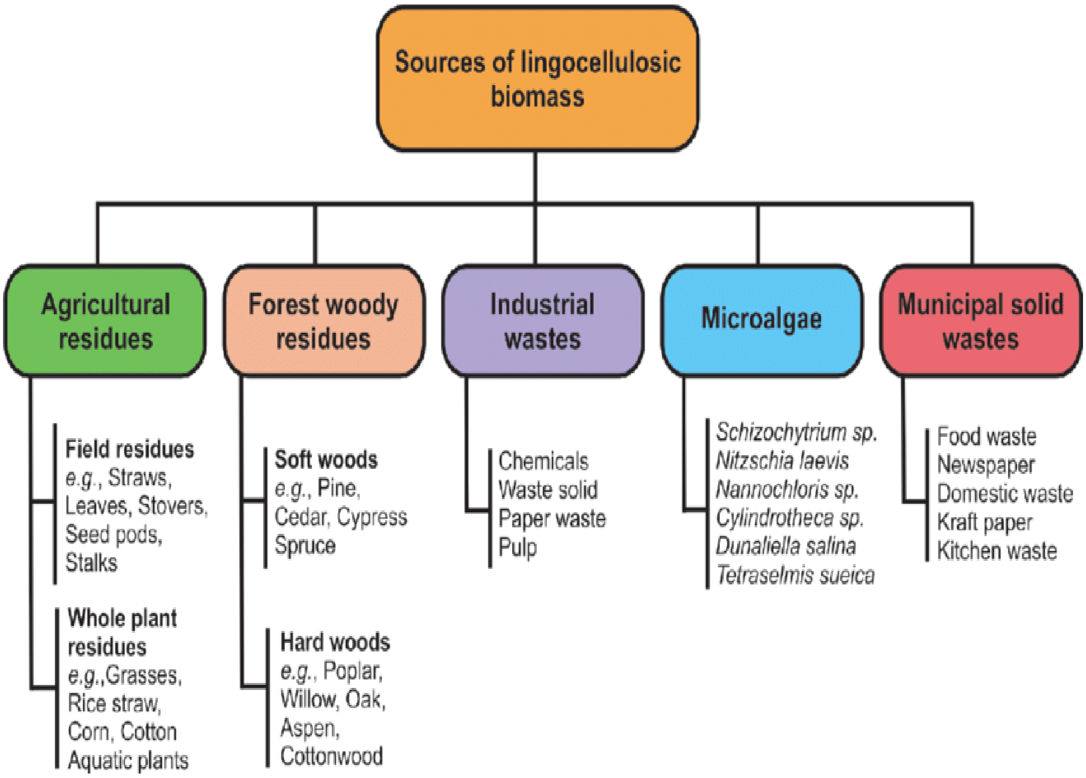


Fig.3 Different Sources of Lignocellulosic Biomass

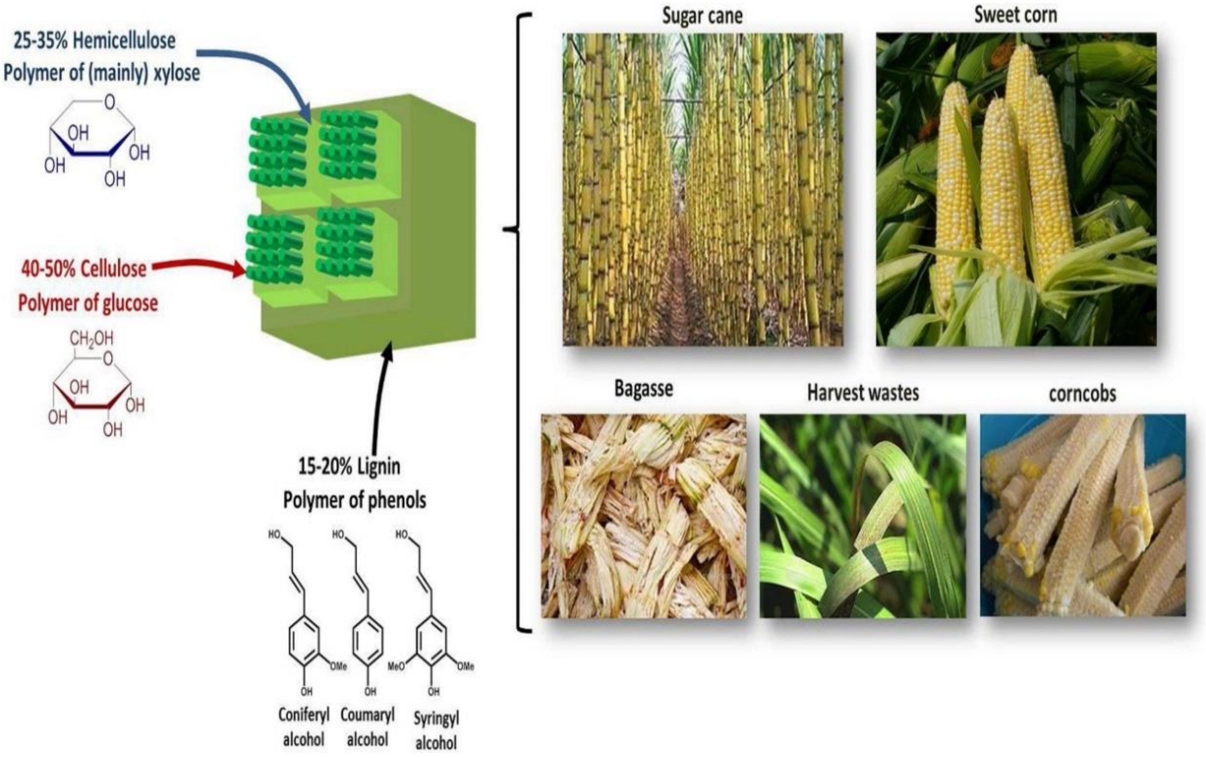
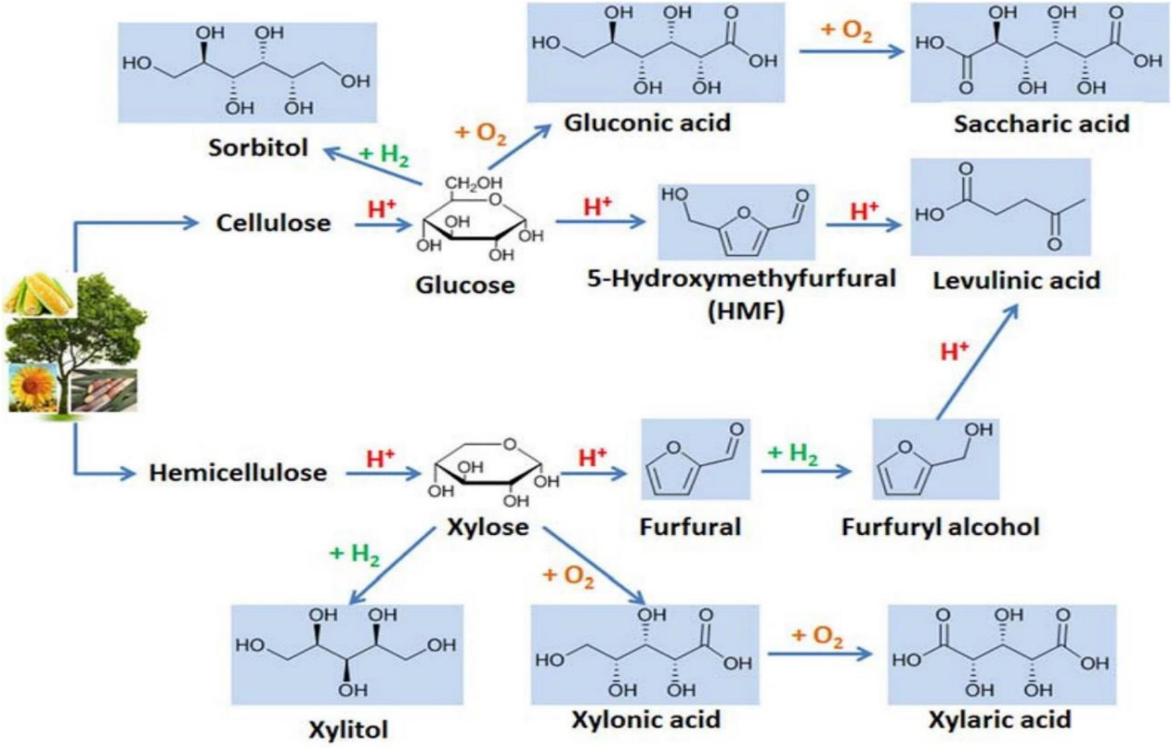


