

SYNTHESIS CHARACTERIZATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS

Submitted in partial fulfilment of the requirement for the award of
Bachelor of Technology Degree in
Chemical Engineering

by

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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This is to certify that this project report is the bonafide work of Manivannan U.S (39190016) and Raguram N(39190024) who carried out the project entitled "SYNTHESIS CHARACTERIZATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS" under our supervision from November 2022 to April 2023

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We MANIVANNAN U.S.(39190016) and RAGURAM N.(39190024) hereby declare that the Project Report entitled **"SYNTHESIS CHARACTERISATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS"** done by us under the guidance of **Dr. Dawn S.S**, Sathyabama Institute of Science and Technology, Chennai at is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Chemical Engineering.

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ABSTRACT

Hydroponics – a technique, where plants are grown without soil using a water-based fertiliser solution. Growing medium can be used in this method, which includes aggregate substrates like vermiculite, coconut coir, or perlite. Small farmers, amateurs, and business enterprises all use hydroponic production systems. Bio-Char is a charcoal-like material that is generated from plant materials such as grass, agricultural and forest residues that are decomposed at high temperatures, commonly during renewable energy production. The procedure transforms the plant material's physical and chemical qualities into Bio-Char, a highly porous, stable, carbon-rich substance. Bio-Char produced from agricultural (agro) waste is studied and supported by various factors (pH, Electrical Conductivity, Bulk Density, Volatile Matter, Ash Content and Moisture Content) to be used as a nutrient supplement in the hydroponics system. One or more variety of seeds are chosen and different amounts of Bio-Char are added with corresponding plants with their respective system. That is, Bio-Char will be used at different concentration and one sample in each system will have no Bio-Char. As a result, the growth rates of the different plants are analysed and the influence of Bio-Char on those plants will also be studied. Therefore we can draw a conclusion on the ideal amount of nutrient supplement that is best suited for growing plants in the hydroponics system. At the same time studying the Nutrient Contents (including Protein, Carbohydrates, Fat, Crude Fiber, Energy and Minerals) gives a clear picture on the influence of the Bio-Char on the plants in various aspects with the data from FTIR and XRD.

Keywords: Bio-Char, Hydroponics, Nutrient.

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LIST OF ABBREVIATION

MSW	-	Municipal Solid Waste
TLUD	-	Top Lift Up-Draft
CHNS/O	-	Carbon Hydrogen Nitrogen Sulphur/Oxygen
TGA	-	Thermo Gravimetric Analysis
CEC	-	Cation Exchange Capacity
PVC	-	Poly Vinyl Chloride
FTIR	-	Fourier-Transform Infrared (Spectroscopy)
PAS	-	Photo Acoustic
ATR	-	Attenuated Total Reflectance
DRIFT	-	Diffuse Reflectance Infrared Fourier Transform
NPK	-	Nitrogen Phosphorus Potassium
USDA	-	United States Department of Agriculture
EC	-	Electrical Conductivity
XRD	-	X-Ray Diffraction

CHAPTER 1 – INTRODUCTION

1.1. WASTE GENERATION

Waste generation is the process of producing resources that eventually become unwanted or unusable and need to be disposed of. This covers a range of solid waste types, including garbage from homes, industrial waste, electronic waste, and hazardous waste. Garbage generation is a major problem that affects society, the environment, and the economy [1].

Population growth, urbanization, consumerism, industrialization, and lack of waste disposal and recycling are all contributing factors to the increase in trash production worldwide. Urbanization brings about a greater population, consumerism produces more items, industrialization produces waste from industrial activity, and lack of waste disposal and recycling increases trash production [2].

1.2. IMPACTS OF WASTE PRODUCTION

The generation of waste has a substantial impact on the economy, the environment, and human health. The air, water, and soil can get contaminated by improper trash disposal. For instance, burning garbage releases noxious gases and pollutants into the environment, causing respiratory issues and climate change. Hazardous waste disposal errors can also contaminate soil and water, harming plant and animal life. The creation of waste has financial effects as well. It can be expensive to correctly dispose of waste, and communities, corporations, and governments may incur higher costs as a result of improper waste management. Additionally, garbage that is not recycled or reused represents a lost chance for resource recovery and can aid in the depletion of natural resources. Finally, there are social effects of trash generation. Inadequate waste management can result in a rise in disease-carrying pests like rats and mosquitoes, which is bad for public health. Additionally, it may have a detrimental effect on local communities' quality of life, resulting in falling property values and a general loss in wellbeing. Overall, trash creation has negative effects that highlight the significance of good waste management practices, which include lowering waste production, improving recycling and reuse, and assuring safe and environmentally friendly disposal techniques. By implementing these

actions, we can protect the environment, public health, economy and other factors by reducing the negative effects of trash creation.

