COMPARATIVE STUDY OF DOWNDRAFT GASIFICATION WITH VARIOUS BIOMASS FUELS

Gagan Sahu
M-Tech in Machine Design (Mechanical Engineering)
Ganga Institute of Technology and Management.
Kablana, Haryana.

Mr. Vivek
Assistant professor
Dept. of Mechanical Engineering
Ganga Institute of Technology and Management.
Kablana, Haryana.

Abstract: The study examines the biomass feed materials of rice husk, waste plastics, and sawdust to gain insights into their composition and properties. The analysis reveals distinct characteristics of each material. Rice husk has a lower carbon concentration, limiting its energy production potential, but it offers a satisfactory contribution of hydrogen. Although nitrogen concentration is moderate, the high oxygen content suggests the presence of oxygenated molecules, while the low sulfur content indicates minimal emissions. Waste plastics exhibit a significantly higher carbon content, indicating a substantial energy potential. With increased hydrogen concentration and low nitrogen and sulfur levels, waste plastics minimize environmental pollution. The presence of oxygenated molecules in waste plastics is significantly reduced compared to rice husk. Sawdust lies between rice husk and waste plastics in terms of carbon content, providing a good energy potential. It contains a comparable amount of hydrogen to rice husk, but nitrogen levels are relatively low. Sawdust has a relatively high oxygen concentration, suggesting the presence of oxygenated chemicals, and its sulfur content is comparable to rice husk and waste plastics. The varying compositions of these biomass materials determine their suitable applications. Rice husk is suitable for processes prioritizing oxygen availability, such as combustion. Waste plastics, with their high carbon and hydrogen content and minimal nitrogen and sulfur emissions, possess significant energy potential. Sawdust, striking a balance between energy potential and oxygenated chemicals, finds diverse applications. Understanding the final analysis of these biomass feed materials is crucial for selecting appropriate feedstocks and optimizing their utilization, considering variables like energy efficiency and emissions control.

Keywords: Biomass Feed Materials, Downdraft Gasification, Hydrogen Concentration And Low Nitrogen And Sulfur Levels

I. INTRODUCTION

The process of turning solid organic matter (biomass) into a mixture of gases that may be used as fuel is referred to as biomass gasification. This process can take place in a biomass gasifier. The following are examples of the many kinds of biomass fuels that may be utilized in gasification:

a) Debris derived from the processing of wood, such as sawdust, chips, and bark;
b) Debris derived from agricultural processes, such as straw, maize stalks, and sugar cane bagasse

c) Waste generated by municipalities, including paper, cardboard, and food waste
d) Algae: Rapidly reproducing aquatic plants that have the potential to be collected and converted into fuel
e) Sewage sludge: Waste material that has been cleaned and stabilized in wastewater treatment facilities

The production of electricity by means of a gasifier requires first the transformation of solid biomass into a combination of gases known as syngas, and then the use of syngas in order to generate power. The following is a quick rundown of the actions that need to be taken:

Gasification: The final product of biomass gasification in a reactor is syngas, a combination of carbon monoxide (CO), hydrogen (H_2), and carbon dioxide (CO_2).

Cleaning and conditioning: The syngas is then conditioned to eliminate any moisture that may have been present, as well as any contaminants, before being stabilized.

Combustion: In order to generate heat, the syngas after it has been cleansed and conditioned is burnt in a combustion chamber.

Recovery of heat: The heat that is produced as a byproduct of the combustion process is utilized to make steam, which then powers a turbine, which in turn produces electricity.

Power Generation: A generator is turned on by the spinning turbine, which results in the production of energy that may be added to the power grid.

A wide variety of power generating technologies, such as steam turbine systems, gas engines, and fuel cells, may be used with gasifiers to produce electricity. The choice of technology for the production of electricity is determined by a number of criteria, including the chemical make-up of the syngas, the scope of the project, the required level of efficiency, and the cost. When compared with other traditional forms of energy, the following are some of the distinguishing characteristics of power production utilizing a gasifier:

a) Cost: The production of electricity via gasification may be more costly than the conventional generation of electricity using fossil fuels. This is owing to the greater cost of biomass feedstocks as well as the more complicated technology required in gasification. On the other hand, it is possible for it to be less expensive if waste biomass is used as the feedstock and the price of carbon emissions is taken into consideration.

b) Efficiency: The efficiency of producing electricity by gasification might vary, depending on the kind of gasifier and the technology that is utilized to produce the electricity. On the other hand, it is often lower than traditional power plants that are based on fossil fuels.

c) Emissions: Gasification-based power production generates less greenhouse gas emissions than traditional fossil fuel-based power plants, making it an alternative that is friendlier to the environment. This makes gasification-based power generation an ecologically preferable choice.

d) Availability of Fuel: Biomass feedstocks that are used in gasification may be cultivated and collected in a manner that is ecologically responsible, which makes them a source of renewable energy. On the other hand, fossil fuels have a limited supply, and their accessibility is determined by both geopolitical and economic considerations.

e) Scalability: Because gasification-based power production can be scaled up or down to meet shifting energy needs, it is a versatile alternative for both large-scale and decentralized power generation. This makes gasification an attractive choice for power generation.

The selection of an energy source for the production of electricity is determined by a number of criteria, including cost, efficiency, influence on the environment, fuel availability, and scalability. Gasification-based power production may be a feasible alternative for the creation of renewable energy, particularly in locations with ample biomass feedstocks. This is notably the case in the United States.

The process of converting solid fuels into combustible gas, also known as syngas, may be accomplished via the use of biomass gasification. Charcoal and tar are two byproducts that result from the gasification process. The gasifier dries, pyrolyzes, oxidizes, and reduces the biomass as part of its processing. The water that was extracted from the biomass was evaporated in the drying zone. During the pyrolysis process, volatiles are discharged into the atmosphere, and tar is produced. This takes place in the oxidation zone, which is the part of the system where the gasification agent was first injected. In this zone, the breakdown of char is slowed down, and the formation of the final syngas composition takes place. There are two different types of efficiency that may be used to talk about the gasification process: cold gas efficiency and hot gas efficiency. The efficiency of cold gas takes into account just the calorific value of the gas that is produced, while the efficiency of hot gas takes into account both the calorific value and the sensible heat of the gas that is produced in proportion to the amount of energy that is input into the gasifier.