Fig.4 structures of LB constituents

The value that added chemicals obtained from cellulose, hemicellulose and lignin have shown in Fig.5 Value added products derived from cellulose, hemicellulose and lignin.



1.4 SUGARCANE PRODUCTION IN WORLD

In 2018, global sugarcane production was 1.92 billion tonnes, with the Brazil accounting for 40% of the total, 21% for India , and Thailand and china accounting for roughly 7% each. Sugarcane agriculture occupied 27 million hectares worldwide in 2018. Sugarcane crops yielded an average of 73 tonnes per hectare globally in 2018. Sugarcane has a potential yield of around 285 tonnes per hectare per year, and tiny slopes of experiment in Brazil have shown that results of 240–285 tonnes/hectare.

In 2016, just 3.1 percent of the overall output of sugarcane met a voluntary sustainability criterion like fairtrade or Bonsucro , although supportable production is increasing significantly faster than conventional cultivation. Between 2008 and 2016, the production of standards-compliant sugarcane climbed by roughly 52 percent each year, whereas conventional sugarcane increased by less than 1% per year. Table 1 shows the total sugarcane output around the world**.**

Sr.No	Country	Production (1000 tonnes)
1	Brazil	455,291
2	India	281,170
3	China	100,684
4	Mexico	50,597
5	Thailand	47,658
6	Pakistan	44,666
7	Colombia	39, 849
8	Australia	38,169
9	Indonesia	30,150
10	USA	26,835

Table.1 World’s top 10 sugarcane production countries

1.5 SUGARCANE CONSUMPTION IN THE WORLD

Between 2000 and 2018, globally sugar consumption climbed from 122.454 million tonnes to 172.442 million tonnes, representing a 2.02% yearly rise. However, world sugar consumption growth has slowed significantly in the second half of this decade, to less than 0.84 percent per year (average for 2016-2018), with no growth in 2018. India, the EU, China, Brazil, the United States, Indonesia, Russia, Pakistan, Mexico, and Egypt are all major sugar consumers.

1.6 SUGARCANE PRODUCTION IN INDIA

Maharashtra , Karnataka, Andhra Pradesh, Gujarat, Bihar, Tamil nadu , Haryana, and Punjab are the states with the biggest cane area, accounting for about half of the country's total. These nine states produce the majority of sugarcane. U.P. is also the leading producer of sugarcane, followed by Maharashtra. Tamilnadu leads the way in terms of productivity, with over 100tonnes per hectare, ahead of Karnataka and Maharashtra. Of all the major sugarcane producing states, Bihar has the lowest sugarcane productivity. After textiles, sugar is the country's second-largest agro-based sector.

1.7 SUGARCANE CONSUMPTION IN INDIA

According to the association,in India consumption has remained stable at 20 kilogrammes per capita per year, as compared to a global average of 24 kilogrammes, as social media ads claiming that the cane-based sweetener is unhealthy dissuade people from eating this. Between 2000 and 2016, per capita consumption growth was among the lowest in the world.