Any object or element that is thrown away, useless, or undesirable is considered as waste. It can come from a multitude of sources which may be solid, liquid, or gaseous. For the sake of preserving both the environment and human health, waste management must be done properly. The various waste types and how they affect the environment will be described below [3].

1.3. TYPE OF WASTES

1.3.1. Municipal Solid Waste (MSW)

Trash produced by homes, businesses, and companies is referred to as municipal solid waste (MSW). It consists of industrial, commercial, and domestic garbage. Hazardous substances like battery, electronics, and chemicals can be found in MSW.

1.3.2. Electronic Waste

Often known as e-waste, this kind of waste includes old computers, televisions, and mobile phones. Because to the accelerating speed of technological innovation and the rising demand for electronic gadgets, e-waste is an issue that is spreading around the globe.

1.3.3. Hazardous waste

Trash that could be hazardous to the environment or human health is referred to as hazardous waste. It can be produced by households, medical facilities, and industrial operations. Chemicals, insecticides, batteries, and radioactive substances are examples of hazardous waste.

1.3.4. Biodegradable Waste

Any trash that may be organically broken down by microorganisms is considered biodegradable. Waste that degrades naturally includes plant matter, paper, and food scraps. Waste that degrades can be composted and added to the soil as a soil amendment.

1.3.5. Non-biodegradable Waste

Anything that cannot decompose spontaneously is considered non-biodegradable waste. Polymers, metals, and glass are a few non-biodegradable garbage examples. Pollution from non-biodegradable garbage can build up in the ecosystem.

1.3.6. Organic Waste

Any garbage that contains organic components is referred to as organic waste. Food trash, yard waste, and animal waste are a few examples of organic waste. Composting organic waste allows for soil amendment [3].

1.4. WASTE DISPOSAL

The act of gathering, moving, and safely getting rid of waste in an environmentally friendly way is known as waste disposal. As the world's population and urbanization continue to rise, it is more crucial than ever to dispose of waste properly. Inadequate waste disposal can have detrimental effects on the environment and human health, including air and water pollution, soil and groundwater contamination, and the spread of infectious illnesses.

Waste management refers to the control of waste products which are no longer be required or desired. It entails gathering, moving, processing, and disposal of garbage in a secure and environmentally responsible way.

Waste disposal and waste management are closely related concepts that involve the proper handling and disposal of waste materials. Waste disposal explicitly refers to the last stage of the waste management process, where waste is disposed of in a safe and responsible manner. Waste management generally refers to the handling, transporting, and disposal of waste. The steps of effective waste management include waste reduction, recycling, composting, and disposal. While recycling entails gathering, classifying, and processing materials that can be reused or repurposed, waste reduction focuses on reducing the amount of garbage generated in the first place. While garbage disposal refers to the final disposition of waste that cannot be recycled or composted, composting entails the breakdown of organic materials into nutrient-rich soil [4].

1.5. TYPES OF WASTE DISPOSAL

1.5.1. Landfills

The most common method of waste disposal is to bury the trash underground in landfills. The garbage is crushed and covered with an outer layer of dirt to suppress odour and prevent the spread of illness. Landfill are appropriate for non-hazardous waste material, but if they are

not adequately managed, they can lead to environmental contamination and health risks.

1.5.2. Incineration

Incineration is the technique of lowering the volume of waste by burning it at high temperatures and turning it into ash and gases. Hazardous trash, medical waste, and industrial waste can all be incinerated. Yet, it has the potential to produce dangerous greenhouse gases and hazardous pollutants that can harm human health and the environment [5].

1.5.3. Recycling

Recycling is the practice of reusing discarded materials to create new goods. It is appropriate for substances including paper, plastic, glass, and metal. Recycling can save resources, cut waste volume, and lessen the effects of trash disposal on the environment.

1.5.4. Composting

The act of turning organic waste, like food scraps and garden waste, into nutrition soil is known as composting. It is appropriate for organic waste and it has agricultural and gardening applications. Composting can provide a beneficial soil amendment and cut down the amount of trash dumped in landfills

1.5.5. Waste-To-Energy

Burning waste to produce heat or power is known as waste-to-energy. It is appropriate for non-recyclable garbage, including industrial and municipal solid waste. Waste-to-energy can decrease the amount of waste transported to landfills and generate electricity, but it can also have negative health and environmental effects.