1.1 Biomass Gasification

When utilized to produce electricity, conventional energy sources like fossil fuels have a major negative influence on the natural environment. Because of the rapid increase in energy demand throughout the world, new energy sources that can take the place of fossil fuels are required. The usage of fossil fuels in today's power plants and vehicles is contributing to an alarmingly rapid increase in the amount of carbon dioxide that is being emitted into the atmosphere. Biomass is becoming an increasingly important focus in research efforts to develop new energy sources that are both renewable and acceptable to the environment. One method for converting biomass into a fuel that may be used in gaseous form is the gasification process. Through a process known as biomass gasification, it is feasible to convert waste from sustainable biomass into gases that can be burned, and these gases may then be used to power the enterprises in question. Gasification and cycling are two processes that are being utilized to connect the use of biomass with the creation of energy in a number of countries, including India. The world started to become dependent on fossil fuels almost as soon as they were found. Fossil fuels, which are a kind of energy source that does not replenish themselves, have been used to power electric power generation as well as vehicle engines. As a result of the detrimental effects that fossil fuels produce, we need fuels that are cutting edge, environmentally friendly, and reliable. This comprises organic wastes such as agricultural residues, municipal garbage, food wastes from the food business, and forestry waste as well as the by-product of wood. Other examples of organic wastes include municipal trash and food wastes from the food sector. Biomass is quickly becoming one of the most interesting potential sources. The investment of billions of dollars in new technologies and infrastructure is being made by the energy industry in order to ensure that it is prepared for what lies ahead. These last several years have been some of the most transformative in the industry's history in the most recent memory. The energy industry forecasts that by the year 2035, not only will we have a far larger choice of alternatives for heating our homes, but emissions will also have been significantly reduced, and all new vehicles will be electric. Traditional energy sources, such as fossil fuels, have a significant impact on the surrounding environment when used for the generation of electricity. India, which is considered to be a developing country, is home to 1.27 billion people, which is equivalent to 17% of the total population of the planet. Because of India's rapidly growing population, there has been an uptick in the quantity of primary energy that is being used. The amount of energy that is required in India is skyrocketing at an incredible pace. In spite of the fact that India's power companies have seen significant growth and expansion in recent years, they are still unable to keep up with the ever-increasing demand in the nation. Not only is there an issue with their being insufficient power or energy, but there is also a problem with there being a widespread lack of power or energy. Ensuring the reliability of the nation's energy supply is a precondition for the continued expansion of the economy. The amount of energy that is used on a per-person basis has a direct bearing on economic expansion or development. When compared to the average of 1803 kg of oil equivalent utilized worldwide, India's per capita energy usage of 540 kg of oil equivalent seems incredibly low. India's economic growth is being stymied in large part due to a shortage of accessible electricity. Therefore, making electricity available to the whole population of India is crucial to promoting economic progress in the country. The term "biomass" refers to all the organic material that comes from plants and the goods they produce. It is a generic name for a large range of products that may be produced via the process of photosynthesis in plants. Photosynthesis is the process through which solar energy is turned into chemical energy and then stored in plants. The chemical energy is subsequently used by the plant. The biomass resource includes energy crops, which are farmed expressly for their energy value, as well as biomass wastes and rubbish made from biomass. It is possible for rich nations as well as underdeveloped ones to meet a significant portion of their electrical needs with the help of biomass. It is the primary source of electricity in the world's least developed countries, placing it in fourth place overall. Already, it is responsible for 15% of the world's energy consumption and 38% of the energy use in developing countries. The residues of biomass are plentiful, particularly in countries that are economically developing.

1.2 Downdraft Gasifier

The downdraft gasifier is the location of a number of chemical processes, including drying, pyrolysis, oxidation, and reduction. In the ongoing investigation, a biomass gasifier equipped with an Imbert downdraft impeller is being used. In contrast to a stratified downdraft biomass gasifier, this gasifier has a throated combustion zone and distinct cross-sectional areas for the pyrolysis and reduction zones. Additionally, this gasifier has a larger reduction zone than the pyrolysis zone. In downdraft gasifiers, the pyrolyzed gas that is created in the pyrolysis zone is mixed with the moisture that is produced in the drying zone, and then the mixture travels downhill. A heated bed of char is supported by a grate as it travels through a pyrolysis combustion zone. Two air nozzles are used in the gasifier to ensure that the oxidation zone, which is the location where the biomass is supplied and oxidized, receives constant air flow. Heat is transferred into the pyrolysis and drying zones as a result of the combustion process. The release of heat from the burning of biomass results in the pyrolysis of biomass particles that are located above the oxidation zone. The pyrolysis zone is where the biomass particles are metabolized, which results in the production of volatiles and charcoal. When a fuel is heated by an external source of heat, pyrolysis processes occur, which result in the release of volatiles and the formation of char. When volatiles are released, heat is transmitted from the hot volatiles to the cooler unpyrolyzed fuel. This heat transfer causes condensation to occur in the colder sections of the fuel. When volatiles are released once again, the process begins all over again, resulting in the release of even more volatiles and the formation of char. A pyrolysis bed that is loaded with biomass particles causes the individual particles to emit volatiles. The pace at which volatiles are emitted varies according to factors such as the temperature and the size of the particles. Carbon dioxide and nitrogen dioxide that was produced during the combustion process join with the gas that was fragmented during the pyrolysis process. When this gaseous mixture passes over the heated charcoal bed, endothermic reduction activities take place. Both the experimental methodology and the specifics of the biomass gasifier that was used for this study may be found in an article that was published previously.

Biomass has a lot of potential as a source of renewable energy in the future. It is not only economical, but it also frees the nation from its reliance on fossil fuels and has a negligible effect on the environment. When compared to fossil fuels, carbon dioxide emissions from biomass are much lower [2,3,4]. This makes the feedstock supply chain more complicated and necessitates the use of biomass in more compact units. Included are characteristics such as a low calorific value and density, a variable geographical distribution, a high moisture content, and seasonal availability. Other characteristics include a variable geographical distribution. The conversion of biomass into usable energy is often accomplished by the utilization of thermochemical, biochemical, and physiochemical processes. The gasification of biomass may provide an alternative source of energy, which can then be converted to heat.

The possibility of producing electricity at a smaller scale using biomass as a fuel source is quite interesting. Because of their straightforward construction, downdraft reactors are famous for being easy to run and requiring little in the way of initial investment.

a) To reduce the production of tars and chars and to increase the yield of reaction products such as hydrogen by enhancing the efficiency of cold gas and optimizing the process parameters.
b) the process of gasification itself results in a considerable reduction in the amount of tar produced. This problem may be remedied by the gasifier being equipped with additional reaction zones, which would then have the gasifying chemical delivered to them.
c) It is possible to generate cogas of a high quality by combining biomass with other fuels such as coal, plastic and other forms of waste or biomass originating from a different origin. This process is known as the cogas fermentation process.
d) Increasing the amount of uniformity and automation present throughout the gasification process.