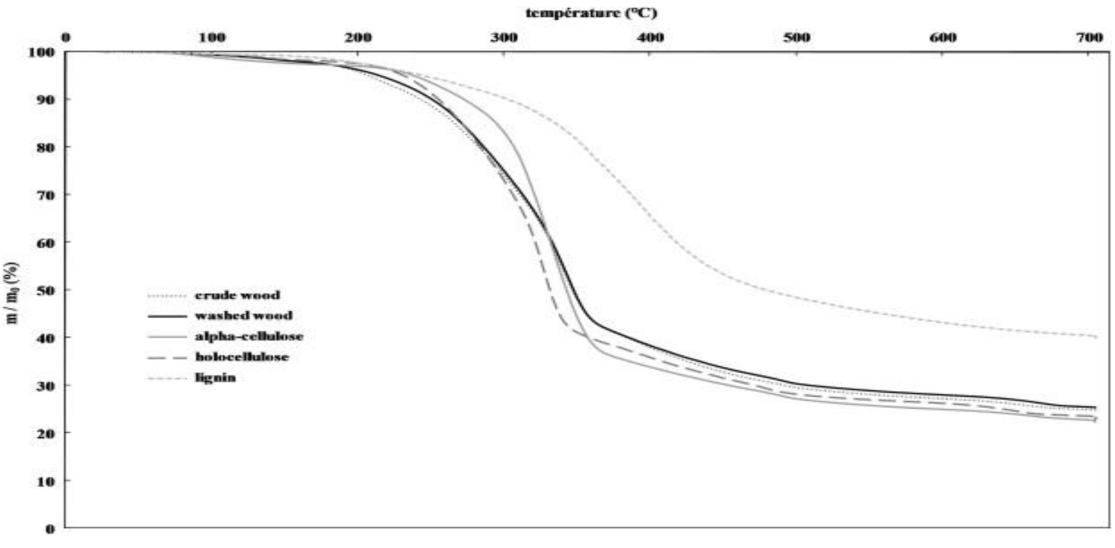
1.8 THERMOGRAVIMETRIC ANALYSIS (TGA)

Thermo Gravimetric Analysis (TGA) has evolved as an alternate approach for assessing the composition of lignocellulosic biomass that is less expensive, more faster and easier to use. When compared to commonly used wet chemical procedures, Thermogravimetric analysis can also be used to determine - hemicellulose and cellulose concentration with more precision. After pre-treatment, TGA was used to determine the biochemical content (lignin, hemicellulose,cellulose) of Avicel, switchgrass, beechwood, alkaline lignin, and maize stover.

TGA is an advantageous because to its high-throughput (at-line) nature and is perfect for evaluating polymers such as lignin, however it is damaging, and temperature ramping can cause polymer modifications.

TGA is a thermo analytical technique that uses a thermo-balance to quantify changes in sample mass (a combination of an electronic microbalance, a furnace, and an appropriate temperature controller). A temperature (or time)/mass (or mass percentage) plot is commonly created when this method is used to analyse material weight loss owing to decomposition, oxidation, or the loss of volatiles like moisture in a specific temperature range. TGA is also useful for measuring thermal and oxidative stability, as well as life expectancy, decomposition profiles, moisture, and volatiles content.

The TGA curve in Fig.6 expresses the weight loss (percentage) as the temperature rises. As the temperature rises, As the temperature of the wood rises, a variety of reactions occur, lowering the weight % . The TGA curve illustrates that the weight % falls as the temperature rises, demonstrating constantly the mass changing due to thermal treatment. When the weight percentage changes , at a lower temperature the breakdown begins and it advances to a higher temperature in the TGA curve. The homogeneity of last segment of the plots correlates to the material's crystallisation, and the temperature at which material crystallises varies.



TGA curve of wood (Fig.6)

CHAPTER-2

REVIEW OF LITERATURE

2.0 REVIEW OF LITERATURE

TGA investigation of sugarcane bagasse as a potential source of biofuel has been carried out with a lot of experimental effort. The following is a summary of the research.

M.Garcia-Perez (2019) , investigated on TGA analysis of sugarcane bagasse as a potential source of biofuel . Thermogravimetry (TG) was used to investigate the thermal degradation of SB ,waste of petrolium, and blends of it under nitrogen at various heating speeds (10, 20, 40, and 60°C/min). The kinetic variable of thermal breakdown have been calculated. Pyrolysis of SB was defined as the addition of individual contributions of hemicellulose, cellulose, and lignin. The bagasse component thermal decomposition kinetics were determined using first order equations. Calculated activation energies for hemicellulose, cellulose and lignin were 103, 233, and 26 kJ/mol, respectively. The additive effect of petroleum residue's three principal fractions can be explained by the kinetic equation orders of 2.3, 2.4, and 1.3, with activation energies of 180, 100 and 220 kJ/mol, respectively. Under the experimental circumstances tested, no substantial interaction in the solid phase in between the components occurred during thermal decomposition of sugarcane bagasse/petroleum residue mixes. The total of the sugarcane bagasse and petroleum remainder individual component kinetic variables was used to calculate the kinetic variables for the sugarcane bagasse/petroleum residue mixture. The data gathered can be utilised to create a correlation between the thermometer and the temperature.