1.5.6. Plasma Gasification

Gasification is the process of dissolving garbage into its component parts by employing hot temperatures and a gasification agent. It is appropriate for both hazardous and medical waste. Although plasma gasification is an expensive and complicated technique, it can reduce the amount of garbage that is dumped in landfills and generate electricity.

1.5.7. Pyrolysis

Pyrolysis is the heating of waste without the presence of oxygen to create a gaseous and a solid residue. It is appropriate for rubber, plastics, as well as other organic materials. Pyrolysis can provide energy and reduce waste volume, but it can also create harmful pollutants [3].

1.5.8. Mechanical Biological Treatment

Waste is separated and processed mechanically and biologically by mechanical biodegradation. It works well for mixed garbage and can make compost, fuel, and recyclables. Mechanical biological treatment is an expensive and complicated technique, but it can reduce the quantity of trash dumped in landfills and generate energy.

1.5.9. Land Application

Application of trash to the ground as fertilizer or a soil supplement is known as "land application." It can increase soil fertility and is appropriate for organic waste. Applying garbage to the land can provide a beneficial soil amendment and cut down on the amount of waste transported to landfills.

1.5.10. Ocean Dumping:

Ocean dumping is the practice of discarding waste products in the ocean. It is suitable for dredging debris and other non-hazardous garbage. Ocean dumping, however, can destroy marine life and produce environmental contamination.

1.5.11. Sanitary Landfilling:

Sanitary landfilling is the practice of burying garbage in a landfill that is intended to reduce health risks and environmental degradation. It is appropriate for non-hazardous solid waste, but if it is not controlled, it can lead to environmental contamination and health risks [1].

1.6. AGRICULTURAL WASTE

Any waste produced by agricultural practices, such as crop cultivation, animal husbandry, and forestry, is referred to as agricultural waste. This trash can come in a variety of shapes and sizes, including agricultural residue, manure, animal remains, and wood chips. Agricultural waste poses a serious threat to the environment because it can contaminate streams, release greenhouse gases, and spread disease. Agricultural waste can be

used in a variety of ways and is a valuable resource that can be recycled. Crop residue, for instance, might be utilized as fuel, bedding, or animal food. Wood chips can be utilized to provide electricity, and manure can be used as fertilizer. Additionally, various types of agricultural waste are utilized to make biofuels, including leftover cooking oil and animal fat.

However, improper handling of agricultural waste can lead to environmental and health problems. For instance, manure runoff can contaminate waterways and lead to eutrophication, a process in which excess nutrients promote the growth of harmful algae and deplete oxygen levels in water bodies. Therefore, it is important to manage agricultural waste properly through appropriate storage, treatment, and disposal methods [5][6][7].

1.7. APPLICATION OF AGRO WASTE

Agricultural waste is the term used to describe the leftovers and by-products produced during agricultural processes like cultivation, harvesting, and processing. These wastes are frequently burned or disposed of, which pollutes the environment. They have historically been seen as an annoyance. Agro-waste, however, is now being acknowledged as a significant resource that may be used for a variety of reasons, from producing energy to soil enhancement, as a consequence of increasing concern for sustainability. We will go into great detail about the numerous applications for agro-waste are as follows:

1.7.1. Bio Fuel

A type of fuel known as biofuel is created from organic material, such as agricultural residues. Ethanol and biodiesel are the two different kinds of biofuels. Whereas biodiesel is made using vegetable oil and animal fats, ethanol is made from crops like corn, wheat and sugarcane. We shall talk about the creation of biofuel from agricultural waste in this article [8].

1.7.2. Corn Stover

When the corn has indeed been harvested, waste material known as corn stover is left behind. Ethanol can be made from this substance. The cellulose inside the maize stover is converted into simple sugars in the process, which are subsequently fermented to produce ethanol.

1.7.3. Sugarcane Bagasse

The fibrous residue that remains when sugarcane has been collected and the juices has been drawn out is known as sugarcane bagasse. Both ethanol and biofuel can be made from this substance [9].

1.7.4. Wheat Straw

Wheat is the residue left over after harvesting wheat. Ethanol can be made from this substance. The method is comparable to that used to make ethanol from corn stover.

1.7.5. Rice Husk

The outer layer of the grain of rice is known as the husk. Both ethanol and biofuel can be made from this substance [6].