In the downdraft gasification process, the gasifying agent travels at a much faster speed than the fuel particles do. This is one of the method's defining characteristics. It is feasible to see gas speeds of up to 33 meters per second close to where the Tuyere connects to the outside world. Agent velocities in fluidized bed reactors may range anywhere from 4 to 6 meters per second. On the outside of the reactor is where you'll find the tuyères that connect to the downdraft gasifier. This is made possible by the fact that the air jet is penetrating the fuel bed. This study is a component of a larger examination of the operation of the wood downdraft gasification process. This inquiry began with the concept of an unstratified conversion process, which led to the discovery of atypical gasification settings. These settings were discovered as a result of this investigation. In further studies, it was shown that under certain conditions, there is no pyrolysis zone, and this was a surprising finding. To put it another way, raw wood particles were fed into the gasifier's tuyeres, and the process resulted in the production of gas. In addition, the approach contained each and every one of the qualities described before. The high flow of tuyere air that is the subject of this research endeavor is responsible for the combustion of wood particulates. Wood particles were deposited inside of a heated quartz conduit to serve as a stand-in for the fuel bed. It has been shown, via the use of a fluidized bed combustion experiment, that the Sherwood number increases in tandem with an increase in the particle size of the inert substance (the number 25 in this context).

1.3 Combustion Mechanism of Single Fuel Particles

This issue is of current significance because of the fast development of technology that allows for the burning of oxyfuels in an ecologically benign manner while also being capable of collecting and storing carbon dioxide. There have been studies conducted on the fluidized bed combustion of coke residual particles and coal, in addition to research on the burning of biomass. In addition, the char residue is burnt as a part of the homogeneous process, which also entails the release of volatiles and their subsequent combustion (heterogeneous process).

1.4 Biomass Fuels

The term "biomass" refers to the organic material that is obtained from plants and animals, and it is both renewable and sustainable. Up until the middle of the 1800s, the majority of the energy that was used annually in the United States came from biomass. Even today, cooking and heating in many countries is accomplished with the use of biomass, especially in less developed countries. In order to cut down on the amount of carbon dioxide that is produced by the combustion of fossil fuels, several industrialized countries are increasingly turning to the practice of using biomass fuels for their transportation and power generation systems. By the year 2020, the amount of primary energy consumption in the United States that will be accounted for by biomass will be around 5 quadrillion Btu, which is equivalent to 5% of the total primary energy consumption in the nation. The chemical energy that is provided by the sun is stored in biomass. The production of biomass in plants takes place via a process called photosynthesis. Direct burning of biomass for the purpose of producing heat is one of the many methods that may be used to manufacture renewable liquid and gaseous fuels from biomass.

- Firewood, pellets, chips, sawdust, and garbage from lumber and furniture production are all examples of wood and wood processing waste. Black liquor from pulp and paper mills is another example of a fuel that is created from biomass.
- Crop and food processing wastes, such as maize, soybeans, sugar cane, switchgrass, woody plants, and algae;
- Examples of biological materials present in municipal solid waste include paper, cotton, wool, food scraps, and yard and wood debris;
- Animal feces and human excrement are also included in this category.

II. REVIEW OF LITERATURE

Awais et al. (2021) discussed the utilization of biomass gasification for energy production. They conducted experiments using sugarcane bagasse and coconut shells in a biomass gasifier with a downdraft design. The study investigated the impact of the equivalency ratio on gasification efficiency, tar content, syngas composition, and heating value. Various cleaning equipment were evaluated for tar removal. The efficiency of the gasifier was found to depend on the biomass feedstock and the equivalency ratio. Syngas volume from sugarcane bagasse and coconut shells was 3.1 m3, with corresponding tar volumes of 2.97 m3 and 2.5 g/Nm3. Carbon monoxide (CO) and hydrogen (H_2) emissions increased, while the emission rate (ER) rose from 0.17 to 0.22. Despite this, syngas' calorific value increased to 4.4 MJ/Nm3. Cleaning instrument efficiency for sugarcane bagasse and coconut shells was 45.7% and 52.9%, respectively, with cyclone separators, wet scrubbers, and biomass filters reaching higher efficiencies.

Gunasekaran et al. (2021) examined thermochemical conversion of agroforestry residual biomass into producer gas (PG) using open-core biomass gasification. The study focused on cocoa pod husks (CPH) as feedstock. Performance of a 115 kWth gasifier was investigated with varied equivalency ratios and CPH moisture content. Optimal values were determined as ER 0.25 and moisture content 5%, resulting in 6.13 MJ/Nm3, 82% conversion efficiency, and 68% cold gas efficiency. Experimental data were compared with predictions, supporting the use of CPH in open-core gasifiers.

De Priall et al. (2021) highlighted the potential of biowaste gasification for renewable energy generation. The study analyzed various biowaste feedstocks, demonstrating up to 20% power and heat increase with proper equivalency ratios. Drying processes used up to 60% of heat generated. Downdraft gasification for heat and electricity cogeneration was proposed as an eco-friendly alternative to landfill disposal.

Dutta et al. (2021) investigated downdraft biomass gasification using tree trash and sawdust pellets. Gas composition and lower heating value (LHV) were studied for different equivalency ratios. Trends in LHV were analyzed across varying ratios and feedstocks.

Gálvez-Pérez et al. (2021) researched olive cake gasification without external heat. Hydrolyzed and raw olive cake were tested, showing differences in gas emissions due to lignin concentration. Torrefied-raw olive cake increased CO and CH_4 production. Metal-loaded samples exhibited variations, but hydrolyzed and raw olive cake were identified as suitable gasification feedstocks.

Murugan et al. (2021) explored cassava stem gasification, achieving optimal results at equivalence ratio 0.3. Gas composition, conversion efficiency, and yield were evaluated.

Sun et al. (2021) discussed gasification for energy production from trash, emphasizing desiccant dehumidification units with heat recovery. Enhanced thermal coefficient of performance and waste heat utilization were achieved using desiccant-coated heat exchangers.

Oni et al. (2021) examined steam-air gasification effects on hydrogen and syngas production. The study varied gasification temperature, equivalent ratio, and syngas yield ratio, finding temperature's influence on hydrogen and syngas yields. They proposed the importance of ER in steam-air gasification reactor design for efficient hydrogen and syngas production.

III. Proposed Method

The suggested criterion for contrasting different types of biomass fuels according to the elemental make-up of such fuels, which is indicated in the question, is not a new concept in the field of study. When trying to comprehend the energy content, reactivity, and combustion properties of biomass fuels, having a solid grasp of their elemental makeup is very necessary. Researchers are able to evaluate the appropriateness of various biomass fuels for certain applications, such as gasification, where the composition of the fuel effects both the process of gasification and the quality of the syngas that is generated. The practice of comparing biomass fuels based on their elemental composition is well-established; however, the novelty in research lies in the particular biomass fuels that are being analyzed, the experimental methodologies that are being utilized, the one-of-a-kind combinations of biomass feedstocks, or the investigation of novel gasification parameters and the impact that these parameters have on the gasification process. The originality of study often originates from the particular aims, methodology, or discoveries within the larger context of biomass gasification research.