Candido (2017), experimented on TGA study of sugarcane bagasse as a source of biofuel. The researchers looked at the production and use of cellulose acetate (CA) from sugarcane bagasse. X-ray diffraction was used to characterise cellulose extracted by a sequential treatment with H_2SO_4 (10 percent v/v), NaOH (5 percent w/v), EDTA (0.5 percent w/V), and H_2O_2 (5 percent v/v) (DRX). Cellulose acetate was analysed using FTIR, DSC, and TGA after acetylation of the recovered cellulose and was used in membrane fabrication. To determine the ideal conditions for membrane manufacture, analysis of the membrane were carried out using DSC(differential scanning calorimetry) and AFM and examined in a water vapour flux. FTIR study revealed that free OH groups had been replaced by the acetyl groups , and heated examination revealed that bagasse CA had better heat characteristics than the commercialgrade CA. The optimal situation for the membrane preparation were a 3 percent (w/v) (polymer/solvent) ratio , 12 minutes of the solvent evaporation time and a coagulation bath temperature of 20°C. Cellulose acetate can be betterly produced from SB and used in the membrane fabrication, according to these findings.

Glauber Cruz (2021), Enzymatic hydrolysis is one of the primary processes in the conversion of sugarcane bagasse to ethanol, according to research. Compared to chemical procedures, this technique has the potential for improved yields and selectivity, as well as lower energy costs and softer working conditions. However, the digestibility of the cellulose present in lignocellulosic biomasses is limited by the presence of several variables such as lignin level, cellulose crystallinity degree, and particle sizes. The goal of pretreatment is to improve the enzyme's access to the substrate. Sugarcane bagasse was subjected to chemical pretreatment in this investigation, which consisted of two steps: the first with dilute sulfuric acid (1 percent (v/v) H2SO4), and the second with alkaline solutions containing various concentrations of NaOH (1, 2, 3, and 4 percent (w/v)). The content of hemicellulose, cellulose, and lignin in the samples was determined by thermal analysis (TG/ DTG and DTA). The morphological structures of the in natura and chemically treated materials were evaluated using scanning electron microscopy (SEM). The results demonstrated that pretreatments were successful in chemical degradation of the samples' lignocellulosic components, and that morphological alterations could be observed.

Bo-Jhih Lin (2015), faculty of chemical engineering, investigated on TGA analysis of sugarcane bagasse as a source of biofuel. Pyrolysis is a common thermochemical process for converting biomass to bio-oil. To accomplish CO2 utilisation, this work investigates the pyrolysis of sugarcane bagasse in a CO2 atmosphere under conventional and microwave-assisted heating. To aid in pyrolysis reactions, charcoal is employed as a microwave absorber in microwave pyrolysis. The findings show that the heating modes have a significant impact on the yields of pyrolysis products. Bio-oil is the primary product in conventional heating, with yields ranging from 51 to 54 percent, but biochar is the only primary product in the heating through microwave, with yields ranging from 61 to 84 percent. In microwave pyrolysis, two distinct absorber mixing ratios of 0.2 and 0.4 are investigated. Absorber blending ratio when decreased from 0.4 to 0.2, the solid yield declines that time the liquid and the gas yields raise. It is because of the lower mixing ratio consuming more energy for bagasse pyrolysis. Microwave pyrolysis produces hydrogen, which has a concentration of in the middle of 2 and 12 volume percent. It is because of the result that secondary biochar degradation and secondary vapour cracking are easier in a microwave-irradiated environment than in a conventionally heated environment.

M.Flavia Rodrigues starling Araujo (2019), did experiment on the production of Biofuel from the TGA analysis of sugarcane bagasse. Sugarcane bagasse is a common byproduct of the ethanol and sugar industries, and its liquefaction can be a low-cost way to make biofuels of liquids. However the resulted biocrude has a great acidity and must be upgraded before use. For the liquefaction of bagasse, fusel oil and ethanol, and it is the main residue of ethanol distillation which composed of higher alcohols, that were utilised like solvents. At 300 °C for 30 minutes under a 10 bar N2 environment, a 2:11 biomass:solvent ratio mixture was utilised. To make a comparison study, a mixture of both solvents was also evaluated. With ethanol, bagasse conversion was 72 percent, but with fusel oi, the greatest result was 91 percent. The liquid product followed by distillation, a bio crude rich in esters and with a high combustion heat (30.6 MJ.kg–1) was obtained. The presence of esters with substituted i.e isoamyl groups (52.2 percent) and, to a least extent, compounds of phenols was shown by GC/MS data (2.7 percent). Heating value of biochar has 32 MJ.kg–1 and has exceptional thermal stability , making it ideal for use as a solid fuel. Biocrude was composed with marine diesel (7%), and the mixture's characteristics were assessed without any alterations. This novel approach demonstrated the utilisation of two waste products, bagasse and fusel oil, to create a biofuel that can be utilised with many of diesel types and is both cost-effective and environmentally friendly.

Jerome A.Ramirez (2020) , investigated on the production of biofuel by the TGA analysis of sugarcane bagasse. Heat chemical conversion of the 11 tonnes per hour of SB to liquid crude biofuels was used to build technoeconomic models for 3 plants in Australia, Queensland. To get the most output out of second-generation feedstock, thermochemical conversion was used. The different energy flows and mass of each process were highlighted by the process models. Factory models were created using current heat and material recovery methods. Liquefaction produced the most product per kilogramme of feed, followed by pyrolysis and gasification. The importance of key plant economic metrics was also stressed. The profitability was ranked as follows based on net present values: > pyrolysis>liquefaction>gasification. The plants were all affected by in product price, thermochemical conversion ratio, and refining conversion ratio, with product price, thermochemical conversion ratio, and the refining conversion ratio having most impact on profitability. Conversion ratios have a significant impact on the minimum selling price of products, but this effect is mitigated by large product volumes. Because tax rates and capital expenses have less of an impact on the minimum selling price than conversion ratios, incentives aimed at enhancing conversion rates and expanding product volume should be considered.