1.7.6. Energy Production

Biogas production, combustion, and gasification are a few of the methods that can be used to turn agricultural waste into renewable energy. Because it lowers greenhouse gas emissions, biomass energy using agro-waste is regarded as an environmentally benign substitute for fossil fuels.

1.7.7. Animal Feed

Using agro-waste as animal feed is an economical way to recycle the trash and give animals a wholesome diet.

1.7.8. Organic Fertility

Agro-waste can be used to create organic fertilizers, including crop leftovers and animal manure. Natural fertilizers increase soil fertility and are rich in nutrients, which lessens the need to use synthetic fertilizers that are bad for the environment.

1.7.9. Soil Improvement

Agro-waste may be utilized to enhance the structure and quality of the soil. Increased agricultural productivity may result from its ability to improve soil fertility, reduce erosion, and retain moisture.

1.7.10. Construction Material

Agro-waste can be utilized as a building material to create lightweight bricks and panels, including such rice husk and bagasse. As a result, less conventional building materials are used, which lowers carbon emissions.

1.7.11. Production Of Paper

Paper pulp can be created using agricultural waste, including rice straw and sugarcane bagasse. As a result, there is less demand need virgin pulp, which also is made by felling trees [10].

1.8. BIO CHAR

Bio-Char is a type of charcoal that is produced from organic materials such as wood chips, agricultural waste, or other biomass. It is created through a process called pyrolysis, which involves heating the organic material in the absence of oxygen. The resultant Bio-Char is a very porous, carbon-rich substance. In crop and garden applications, it can be used as a soil conditioner to enhance fertilization, water holding capacity, and nutrient availability. A sustainable and eco-friendly substitute for conventional fertilizers and soil additions is Bio-Char. It may be made from a variety of organic waste products, which lessens the demand for landfills and encourages the circular economy.

There are numerous advantages of Bio-Char for healthy soil and plant growth. By enhancing the soil's capacity to hold onto water, minerals, and organic matter, it can raise soil fertility. This may result in better plant health and higher crop production. Moreover, Bio-Char can aid in soil carbon sequestration, which lowers greenhouse gas emissions and may assist to slow down the effects of climate change. Also, it may lessen the demand for synthetic fertilizer, which can be costly to create and deliver. Bio-Char has been demonstrated to always have potential uses in the treatment of water and the removal of pollution, in addition to its advantages for the health of the soil and plant growth. It can be used to clean up soil and water of impurities like organic pollutants and heavy metals [11].

1.9. SOURCES OF BIO CHAR

Depending on the area and the accessibility of biomass materials, the precise cause of Bio-Char can vary greatly. There are several different organic resources that can be used to make Bio-Char, such as:

- Agriculture waste: Crop wastes, including maize stalks, wheat straw, rice straw, sugarcane bagasse, and other plant materials left behind after harvesting, can be utilized to make Bio-Char.

- Forest trash: In addition to using sawdust as a feedstock, Bio-Char can also be produced using wood chips, bark, branches, and other types of forest waste.
- Livestock manure, poultry litter, and bone meal are a few types of animal waste that can be used to make Bio-Char.
- Urban green waste: Grass trimmings, leaves, yard debris, and other organic waste products from gardening and landscaping projects can be utilized to generate Bio-Char.
- Aquatic plants: The manufacturing of Bio-Char can also use water hyacinth, water lettuce, and other aquatic plants as feedstock.
- Industrial waste: Bio-Char can be produced using coconut shells, rice husks, nut shells, and other leftovers from processes including rice milling, nut breaking, and coconut processing.
- Energy Crops: Switch-grass, miscanthus, bamboo, and other quickly expanding plants cultivated expressly for the production of bioenergy can also be used to generate Bio-Char.

The chemical make-up, porosity, surface area, and stability of Bio-Char can all be impacted by the feedstock used. For instance, some feedstock, like hardwoods, create Bio-Char with a high carbon content and a high degree of stability, whereas others, like agricultural waste, might produce Bio-Char with a high nutrient content and a high degree of porosity. The choice of feedstock is also influenced by accessibility, price, and regional laws. When producing Bio-Char, waste materials that would otherwise be wasted can sometimes be used, reducing waste and possibly benefiting farmers, loggers, and other businesses economically [12].