IV. GASIFICATION PROCESS USING DOWNDRAFT FIXED-BED GASIFIER FOR DIFFERENT FEEDSTOCK

Fuels that are traditionally used are seeing their prices rise as a direct result of increasing demand for such fuels. As a direct consequence of this, renewable energy sources derived from biomass are receiving an increased amount of focus. Rice husks, waste plastics, and sawdust are three examples of some of the most numerous types of biomass feedstocks found around the globe. Around 120 million tonnes of rice husk are generated on a worldwide scale every year, giving it a potential yearly energy production of 109 gigajoules and a heating value of 15 megajoules per kilogram. Gasification is the method that the great majority of methods for converting biomass rely on to produce synthetic gas. This gas may then be used to power internal combustion engines (IC), fuel cells, and boilers. Rice husks and sawdust may be used to produce significant quantities of synthetic gas by the manipulation of the working parameters of a downdraft fixed-bed gasifier. These working characteristics include the temperatures of the reaction zone and the combustion zone, the intake air and flow rates, and the humidity of the intake air.

3.1 Biomass renewable energy

It is possible to get energy at a lower cost by using biomass, which is a renewable source of energy. This may be accomplished. By using this technology, it may be possible to satiate the energy requirements of the globe while simultaneously and precisely cutting emissions of greenhouse gases. Additionally, as conventional fuel inventories dwindle, there is a growing interest in the development of energy generation systems that are based on renewable biomass sources. The increased interest in biomass renewable energy may also be attributed to the fact that it produces less carbon dioxide emissions and places less of a demand on fossil fuels. The most frequent kind of renewable energy that derives from wood is called biomass. One example of a thermal or chemical process that may be utilized to generate energy is shown in Figure 1. When it comes to extracting energy from biomass, thermal processes such as gasification, pyrolysis, and combustion are the most common options. On the other hand, biogas, hydrogen, and ethanol gas are possible to be created from biomass renewable sources via the use of chemical reagents and methods. This chapter offers an overview of the many gasification processes that may be used to the conversion of biomass into gas and discusses the various methods that can be employed.

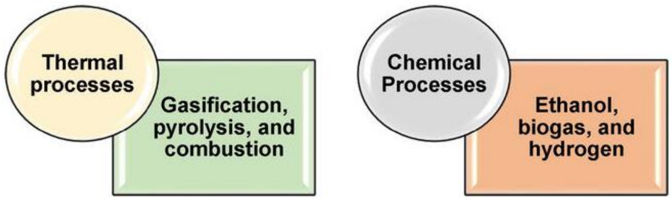

Fig. 1: Different power generation processes for biomass.

About one-fifth of the world's energy originates from biomass, the majority of which is produced in less developed countries (about two-thirds). Everyone has easy access to this source of renewable and non-polluting energy. The annual production of biomass throughout the globe is estimated to be over 146 billion metric tonnes. As can be seen in the figure that follows, renewable biomass energy may be put to use not just for energy production but also for non-energy applications.

V. CONVENTIONAL BIOMASS CONVERSION TECHNOLOGIES GASIFICATION

The starting material is heated to over 700 degrees Celsius with this method, and just a little amount of oxygen and steam are introduced into the reaction in order to get the desired outcome. Another name for synthetic gas is production gas. Because of the power that is produced, biomass may be gasified, and then the resultant gas can be burned to produce electricity. This might be considered a renewable source of energy. Carbonaceous feed material of the Char type (C) is combined with steam (H2O) to produce carbon monoxide (CO) and hydrogen (H2) during the gasification process.

$$C + H_2O \rightarrow H_2 + CO \qquad E_1$$

$$C + CO_2 \rightarrow 2CO \qquad E_2$$

In the gasifier reactor, a little amount of air or oxygen is used during the combustion of organic feed material, which results in the production of energy and carbon dioxide.

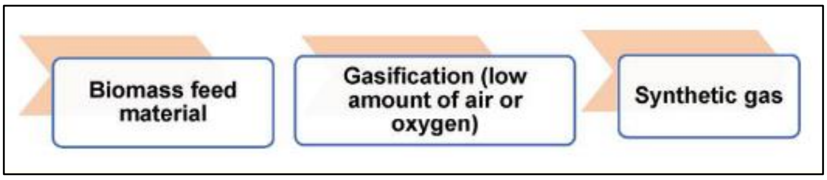

Fig. 2: Flow diagram of biomass gasification process.

4.1 Procedure of a downdraft gasifier using different biomass fuels

Experimental investigation of a downdraft gasifier using different kinds of biomass fuels is an important area of research that may contribute to the advancement of renewable energy technologies. Downdraft gasifiers facilitate the process of transforming biomass into a combustible gas that may be used for a wide range of applications, such as the generation of electricity and transportation fuel. The purpose of this experiment is to determine how well different types of biomass fuels, such wood chips, sawdust, rice husks, and maize cobs, can be burned in a downdraft gasifier. The gasifier would be operated under varying conditions, such as temperature, air flow rate, and biomass feed rate, to determine the optimum operating parameters for each fuel. The experimental setup would consist of a downdraft gasifier, a fuel feed system, an air supply system, and a gas collecting system. The gasifier would be equipped with sensors to measure temperature and pressure, and the gas would be analysed using a gas chromatograph to determine its chemical composition. The following are the procedures that would be involved in the experimental investigation:

a) The preparation of biomass fuels: In order to produce the various forms of biomass fuels, the raw materials would first need to be dried and then ground down to an even consistency.

b) The operation of the gasifier: The gasifier would be run using each distinct kind of biomass fuel under varied operating parameters, such as temperature, air flow rate, and the amount of biomass that was fed into it. During the procedure, the gas composition as well as the amount of tar would be examined.

c) Analysis of the gas composition: The gas composition would be studied with the use of a gas chromatograph in order to identify the quantity of hydrogen, methane, carbon monoxide, and other gases that are present in the gas that is generated.

d) An examination of the tar content the amount of tar present in the gas would be determined with the assistance of a tar sample equipment and then examined using a tar analyzer.

e) Performance assessment: The performance of the gasifier would be assessed based on the gas composition, the tar content, and other characteristics such as the energy efficiency and the carbon conversion efficiency. This evaluation would be done while utilizing each different kind of biomass fuel.

The findings of the experimental inquiry would give useful information on the operation of a downdraft gasifier while using a variety of forms of biomass fuels. The functioning of the gasifier may be optimized with the help of this information, and the most appropriate biomass fuel can be chosen for a certain task with the help of the information as well. In addition, the data acquired may be utilized to simulate the performance of the gasifier and build new designs for future applications based on the information gained.

4.1.1 Parameter comparing the biomass

The biomass fuels are compared based on their elemental composition, represented by weight percentages (wt%). The parameters used for comparison are:

a. **Carbon (C) content:** Indicates the amount of carbon present in the biomass fuel.
b. **Hydrogen (H) content:** Represents the amount of hydrogen present in the biomass fuel.
c. **Nitrogen (N) content:** Reflects the nitrogen content in the biomass fuel.
d. **Oxygen (O) content:** Indicates the percentage of oxygen in the biomass fuel.
e. **Sulphur (S) content:** Represents the sulphur content in the biomass fuel.