L.C. Morais (2017) , started on the production of Biofuel by the TGA study of SB . The inefficient and the indiscriminate disposal of the SCB has gotten a lot of press. Exploration of bioenergy capabilities of biomasses and associated bio chars is critical to achieving their usage. Understanding the thermal conversion processes of biomass and bio chars is critical in this context if they are to be used in the production of bioenergy. in this study the goal was to use thermogravimetric analysis (TG) to evaluate the heating behaviour of sugarcane bagasse biomass remaining and biochar. Heating studies were occurred at 5, 7.6, and 10 °C /min in an inert and oxidative environment. The maximum mass loss rate for hemicellulose was 255°C, Cellulose was 335°C, and the lignin breakdown ranged of 195-505°C, although the greater loss of mass rate was 435°C, and 200°C was the devolatilization. The changes in apparent Ea express singlestep kinetics in the decomposition process, and the model of OFW is more in the line including the data of experiment and more accurately describes the intricacy of the decomposition process. Carbon, oxygen, aluminium, magnesium, and iron were found in SEM/EDX tests.

Witchakorn Charusiri (2018), existance of scrap tire and sugarcane bagasse(SB) was investigated in this study like co-pyrolysis feedstock 17with a centre of attention on yield of liquid. In varied mixing ratios,2 raw materials were supplied to a fixed bed reactor. The experiments were carried out at 505°C with a rate of heating of 25°C/min and a carrier gas of Nitrogen 19 (flowrate: 50mL/min). SB/scrap tyre 2:4 yielded the greatest liquid yield (49.9% vs. 42.2%), it was then 21characterized for chemical and physical parameters using several chromatographic and 22spectroscopic analytical techniques. The quantity of the co-pyrolysis liquid and quantity yield suggested significant synergistic effects. In comparison to pure sugarcane bagasse 25pyrolysis oil, the optimal feedstock combinly formed oil 24 with a constant calorific value of 45 MJ/Kg and lower in viscosity. After the necessary processing, co-pyrolysis oil expressed a great prospective for its use as a feedstock for the fuel manufacture.

Jui-Li-Ren (2007), The conditions for preparing etherified hemicelluloses from sugarcane bagasse with ETA (2, 3-epoxypropyltrimethylammonium chloride) in aqueous solution with NaOH as a catalyst were compared. The degree of substitution and percentage of yield were used to determine the degree of etherification. On the reaction yield and degree of substitution, the reaction impact duration of 4–8 h, the reaction temperature of 55–810°C, alkaline activation temperature of 35–610°C, and alkaline activation time is of 2–62 min were studied in depth. By varying the duration and reaction temperature , as well as temperature and time, the degree of substitution and overall yield of etherified hemicelluloses from SB with ETA using NaOH as a catalyst ranged from 35.2 to 41.9 percent and 0.15-0.38, respectively. By varying the duration and reaction temperature , as well as the temperature of alkaline activation and time, the result of etherification was measured by yield percentage and degree of substitution, which ranged from 35.2 to 41.9 percent and 0.14 to 0.33 percent and 0.14 to 0.33 percent, respectively. Fourier transform infrared spectroscopy (FTIR) and Carbon-13 NMR spectroscopy, thermal analysis, and GPC were used to characterise the novel materials. It was discovered that after chemical modification, the thermal stability of hemicellulosic ethers reduced, and the etherified hemicelluloses molecular weights were lower than those of the native hemicelluloses. The quaternization of hemicelluloses and esterification reaction were confirmed by 13C NMR spectra.

CHAPTER-3

3.0 MATERIALS AND METHODS

3.0 MATERIALS AND METHODS

For the Thermo Gravimetric Analysis study,05 sample data of corn have been collected from different journals. Details about samples have been mentioned in table1.

TABLE-1

Sl no.	Biomass sample	Biomass reference place
1	Sugarcane bagasse	Layyah [M.Garcia Perez (2019)]
2	Sugarcane bagasse	Brazil [Glauber Cruz (2021)]
3	Sugarcane bagasse	Cerquilho city [L.C.Morais (2017)]
4	Sugarcane bagasse	Pakistan [Bo Jhih Lin(2015)]
5	Sugarcane bagasse	Thailand[WitchakornCharusiri(2018)]

Table1. Collection of biomass sample from different places.

The thermogravimetric analysis of sugarcane bagasse residue involves following steps:-

⇒The sample was collected from different places in all over the world. To remove the contaminants, the sample was rinsed under the running water, crushed, and sieved into various size fractions by using ASTM standard sieves.

⇒ The particle sizes that were chosen as averages were 0.35mm which were required by the TGA instruments that were used for analyses.

⇒Different TGA instruments were used for different sugarcane samples. Here The sample is slowly heated in a controlled atmosphere. Here the study had been done in an inert atmosphere i.e in presence of nitrogen.

⇒ The change in the substance's weight as a function of temperature or time is recorded. It provides information on sample composition changes, thermal stability, and kinetic parameters for chemical processes.

⇒ The TGA analysis of several biomass samples was carried out at varying flow rates and heating rates, as shown in table 2.

TABLE-2

Sl no.	Biomass sample	Instruments used	Flow rate	Heating rate
1	Sugarcane bagasse	TGA-701	35ml/min	20°C/min
2	Sugarcane bagasse	TGA-50H	100ml/min	10°C/min
3	Sugarcane bagasse	SDT-Q600	120ml/min	10°C/min
4	Sugarcane bagasse	Mettler Toledo	20ml/min	20°C/min
5	Sugarcane bagasse	Netzsch-409	40ml/min	20°C/min

Table 2 shows the different flow rates and heating rates used in the TGA experiment.