1.10. APPLICATION OF BIO-CHAR

1.10.1. Soil amendment:

Bio-Char is capable of serving as a soil supplement to strengthen the soil, boost crop yields, and lessen the need for fertilizer. Bio-Char's porous structure can store water and nutrients while enhancing soil aeration and lowering soil compaction. Bio-Char can also boost the activity of soil microbes, which aids in the decomposition of organic materials and the release of nutrients for plant growth.

1.10.2. Fuel source

Using Bio-Char as fuel is possible both on its own and in mixtures with other fuels like woody biomass or sawdust. Because of its high energy content, Bio-Char may produce both heat and electricity when burnt in stoves or boilers. Using Bio-Char as a source of fuel can aid in decreasing emissions of greenhouse gases and advancing the production of sustainable energy [10].

1.10.3. Carbon sequestration

Bio-Char, a stable form of carbon that can linger inside the soil for a number of years, is a form of carbon sequestration. Carbon may be held in the soil and kept away from the atmosphere by adding Bio-Char, which helps to slow down global warming.

1.10.4. Water filtering

Bio-Char's porous structure makes it a useful water filtration and purification tool. Bio-Char is a useful technique for water purification and purification because it may remove toxins from water, including heavy metals, pesticides, and medicines.

1.10.5. Supplemental feed for livestock

Activated carbon could be put to pet food to help livestock digest and assimilate nutrients. In addition, Bio-Char can assist with odour control and air quality improvement in animal quality housing [5].

Ultimately, Bio-Char has the possibility to have major positive effects on the environment and the economy. The use of Bio-Char may become a crucial tool in the battle against global warming and environmental deterioration with further study and development.

1.11. SYNTHESIS OF BIO-CHAR

Pyrolysis is a method for creating Bio-Char that includes heating organic materials without oxygen. There are numerous ways to make Bio-Char, and each has benefits and drawbacks. Typical techniques include:

1.11.1. Traditional Pit Kilns

This process entails excavating a pit in the earth, putting organic materials inside of it, and then covering the pit with soil. The ingredients are then slowly burnt over a number of days to create charcoal. While

this process is straightforward and inexpensive, it has the potential to be ineffective and yield substandard Bio-Char.

1.11.2. Improved Top-Lit Updraft (TLUD) Stoves

This technique involves burning organic materials in a stove that has a combustion chamber and a chimney. The TLUD stove produces high-quality Bio-Char and lowers pollution by burning the ingredients top to bottom.

1.11.3. Gasification

In the gasification process, organic materials are heated in a confined container to generate gases that can be collected and burned as fuel. Bio-Char makes up the remaining solid matter. Although this approach can be effective and yield high-quality Bio-Char, it may also be more expensive and need more equipment [11][10].

1.11.4. Microwave Pyrolysis

By heating organic materials with microwave energy, Bio-Char is produced swiftly and effectively. Although though this technique is still being refined and isn't yet commonly utilized, it's got the ability to be a cheap and energy-effective way to make Bio-Char.

The organic materials used, as well as the heating temperature, time and the oxygen level during the pyrolysis process, all have an impact on the quality of Bio-Char produced, regardless of the method. Bio-Char of the highest level need to be stable, black, porous, and contain little ash or volatile material. Overall, the production of Bio-Char is a crucial field for study and development because it has the possibility to have a wide range of positive effects on the environment and the economy [13].

1.12. BIO CHAR SYNTHESIS AND LIMITATIONS

1.12.1. Advantages

- Mitigation of climate change: By removing carbon from the environment, Bio-Char can be utilized to lessen the consequences of global warming.
- Adding Bio-Char to soil can help it retain nutrients, hold more water, and improve its structure, which will enhance plant growth and crop production.

- Waste management: The production of Bio-Char from a variety of naturally occurring waste materials offers a way to lessen waste while also creating a useful product.
- Energy derived from renewable sources: It is possible to collect and burn the gases released during the synthesis of Bio-Char [14].

1.12.2. Limitations

- Cost: Making high-quality char can be costly, especially when specialized equipment is needed.
- Scale: Since Bio-Char is primarily produced on a tiny scale, its influence on major environmental issues may be constrained.
- Energy usage: Producing Bio-Char can demand a lot of energy, especially if complex machinery is employed.
- Emissions: The creation of Bio-Char can lower greenhouse gas emissions, but it can also result in the generation of other pollutants such as particulates and organic compounds that are volatile.

Overall, the advantages and limitations of Bio-Char synthesis depend on a variety of factors, including the specific method used, the quality of the Bio-Char produced, and the intended application of the Bio-Char. While Bio-Char synthesis is not a panacea for environmental problems, it has the potential to provide numerous benefits when produced and used appropriately [14].