These criteria not only give insights into the elemental makeup of the biomass fuels, but they can also be used to compare the potential energy content of the biomass fuels, the characteristics of their burning, and their influence on the environment. We are able to evaluate the compatibility of various biomass fuels for downdraft gasification and calculate their prospective performance in terms of syngas production and emissions by comparing these characteristics.

4.2 Experimental Investigation of Downdraft Gasifier Using Different biomass feedstock materials

This process makes use of low quantities of oxygen and carbon dioxide. In the synthetic gas that is produced, there are traces of hydrogen (H_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen (N_2), and bio-oil. Gasification is a process that may use biomass feed materials like sawdust and rice husk since these resources are plentiful, have a high production rate, and cause minimal damage to the environment. Despite this, the vast majority of people on the planet utilize plastics in their day-to-day lives due of the insoluble nature of plastics in water and the ease with which plastics can be obtained. The quantity of trash made up of plastic that is being produced all over the globe is growing at an alarming pace. Take, for instance, the fact that Asia is home to the vast majority of the world's rubbish made of plastic and also generates almost a third of it [65]. By using it as a biomass feedstock for gasification, it is thus conceivable to convert a significant amount of rubbish made of plastic into energy. On the other hand, there will be a considerable reduction in the amount of global pollution caused by wasted plastics. Plastic trash has the potential to be converted into oil via the process of rapid pyrolysis. Producing producer gas or syngas from a wide range of biomass feedstock materials is possible with the use of a downdraft gasifier. The following is a list of nine distinct kinds of biomass feedstock materials that are suitable for use in a downdraft gasifier:

a) **Wood chips**: Wood chips are one of the most common biomass feedstocks used in downdraft gasifiers. They are typically made from waste wood from sawmills or logging operations.
b) **Sawdust:** Sawdust is another common feedstock for downdraft gasifiers. It is a byproduct of wood processing and is readily available in many areas.
c) **Agricultural waste:** Agricultural waste, such as crop residues, straw, and husks, can be used as feedstock in a downdraft gasifier. This type of biomass is often readily available in rural areas.
d) **Municipal solid waste:** Municipal solid waste, such as household trash, can also be used as a feedstock for downdraft gasifiers. This can help reduce landfill waste and produce renewable energy.
e) **Grasses:** Certain types of grasses, such as switchgrass and miscanthus, can be used as feedstock in downdraft gasifiers. These grasses are often grown specifically for biomass production.

f) **Algae:** Algae can also be used as feedstock in downdraft gasifiers. This is a relatively new and promising application for algae, which are known for their high growth rates and ability to sequester carbon.

g) **Coconut shells:** Coconut shells are a common feedstock for downdraft gasifiers in tropical regions. They are readily available and can be used to produce renewable energy.

h) **Nut shells:** Nut shells, such as peanut shells and almond shells, can also be used as feedstock in downdraft gasifiers. These materials are often considered waste products and can be used to produce renewable energy.

i) **Livestock waste:** Livestock waste, such as manure and bedding material, can be used as feedstock in downdraft gasifiers. This can help reduce odors and produce renewable energy from a readily available source.

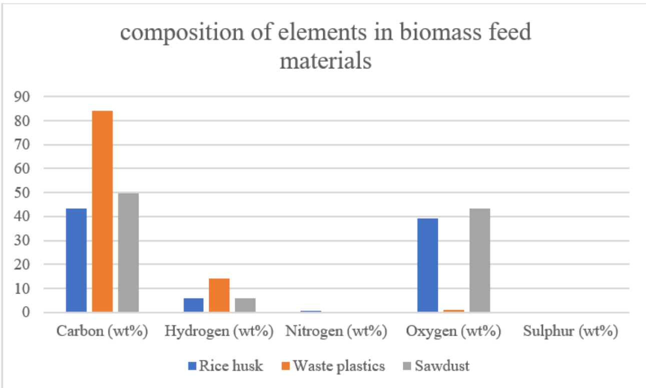

Fig. 3: Composition of elements in biomass feed materials

The final analysis yields information on the weight percentages of various elemental components that are present in the biomass feed materials. Rice husk is a by-product of the rice milling industry and is often utilized as a feedstock material in biomass gasification systems. This is because rice husk contains cellulose, which may be converted into energy. According to the findings of the conclusive study, the rice husk has a weight-based composition of 43.5% carbon, 5.8% hydrogen, 0.7% nitrogen, 39.3% oxygen, and 0.2% sulfur. Another sort of biomass feed material that is being increasingly used in gasification systems is used plastics that have been discarded. The final examination reveals that used plastics have a relatively high concentration of carbon, namely 84.3% by weight of the element, in addition to 14.2% hydrogen, 0.3% nitrogen, 1.0% oxygen, and 0.2% sulfur by weight.

Sawdust is a by-product of the wood industry that is often utilized as a biomass feed material in gasification systems. Sawdust may also be used as an insulation material. Sawdust was subjected to a comprehensive study, which revealed that, by weight, it consists of 49.8% carbon, 6.0% hydrogen, 0.2% nitrogen, 43.2% oxygen, and 0.2% sulfur. Biomass feedstock options that may be utilized in a downdraft gasifier range from rice husk to waste plastics to sawdust. The following inferences may be made about the compatibility of these materials based on the findings of the final research, which are shown in the table below.

a) Rice husk has a high oxygen level but a relatively low carbon content, which may cause the gasification process to be less effective. However, it has a low sulfur content, which is advantageous in terms of decreasing emissions. This is because sulfur is a pollutant.

b) Since waste plastics contain a high concentration of carbon, they are an excellent candidate for gasification as a source of fuel. In addition to this, however, they contain a high hydrogen concentration, which may change the make-up of the gas that is created, and a relatively low nitrogen content, which can cause the combustion process to be insufficiently completed.

c) Sawdust has a moderate carbon level but a high oxygen content, both of which have the potential to alter the effectiveness of the gasification process. In spite of this, it has a low nitrogen concentration, which, when combined with its low rate of oxidation during burning, makes it less likely that nitrogen oxides would be produced.

4.3 Experimental Investigation of Downdraft Gasifier Using Different Biomass Fuels

The phrase "Experimental Investigation of Downdraft Gasifier Using Different Biomass Fuels" is most likely the title of a research paper or technical report that discusses a study on the use of a downdraft gasifier using a variety of biomass fuels. The study was conducted in the United States. It is possible that the goal of the research was to explore the performance of the gasifier while using various feedstock materials and to find any discrepancies or issues that exist when utilizing various types of biomass fuels. For the purpose of the research, we may have conducted tests using a variety of biomass fuels, such as rice husk, sawdust, or waste plastics, and measured a number of factors, including temperature, gas composition, and the effectiveness of the gasification process. The researchers may have analyzed the data to discover which feedstock materials perform the best in the downdraft gasifier. This determination may have been made based on parameters such as the quantity and quality of gas produced, the quantity of ash and other by-products created, and the overall efficiency of the process.