CHAPTER-4

RESULT AND DISCUSSION

4.0 RESULTS AND DISCUSSION

4.1Results

Sample-1

TGA was used to place sample-1. The environment was kept inert with N2 gas flowing at a constant rate of 5 L/min and a ramp rate of 20°C/min. The result obtained shown in Fig.9

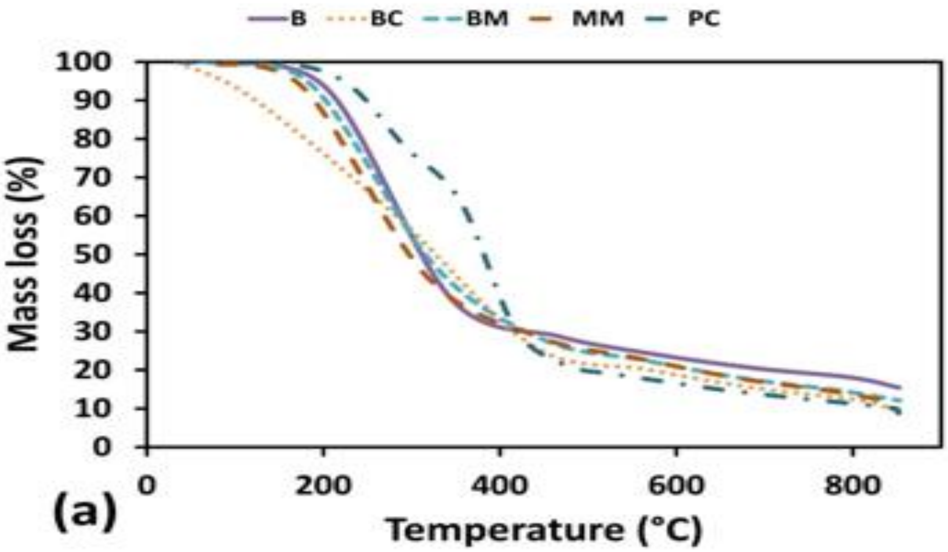


Fig.9 Distribution of TGA of sugarcane bagasse

Sample-2

For the TGA study of sample-2, 5mg of biomass was analysed at temperatures ranging from 26–800°C, with a volumetric flow rate of nitrogen of 100mL min1 and a heating rate of 10°C min1.The result obtained shown in Fig. 10.

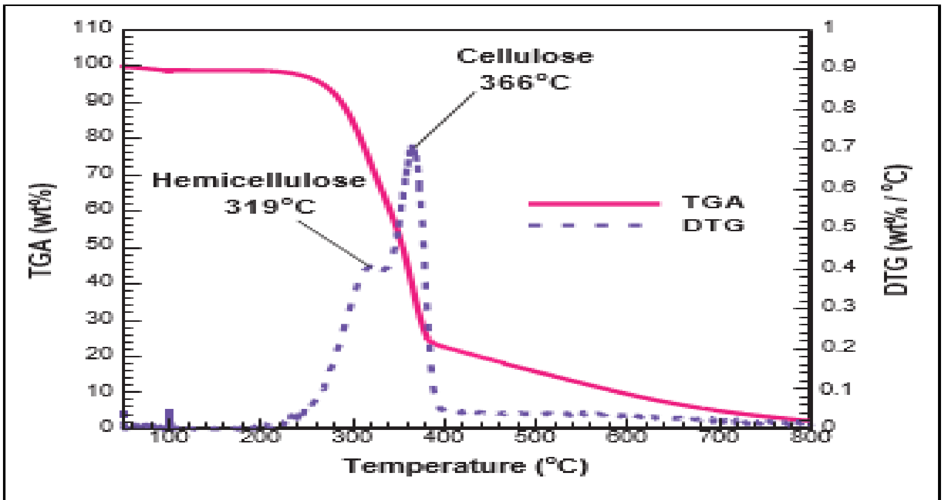
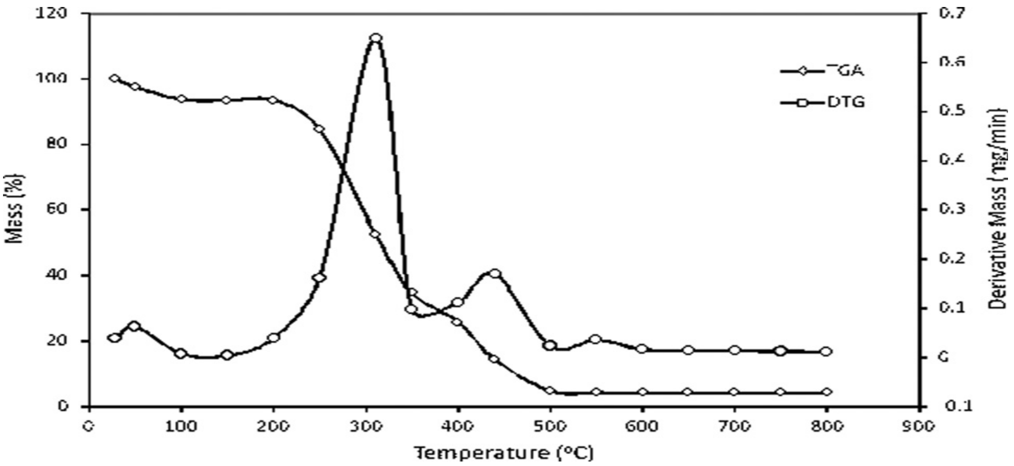


FIGURE 2 | Distributions of TGA and DTG of raw sugarcane bagasse.

Distribution of DTG and TGA of raw sugarcane bagasse(SB).

Sample 3

The Figure 11 depicts the thermal behaviour of the current SB. The TGA and mass loss of derivative profiles are plotted as a degree of temperature in the 40–800° C temperature range at a constant heating rate of 11 C/min.



TGA and DTG curves of sugarcane bagasse (Fig.11).

Sample 4

Here the sample was placed in TGA instrument is shown below.The flowing rate of gas was20ml/min and the heating rate was kept at 100-500°C.