1.13. CHARACTERIZATION OF BIO-CHAR

- Analysing The Elements: The hydrogen, nitrogen, oxygen, carbon, hydrogen, and sulphur content of Bio-Char is examined. Techniques like combustion analysis or elemental analysis with a CHNS/O analyser can be used for this.
- Surface Area And Pore Size Distribution: Using methods like nitrogen adsorption using a BET analyser, the particular area of surface of Bio-Char can be determined. Mercury intrusion porosimetry can be used to determine the distribution of pore sizes.
- Ash Content: The cation exchange capacity and nutritional content of Bio-Char are both impacted by the ash content of the material. By

weighing the residue after ashing the charcoal in a furnace, it can be calculated.

- pH: After mixing it in distilled water, you can use a pH metre to determine the pH of Bio-Char.
- Functional Groups: Methods like Fourier-transform infrared (FTIR) spectroscopic can be used to examine the existence of functional groups like carboxyl, hydroxyl, and phenolic groups.
- Thermal Stability: Thermo gravimetric analysis (TGA), which analyses the weight loss of Bio-Char with raising temperatures, can be used to identify the thermal stability of Bio-Char.
- Cation Exchange Capacity (CEC): A crucial characteristic that affects Bio-Char's potential to store and release nutrients is its CEC. Ammonium acetate or sodium chloride extraction can be used to find out.
- Microbial Activity: Depending on its characteristics and pace of application, Bio-Char can have a variety of effects on soil microbial activity. Utilizing techniques like respiration or DNA analysis, microbial activity can be assessed.

These methods can enlighten researchers about the physical and chemical characteristics of Bio-Char, allowing them to better understand its potential uses in carbon sequestration, water purification, soil remediation, and as a feedstock for bioenergy generation [15].

1.14. BIO CHAR AS NUTRIENT SUPPLIMENT

An efficient soil fertilizer addition is Bio-Char. In the absence of oxygen, organic material, including such wood pellets or agricultural residues, is heated to create Bio-Char, a type of charcoal. Bio-Char can be used to amend soil to increase soil fertility, increase the soil water-holding ability, and improve soil structure. Nitrogen, potassium, and phosphorus, can all be absorbed and retained by Bio-Char, which is rich in carbon. Also, it offers a home for helpful soil microbes, which may aid in fostering plant health and growth.

By storing carbon in the soil, Bio-Char can aid in lowering greenhouse gas emissions in addition to its capacity to hold nutrients. Hence, there will be less carbon dioxide in the atmosphere, which can assist to slow down

climate change. It is crucial to take into account both the particular requirements of both the plants being grown and the purity of the Bio-Char when utilizing it as a nutritional supplement. The best quantity of Bio-Char to utilize will depend on the soil types, climate, and other variables. Certain forms of Bio-Char may be better at retaining specific nutrients than others [13].

1.15. FARMING AND CULTIVATION

Agriculture includes two key components: formation and cultivation. Farming is the process of preparing land for planting, whereas cultivating is the control of crops as they grow and develop.

In general, the term "farming" refers to the broader idea of managing agricultural output, which encompasses a variety of tasks like the cultivation, harvesting, processing, and marketing of crops or livestock. To create food, fiber, fuel, and other goods, it makes use of land, labor, capital, and technology. Farming can be a full-time profession, and it frequently requires a sizable time and financial commitment.

On the other hand, the term "cultivation" explicitly refers to the procedure of preparing the soil, sowing seeds, and growing crops or plants until they are fully mature. It is a branch of farming that focuses on the particular techniques used to cultivate crops, like irrigation, fertilization, and pest control. Growing crops can be a seasonal or part-time job, and it isn't always necessary to make substantial financial commitments.

1.15.1. Farming

The act of forming involves preparing the ground for agricultural planting.

There are multiple steps involved, including:

- Soil preparation: In order to loosen the soil and facilitate root growth, it is tilled, ploughed, or otherwise turned.
- Fertilization: To give crops the necessary nutrients, fertilizers are incorporated into the soil.
- Irrigation: The soil is moistened by the addition of water.
- Planting: To start the growth process, seeds or seedlings are buried in the ground.