It's possible that the findings of this research may provide important information on how to make the most efficient use of biomass fuels in downdraft gasification systems. This information might be helpful to businesses and academics who are interested in creating renewable energy technology. Downdraft gasifiers are able to make use of many different types of biomass fuels, including the following:

a) Wood chips
b) Sawdust
c) Rice husk
d) Corn cobs
e) Bagasse (sugar cane residue)
f) Coconut shells
g) Peat
h) Bark
i) Switchgrass
j) Miscanthus

The acceptability of these biomass fuels for use in a downdraft gasifier may be affected by a variety of characteristics, including particle size, the amount of moisture they contain, and the amount of ash they contain. The selection of a biomass fuel source may also be influenced by considerations pertaining to its availability, price, and compliance with any applicable local legislation.

Biomass Fuel	Description
Wood chips	Small pieces of wood obtained from sawmills or logging operations
Sawdust	Fine particles of wood created during woodworking operations
Rice husk	The outermost layer of rice grains that is separated during milling
Corn cobs	The central part of corn ears that remains after the kernels have been removed
Bagasse	The fibrous residue that remains after the extraction of juice from sugar cane
Coconut shells	The hard outer shells of coconuts
Peat	A partially decayed organic material found in wetlands
Bark	The outer layer of trees
Switchgrass	A tall, perennial grass that is native to North America

Miscanthus	A tall, perennial grass that is native to Asia

Ultimate analysis of some commonly used biomass fuels in downdraft gasifiers:

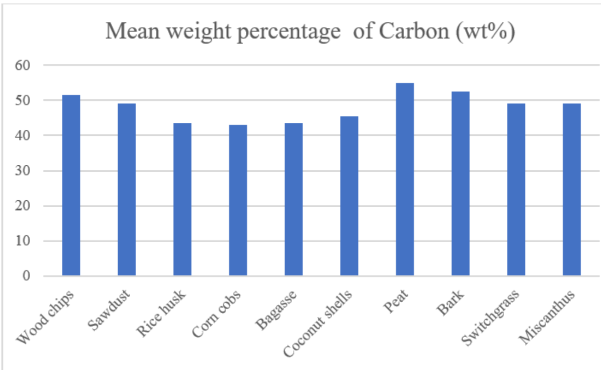

Fig. 4: Mean weight percentage of Carbon (wt%)

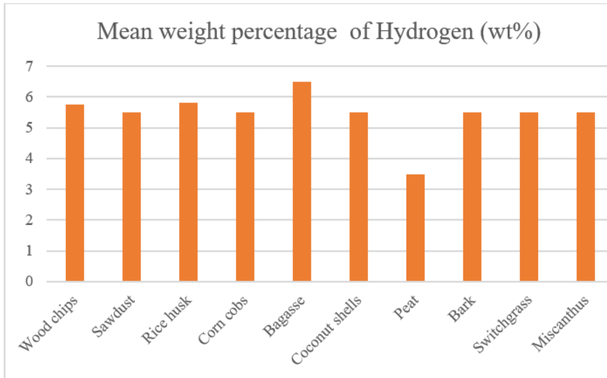

Fig. 5: Mean weight percentage of Hydrogen (wt%)

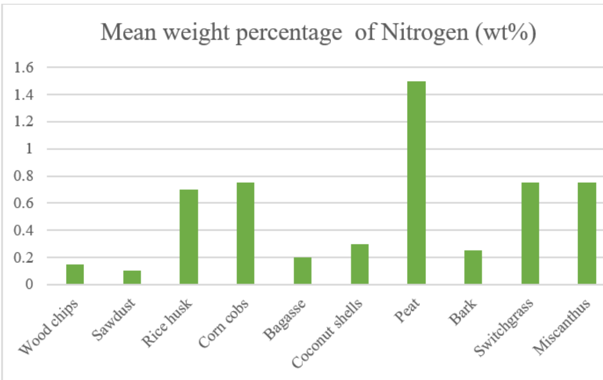

Fig. 6: Mean weight percentage of Nitrogen (wt%)

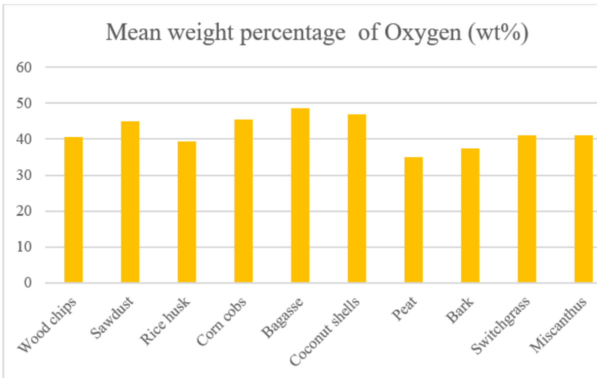

Fig. 7: Mean weight percentage of Oxygen (wt%)

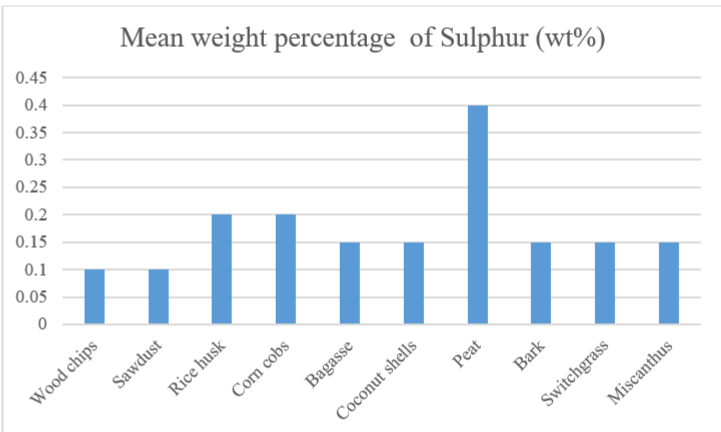

Fig. 8: Mean weight percentage of Sulphur (wt%)

According to the final study of various biomass fuels used in downdraft gasifiers, it can be determined that different kinds of feedstock have distinct characteristics, which impacts the acceptability of the feedstocks for use in the gasifier. These characteristics include factors such as temperature, moisture content, and density. For instance, wood chips, sawdust, and bark all have a high carbon concentration, which enables them to produce combustible gases effectively. On the other hand, rice husk, maize cobs, and bagasse all have a relatively high oxygen content, which inhibits the efficiency with which they may be burned. In a similar vein, coconut shells and peat both have a high ash content, which may lead to difficulties with fouling and corrosion in the gasifier. On the other hand, switchgrass and miscanthus both have a high nitrogen content, which can lead to the creation of nitrogen oxides that are not desired during the gasification process. Because of this, the selection of the biomass feedstock should be based on its final analysis and whether or not it is suitable for the application that is being planned. The table not only includes the elemental make-up of the fuels, but it also includes information on the weight percentages of each individual element. This information is necessary in order to have a proper knowledge of the potential for emissions as well as the effect that the fuels have on the surrounding environment.