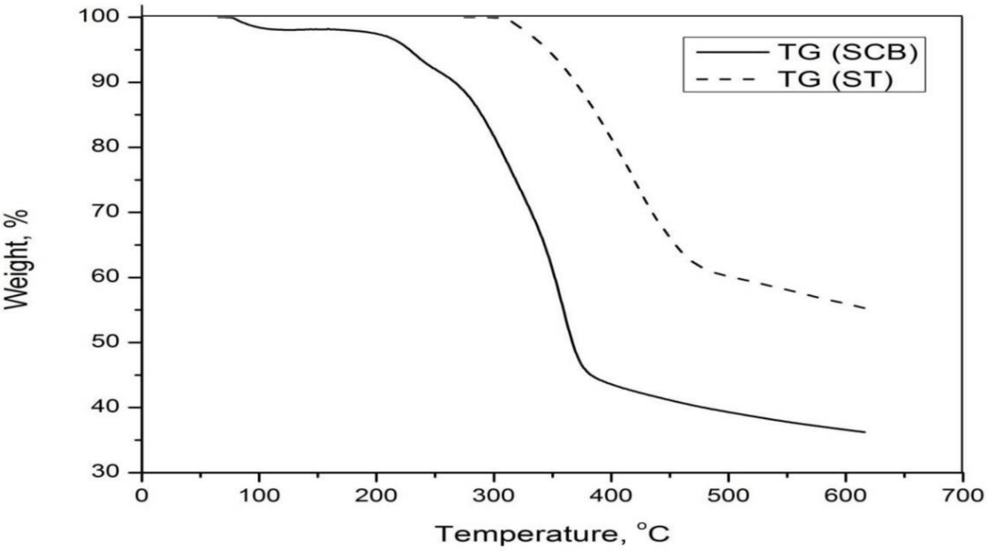


Fig.12 TGA curve of sugarcane bagasse sample at 100-500°C

Sample 5

Nearly 5 milligram of dry SB was under go heating from the room temperature to 801 °C at a constant rate of 21 °C min1 with the flowing of N2 gas at a given rate of 41 mL min1. The thermal degradation behaviour of sample SCB was monitored in real time.

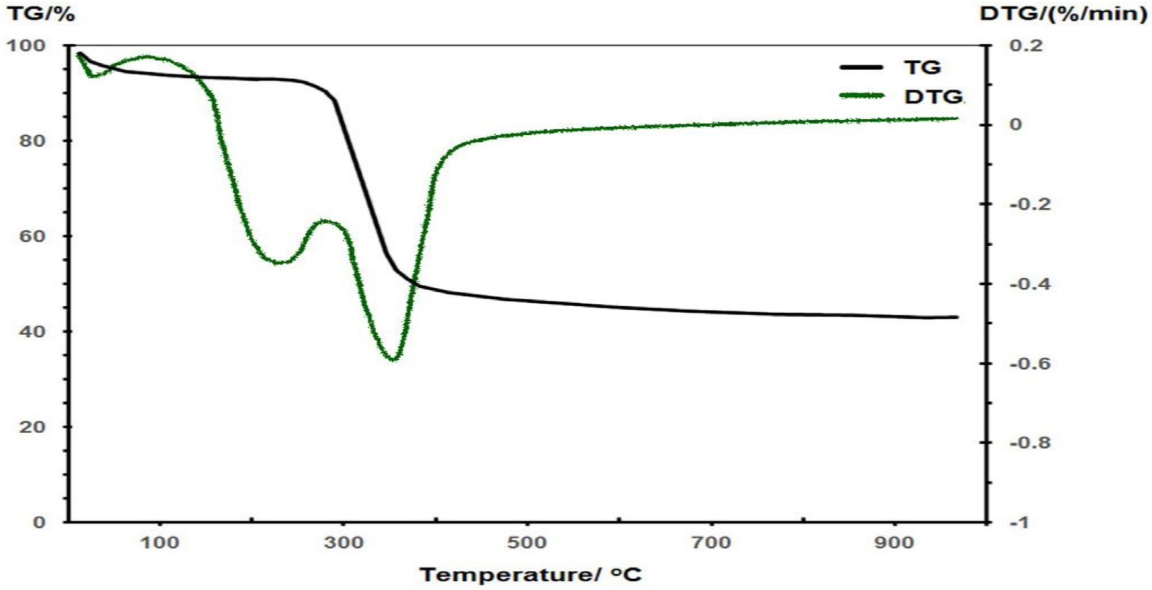


Fig.13 Distribution of TGA and DTG of sugarcane bagasse

DISCUSSION

The **sample 1**, was placed in TGA. Removable of moisture was carried out by heating to 105°C and then maintaining that temperature for another 15 minutes. After that, the given samples were heated to 855°C at a constant ramp rate. The process was repeated at constant temperatures until the samples reached to constant weight. To ensure data reliability, the experiments were replicated twice. Figure 9 depicts the thermogravimetric analysis curves of the analysed sugarcane bagasse samples. TGA curves of biomass are divided into three major regions based on composition: hemicellulose zone (246-291°C), cellulose zone (291-351°C), and lignin zone (351-526°C). Nonetheless, the lignin zone extends throughout the decomposition range. In total of the samples, the greater weight loss was completed up to about 550°C.