1.15.2. Cultivation

Crops are grown and developed while being managed through cultivation. There are numerous steps involved, such as:

- Crop maintenance: Pest and disease infestations are tracked down and treated as necessary.
- Irrigation: Crops are irrigated as necessary to keep them moist.
- Fertilization: Extra fertilizers are put into the soil as necessary to supply the crops' crops with nutrients.
- Harvest: When a crop is fully developed and prepared for consumption, it is harvested.

A successful agricultural industry depends on both farming and cultivation. While efficient cultivation techniques can assist optimize agricultural yields and reduce losses due to pests and diseases, proper soil preparations and planting procedures can help assure healthy growth and development of crops. Agricultural can be a profitable and sustainable business that feeds people all over the world with the right management.

In agriculture, there are various different forms of cultivation, such as:

- Intensive cultivation: In order to get high yields, this style of farming uses a lot of effort, money, and resources, such pesticides and fertilizers. In order to cultivate crops on a big scale while maximizing earnings, intensive cultivation is frequently used in commercial farming.
- Extensive cultivation: Many inputs of labor, money, and resources are used in small amounts during extensive cultivation, resulting in low yields. In subsistence farming, when crops are largely cultivated for the farmer's personal consumption, extensive cultivation is frequently practiced [5].
- Organic cultivation: In this style of farming, natural pest control techniques like crop rotation and companion planting are used together with natural fertilizers like compost. Due to worries about the effects that conventional agricultural practices have on the

environment and human health, organic farming is growing in popularity.

- Precision cultivation: This method of farming maximize yield while minimizing waste by using technology, including such GPS and remote sensing, to accurately regulate the application of inputs, such as fertilizers and pesticides.
- Hydroponic cultivation: This method of growth uses a nutritionally water solution to produce plants without utilizing soil. Due to its water efficiency and storage space, hydroponic farming is becoming more and more popular.
- Mixed cultivation: In this method of farming, several crops are grown side by side in the same field. By fostering biodiversity, mixed farming can help minimize pest and disease issues and enhance soil health.

For various crops, geographical locations, and farming techniques, several forms of cultivation could be preferable. To satisfy their objectives and the needs of their markets, farmers may decide to combine these different farming techniques [16].

1.16. CONVENTIONAL FARMING TECHNIQUES

The term "conventional farming," usually referred to as "traditional farming," is an agricultural practice that relies on the application of artificial fertilizers, pesticides, and herbicides to manage crops and control pests. Large-scale monoculture, or the cultivation of a single crop over a considerable amount of land, is a common practice in conventional farming. Chemical inputs are employed in traditional agriculture to increase crop yields and safeguard crops against pests and illnesses. Contrary to popular belief, traditional farming can have a negative influence on the environment due to the extensive use of synthetic chemicals, which can lead to soil erosion, water pollution, and biodiversity loss. In addition to being extremely mechanized, conventional farming typically uses tractors and other equipment to prepare the soil, plant crops, and harvest the crop's output. This can result in soil compaction, erosion, a rise in energy consumption, and a rise in greenhouse gas emissions. Despite the fact that conventional farming has been successful in producing plenty food to satisfy the world's expanding

population, organic farming and agro ecology are increasingly being recognized as more environmentally friendly alternatives [15].

1.17. ALTERNATIVE FARMING TECHNIQUES

A wide range of farming strategies that are different from traditional farming techniques are included in alternate farming, commonly referred to as alternative farming. These techniques frequently focus on conserving soil health and biodiversity and are more environmentally friendly and sustainable. Here are a few instances of alternative farming techniques:

- Organic Farming: Using natural pesticides and fertilizers as opposed to synthetic ones is what is meant by organic farming.
- Agro Ecology: Agro ecology is a farming method that aims to resemble natural ecosystems. It places a strong emphasis on the use of crop rotation, intercropping, and other techniques that support biodiversity and ecological harmony.
- Permaculture is an all-encompassing method of farming that places a focus on creating self-sufficient, low-input agricultural systems.
- Regenerative Agriculture: A farming strategy that aims to enhance soil health, boost biodiversity, and store carbon in the soil with a focus on long-term sustainability.
- Aqua-Ponics: Aqua-Ponics is a farming technique that combines hydroponics (plant growth in water) and aquaculture (raising fish) to produce a closed-loop system that reduces waste and increases output.

The popularity of alternative farming techniques is rising as a result of their emphasis on biodiversity, soil health, and sustainability. These methods present a viable substitute for conventional farming, which can be resource-intensive and have detrimental effects on the environment [15].