It may be deduced from the high carbon content of the fuels that they have a greater capacity for releasing carbon dioxide into the atmosphere. Since peat and wood chips have the largest carbon content, they have the potential to emit a significant amount of carbon dioxide when they are gasified. The amount of nitrogen that is present in the fuels may have an influence on the quantity of nitrogen oxides that are formed during gasification, which in turn can have an adverse effect on the quality of the air. Rice husk and peat have the largest nitrogen concentration, which implies that when they are gasified, they have the potential to create larger quantities of nitrogen oxides. The oxygen content of the fuels is significant because it has an impact on the quantity of oxygen that must be present throughout the gasification process. Fuels that have a greater oxygen content need less external oxygen to be added during the gasification process. This may have an effect on the efficiency of the gasifier. Since bagasse and sawdust have the largest oxygen content, gasification of these two materials requires a lower concentration of oxygen from the atmosphere.

The amount of sulfur that is included in the fuels is significant because, when gasified, it may contribute to the emissions of sulfur dioxide. Additional emissions control may be necessary when using fuels with a higher sulfur content in order to mitigate the negative effects on air quality. Due to the high sulfur content of peat and switchgrass, extra emissions control measures may need to be implemented during the gasification process when using these two materials. Based on the findings of the comprehensive investigation, we are able to make the following observations about the biomass fuels that are often used in downdraft gasifiers:

a) Carbon content: The carbon content of these biomass fuels varies anywhere from 41.0 to 60.0.0 percent. Because of this, they are appropriate for use as fuel in gasification operations, which are necessary for the creation of syngas, which is a byproduct of carbon.

b) The amount of hydrogen these fuels contain: the amount of hydrogen found in these fuels varies from 3.0% to 7.0%. Because it can combine with carbon to produce methane, hydrogen is another essential ingredient in the formation of syngas. Syngas is a byproduct of this reaction.

c) Nitrogen content: The nitrogen content of these fuels is typically low, ranging from 0.05% to 2.0% of the total weight of the fuel. Although nitrogen is not a particularly significant component in the generation of syngas, it is one of the factors that may contribute to the development of NOx emissions.

d) The amount of oxygen that is present: the amount of oxygen that is present in these fuels varies from 30.0% to 50.0%. During the gasification process, oxygen and carbon may combine to produce carbon dioxide (CO_2), which is one of the primary components of syngas.

e) Sulfur content: The sulphur level of these fuels is typically low, ranging from 0.05% to 0.5% of the total weight of the fuel. On the other hand, it is essential to keep in mind that even trace amounts of sulphur may be a factor in the production of SOx emissions, which can have a harmful effect on the surrounding environment.

VI. CONCLUSION AND FUTURE SCOPE

The end research reveals important insights into the make-up of biomass fuels that are often employed in downdraft gasifiers. Both wood chips and sawdust have a number of features, including a moderate amount of carbon and hydrogen, a comparatively low amount of nitrogen and sulfur, greater quantities of oxygen, and moderate moisture levels. Rice husk is composed of moderate amounts of hydrogen, oxygen, and sulfur in addition to a lower carbon content and a greater nitrogen concentration than other components. The amount of carbon and hydrogen found in corn cobs is equivalent to that of wood chips and sawdust, while the amount of nitrogen and sulfur found in corn cobs is somewhat greater. In terms of the amount of carbon and hydrogen present, bagasse is comparable to wood chips and sawdust; on the other hand, the amount of carbon and hydrogen present in coconut shells is comparable, but the amount of nitrogen and sulfur present is somewhat greater. Peat is distinctive due to its heightened amounts of nitrogen and sulfur, as well as its higher carbon and lower hydrogen contents. Peat also has a smaller proportion of hydrogen. Bark has a composition that is quite similar to that of wood chips and sawdust, although it has a slightly greater percentage of nitrogen and a lower percentage of oxygen. Last but not least, switchgrass and miscanthus have a composition that is comparable, with a moderate amount of carbon and hydrogen content, a relatively low amount of nitrogen and sulfur content, and lower amounts of oxygen. In conclusion, the composition of these biomass fuels may vary widely, which can affect how well they work in downdraft gasifiers. These differences might have ramifications for the environment. During combustion, the amount of nitrogen and sulfur present may have an effect on emissions, while the amount of carbon and hydrogen present plays an important part in the total amount of energy released. The oxygen content gives an indication of the amount of oxygen that is available for combustion activities. Therefore, while choosing and optimizing biomass fuels for downdraft gasification, it is very necessary to take into consideration the specific compositions of such fuels in order to guarantee operations that are both effective and kind to the environment. The final study of the biomass feed materials, which include rice husk, waste plastics, and sawdust, gives crucial insights into the composition of these materials and the properties that they possess. In comparison to waste plastics and sawdust, rice husk has a much lower carbon concentration, which indicates that it has a reduced potential for energy production. It has an average quantity of hydrogen, which is indicative of a satisfactory contribution to the total energy. Although the nitrogen concentration is considered to be moderate, the oxygen content is considered to be rather high, which may indicate the existence of oxygenated molecules. The amount of sulphur present is quite low, which indicates that it contributes very little to the possibility of emissions. The waste plastics, on the other hand, have a carbon content that is noticeably greater, which indicates that they have a large energy potential. Because of the high hydrogen concentration, their contribution to energy is increased even more. The nitrogen and sulphur levels in waste plastics are quite low, which helps to keep these pollutants to a minimum in the environment. The presence of oxygenated molecules is also significantly decreased, which may be inferred from the comparatively low oxygen level. In terms of the amount of carbon it contains, sawdust is somewhere in the middle between rice husk and waste plastics. In spite of the fact that it has a lower carbon content than waste plastics, it nonetheless provides a good potential for energy use. While there is a significant amount of hydrogen, comparable to that of rice husk, there is a comparatively low amount of nitrogen. Sawdust has a relatively high oxygen concentration, which is a strong indicator that oxygenated chemicals are present. The amount of sulphur is comparable to that found in rice husk and in discarded plastics.

In general, these biomass feed materials have a wide variety of compositions, each of which affects the range of applications that are appropriate for using them. Rice husk could be an appropriate material for use in processes like combustion, which prioritize the availability of oxygen in the material. The high carbon and hydrogen content of waste plastics, along with their minimal emissions of nitrogen and sulphur, make for a material with a significant energy potential. Sawdust is useful for a wide variety of applications because it strikes a healthy balance between its energy potential and the oxygenated chemicals it contains. It is essential to have an understanding of the final analysis of these biomass feed materials in order to pick the suitable feedstock and optimize the exploitation of these materials in certain processes, taking into consideration variables such as energy efficiency and emissions control.