For **sample 2**, Figure 10 shows the TGA distributions and DTG studies of sugarcane bagasse(SB). Decomposition of biomass through heating occurs primarily at the range of temperature 203-403°C, according to distributions.Temperatures of the breakdown of hemicellulose, cellulose, and lignin were reported to be in the given ranges of 202–317, 317–402, and 162–902°C, respectively, due to their intrinsic differences in lignocellulosic structure. As a result, first peak obtained at 320°C (10) is because of hemicellulose heating breakdown in sugarcane bagasse, whereas the 2nd peak shown at 367°C is because of cellulose heated deterioration. Lignin breakdown in a high temperature setting can explain the constant and gradual degradation of biomass at temperatures above 400°C. When the reaction temperature rises beyond 400°C, the TGA curve shows that over 78 wt% of bagasse is thermally degraded. As a result, pyrolysis of sugarcane bagasse should be occured at over 405°C temperature. As a result, SB pyrolysis at 3reaction temperatures of 455, 505, and 555°C is considered in this research. The constant and gradual breakdown of biomass at temperatures above 400°C can be explained by lignin decomposition in a high temperature environment. When the reaction temperature exceeds 400°C, the TGA curve shows that over 78 wt% of bagasse is thermally degraded. As a result, bagasse pyrolysis should be carried out at temperatures over 400°C. As a result, bagasse pyrolysis at three reaction temperatures of 450, 500, and 550°C is considered in this research.

The loss of mass of Sugarcane bagasse at the time of thermogravimetric analysis may be separated into three regions, as shown in Fig. 11 for **sample 3**. The first region of the thermogravimetric curve extends from 35 to 205°C and may be classified into 2 parts. The elimination of free moisture is responsible for the first stage, which runs from 30 to 100°C (6 percent). The second portion is a nearly horizontal line which is from 102 to 205°C, with a loss of mass of 2% because of the removal of bound water and vaporization of tiny quantities of Volatile matter. The major devolatilization happens in the second zone, and the highest loss of mass is attained. It happens between 205 and 450 degrees Celsius. Based on the rate of mass loss this zone could also be classified into two sections. The first section is in the 205–335°C range of temperature, with a loss of mass of 53%. This breakdown of hemicellulose and cellulose has resulted in this section. The second portion is also in the 337–455°C temperature range, with a loss of mass 28%. The degradation of cellulose is represented in this section. This zone is a hotbed of pyrolysis activity. The third region of the TGA plot begins at 455°C and extends to 805°C; in this zone the mass loss is relatively minimal because of the sluggish rate of deterioration (6 percent). The lignin breakdown is assumed to be the cause of this zone, known as the zone of passive pyrolysis. Roughly at a temperature of 505°C, the decompose process is nearly complete.

In general, thermal degradation of biomass under ordinary heating rates shows that hemicellulose pyrolysis occurs at less than 350°C, cellulose pyrolysis occurs between 250 and 500°C, and lignin pyrolysis spreads almost all the temperature evenly over 500°C, with no sharp mass loss peak appearing because lignin is relatively more thermally stable than hemicellulose and cellulose.

Figure 12 depicts the TGA findings of SCB **sample 4**. It indicated a loss of weight as the temperature rose. SCB decomposition began sooner due to its inherent thermal stability at 200°C. Because SCB is mostly made of lignocellulose and has a high water content, its pyrolysis is divided into 3 phases. The 1st stage of Sugarcane bagasse breakdown obtained from room temperature to 138°C with an 8.5wt percent loss of weight, followed by the 2nd stage from 205°C to 385°C with a minimum weight loss of 53.8 percent and The last step varied from 385°C to 485°C, with an additional 12.9 percent weight loss. Moisture and extractives are released during the first step. While the second stage is related with the breakdown of cellulose and hemicellulose. Because of its complex structure, lignin gets destroyed in the final stage

The TGA thermogram of SCB **sample 5** is depicted in Fig.13, and it indicates that SCB breakdown may be split into 3 stages. The 1st stage lasts from the room temperature to 105 °C and is characterised by a little loss of weight in the weight-loss plot and a small peak obtained in the rate of curve of weight-loss. These losses were attributable to water removal (6.1wt%) and the light volatile vapours loss from the raw biomass materials. These losses are caused by moisture evaporation in lignocellulosic material. Degradation of hemicellulose begins about 200 °C. The heat breakdown of cellulose is responsible for the following peak at around 350 °C. However, because cellulose and hemicellulose breakdown is a continual process. The highest disintegration rate related to the loss of mass that happened between 240 °C and 325 °C. The second step of the curve likewise showed the rate of weight loss was greatest at a maximum temperature of 345 °C. The breakdown of hemicellulose and cellulose resulted in the emission of volatile substances (49 wt percent). The mass loss is attributed to lignin breakdown in the last stage, when heat degradation proceeds very steadily, and the weight loss maintains from 240 to 902 °C, implying that the lignin was steadily dissolving into a solid remainder (biochar of 40 wt. percent). The weightloss curve shows a modest increased weight reduction.

CHAPTER 5

5.0 CONCLUSION

5.0 CONCLUSION

In this review, Thermo Gravimetric Analysis data of 5 sugarcane bagasse collected from different journals have been studied at different heating rates and different flow rates. Moisture evaporation took place at 105°C, 110°C, 55°C, 100°C, 80°C for the samples 1 , 2, 3, 4 and 5 respectively. Hemicellulose degrades at a range of 30-200°C, Cellulose degrades at a range of 200-380°C and lignin started degrading at above 330°C .

Sugarcane bagasse has considerable ability for the production of biofuel through the pyrolysis process due to its low moisture and ash content, as well as its greater calorific values (18 MJ/kg) and high volatiles content (78%). Sugarcane bagasse contains less nitrogen and sulphur than many other types of bio mass. SB's empirical formula is $CH_{1.57} O_{0.82} N_{0.005}$ .based on ultimate analytical data. The primary vaporisation of SB carried out at the temperature range of 205–505°C after heat treatment. According to the KAS and OFW techniques, average activation energy is 92.68 kJ/mol and 106.45 kJ/mol respectively. Between 255 and 355°C temperatures the highest degree of conversion can be found out. Between the proposed and experimental data, the maximum error limit on conversion is 11.6 %, 8.5% and 6.0% for 20°, 5° and 10°C/min respectively . SB appears to have a lot of pyrolysis potential. This dissertation work will helpful for further study of sugarcane bagasse in pyrolysis.

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