VII. Future Scope

The experimental analysis of downdraft gasifiers employing various types of biomass fuels in production technology paves the way for future research and development in a number of different directions. The optimization of gasification parameters is one of the areas that will be the focus of future research. There is a possibility that by fine-tuning parameters such as temperature, residence duration, and fuel-to-air ratio, gasification efficiency may be increased, syngas quality can be improved, and emissions can be reduced even further. Researchers are able to expand their knowledge of downdraft gasification technology and improve its performance if they investigate and optimize these factors in a methodical manner. Exploration of more sophisticated gasification technologies is yet another route that should be pursued in the course of future research. Although the experimental inquiry is mostly focused on downdraft gasifiers, there are other kinds of gasifiers, such as fluidized bed gasifiers or plasma gasification systems, that provide distinct benefits in terms of efficiency, flexibility, and feedstock variety. These include plasma gasification systems. The investigation of the performance of these more sophisticated gasification methods utilizing a variety of biomass fuels might give beneficial insights for the technological application of their use in production. In addition, there is room for improvement in regards to the usage of the syngas that is generated during the process of downdraft gasification. While the experimental examination is focused on the gasification process itself, further research might investigate the many downstream uses of syngas, such as the generation of electricity or heat, or the synthesis of value-added compounds. It is possible to optimize the energy potential and economic feasibility of the gasification process by having a thorough understanding of syngas and by optimizing how it is used. Integration with many other types of renewable energy systems is yet another topic that needs more investigation in the future. Investigating the potential for combining downdraft gasifiers with other supplementary renewable energy sources, such solar or wind power, may increase the overall efficiency and sustainability of the process of generating energy. Energy systems that draw electricity from many renewable sources have the potential to be more reliable and stable than those that use just one source.

REFERENCES

1. Awais, M., Li, W., Munir, A., Omar, M. M., & Ajmal, M. (2021). Experimental investigation of downdraft biomass gasifier fed by sugarcane bagasse and coconut shells. *Biomass Conversion and Biorefinery*, *11*(2), 429-444.
2. Gunasekaran, A. P., Chockalingam, M. P., Padmavathy, S. R., & Santhappan, J. S. (2021). Numerical and experimental investigation on the thermochemical gasification potential of Cocoa pod husk (Theobroma Cacoa) in an open-core gasifier. *Clean Technologies and Environmental Policy*, *23*(5), 1603-1615.
3. De Priall, O., Gogulancea, V., Brandoni, C., Hewitt, N., Johnston, C., Onofrei, G., & Huang, Y. (2021). Modelling and experimental investigation of small-scale gasification CHP units for enhancing the use of local biowaste. *Waste Management*, *136*, 174-183.
4. Dutta, A., Das, S. K., & Roy, P. C. (2021, February). Experimental Investigation on a Downdraft Biomass Gasifier Using Tree Waste and Sawdust Pellet. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1080, No. 1, p. 012033). IOP Publishing.
5. Gálvez-Pérez, A., Martín-Lara, M. A., Calero, M., Pérez, A., Canu, P., & Blázquez, G. (2021). Experimental investigation on the air gasification of olive cake at low temperatures. *Fuel Processing Technology*, *213*, 106703.
6. Murugan, P. C., Navaneethakrishnan, P., & Sekhar, S. J. (2021, February). An experimental investigation on utilizing cassava stalk as biomass sources in a gasifier. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1057, No. 1, p. 012040). IOP Publishing.
7. Sun, X. Y., Chen, J. L., Zhao, Y., Li, X., Ge, T. S., Wang, C. H., & Dai, Y. J. (2021). Experimental investigation on a dehumidification unit with heat recovery using desiccant coated heat exchanger in waste to energy system. *Applied Thermal Engineering*, *185*, 116342.
8. Oni, B. A., Sanni, S. E., Ikhazuangbe, P. M. O., & Ibegbu, A. J. (2021). Experimental investigation of steam-air gasification of Cymbopogon citratus using Ni/dolomite/CeO2/K2CO3 as catalyst in a dual stage reactor for syngas and hydrogen production. *Energy*, *237*, 121542.
9. Soares, R. B., Martins, M. F., & Gonçalves, R. F. (2020). Experimental investigation of wastewater microalgae in a pilot-scale downdraft gasifier. *Algal Research*, *51*, 102049.

10. Singla, M., Singh, M., & Dogra, R. (2020). Experimental investigation of imbert downdraft gasifier using rice straw briquettes. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 1-11.

11. Yao, X., Zhao, Z., Li, J., Zhang, B., Zhou, H., & Xu, K. (2020). Experimental investigation of physicochemical and slagging characteristics of inorganic constituents in ash residues from gasification of different herbaceous biomass. *Energy*, *198*, 117367.

12. Cerone, N., Zimbardi, F., Contuzzi, L., Baleta, J., Cerinski, D., & Skvorčinskienė, R. (2020). Experimental investigation of syngas composition variation along updraft fixed bed gasifier. *Energy Conversion and Management*, *221*, 113116.

13. Guo, Q., Cheng, Z., Chen, G., Yan, B., Li, J., & Ronsse, F. (2020). Assessment of biomass demineralization on gasification: From experimental investigation, mechanism to potential application. *Science of The Total Environment*, *726*, 138634.

14. Littlejohns, J. V., Butler, J., Luque, L., & Austin, K. (2020). Experimental investigation of bioenergy production from small-scale gasification of landfill-diverted wood wastes. *Waste and Biomass Valorization*, *11*(12), 6885-6901.

15. Thamizhvel, R., Sethuraman, N., Sakthivel, M., & Prabhakaran, R. (2020, December). Experimental Investigation of Diesel Engine by using Paper Cup Waste as the Producer Gas with help of Down-Draft Gasifier. In *IOP Conference Series: Materials Science and Engineering* (Vol. 988, No. 1, p. 012015). IOP Publishing.

16. Christy, J. V., Mourad, A. H. I., Idrisi, A. H., Thekkuden, D. T., & Cherupurakal, N. (2020). Experimental Investigation of Syngas Production through Gasification of Biomass Char in a Fluidized Bed Reactor. In *2020 Advances in Science and Engineering Technology International Conferences (ASET)* (pp. 1-6). IEEE.

17. George, J., Arun, P., & Muraleedharan, C. (2019). Experimental investigation on co-gasification of coffee husk and sawdust in a bubbling fluidised bed gasifier. *Journal of the Energy Institute*, *92*(6), 1977-1986.

18. Hai, I. U., Sher, F., Zarren, G., & Liu, H. (2019). Experimental investigation of tar arresting techniques and their evaluation for product syngas cleaning from bubbling fluidized bed gasifier. *Journal of Cleaner Production*, *240*, 118239.

19. Kamble, P., Khan, Z., Gillespie, M., Farooq, M., McCalmont, J., Donnison, I., & Watson, I. (2019). Biomass gasification of hybrid seed Miscanthus in Glasgow's downdraft gasifier testbed system. *Energy Procedia*, *158*, 1174-1181.

20. Antolini, D., Ail, S. S., Patuzzi, F., Grigiante, M., & Baratieri, M. (2019). Experimental investigations of air-CO2 biomass gasification in reversed downdraft gasifier. *Fuel*, *253*, 1473-1481.