1.18. ADVANTAGES OF ALTERNATIVE FARMING

Alternative farming techniques have a number of benefits over traditional agricultural techniques, such as:

1.18.1. Environmental Sustainability

Alternative farming practices, such organic farming, agroecology, and regenerative agriculture, place an emphasis on using natural inputs and

preserving soil health and biodiversity, which results in a more resilient and sustainable farming system.

1.18.2. Synthetic Chemicals

The use of artificial fertilizers, pesticides, and herbicides, which can have detrimental effects on the environment and human health, is reduced by alternative farming techniques.

1.18.3. Food Safety & Soil Health

Alternative agricultural practices put a priority on food safety by reducing the use of chemical inputs and highlighting organic means of preventing pests and diseases. Agro ecology and regenerative agriculture, as well as alternative farming techniques, prioritize soil health through techniques including crop rotation, cover crops, and reduced tillage, which can enhance soil fertility, lower erosion, and boost water retention.

1.18.4. Increased Biodiversity

The preservation of biodiversity is a top priority for alternative farming techniques like agro ecology and permaculture, which encourage the coexistence of many plants, animals, and wildlife on the farm.

Overall, alternative farming techniques prioritize food safety, soil health, and biodiversity while also providing a more sustainable and environmentally friendly approach to agriculture.

1.19. ALTERNATE FORMS OF CULTIVATION

Agriculture uses a variety of alternative farming methods. These are a few instances:

- Organic Farming: It's a method of cultivation that uses organic pest and fertilizer management techniques rather than artificial chemicals. Crop rotation as well as utilizing cover crops are common practices in organic farming to enhance soil health.
- Hydroponics: Using a nutrient-rich fluid in place of dirt, hydroponic farming entails cultivating plants. Crops can be grown using this technique both inside and in regions with inadequate soil.
- Agroforestry: Agroforestry is a technique of land use management that blends trees with livestock or agricultural products. By using this

technique, you can increase soil fertility, lessen erosion, and give plants and animals shade and protection.

- Precision Farming: To maximize crop yield, precision farming employs technology such as GPS and sensors. Farmers can increase yields, boost efficiency, and minimize waste by using this technique.
- Permaculture: Permaculture is a development method that imitates natural ecosystems in order to develop agricultural systems that are sustainable. This approach places an emphasis on regenerative methods, healthy soil, and biodiversity.

These are only a few instances of alternative agricultural growing methods. Depending on their requirements and objectives, farmers may decide to combine these strategies since each has advantages and disadvantages of its own [15][17].

1.20. NECCESITY OF ALTERNATIVE FARMING

Due to a number of environmental, economic, and societal issues, alternative farming approaches are becoming more and more significant. Alternative agricultural methods are essential for a number of reasons, including:

- Climate Change: Climate change is causing weather patterns to shift, including rising temperatures and irregular rainfall, which can result in crop failure and lower yields. By enhancing soil health and water retention, alternative agricultural techniques like intercropping and agroforestry can assist to lessen the consequences of climate change.
- Environmental Sustainability: Traditional agricultural practices frequently consume a lot of water, fertilizer, and pesticides, which can have detrimental effects on the environment such soil erosion, water pollution, and biodiversity loss. Utilizing natural resources, cutting down on waste and pollution, and maintaining biodiversity are the main focuses of alternative farming methods including agro ecology, conservation agriculture, and organic farming. Regenerative agriculture and organic farming are two examples of alternative farming practices that work to enhance soil health and encourage biodiversity.

- **Water Scarcity:** Traditional irrigation practices are frequently wasteful and ineffective, and water scarcity is a problem that is becoming more and more urgent in many regions of the world. Water usage can be decreased and water efficiency can be increased by using alternative farming techniques like irrigation water and conservation agriculture.
- **Health Issues:** Chemical pesticides and fertilizers are frequently used widely in conventional farming method, which can have a harmful impact on both the environment and human health. By using fewer chemicals and promoting the production of sustainable and healthful foods, alternative farming techniques like organic agriculture and integrated pest control attempt to limit the usage of chemicals.
- **Food Security:** To meet the needs of a growing world population, more food must be produced with fewer resources. Alternative methods, such as aquaponics, hydroponics, and vertical farming, offer solutions to grow food in cities and other places with limited access to land, water, and other resources.
- **Social Equity:** Alternative approaches can aid in addressing social challenges such as rural poverty, gender inequality, and problems with land tenure. For instance, agro ecology places an emphasis on farmers' stewardship of their land and can give women and communities who are marginalized the power to take charge of their own food production.
- **Economic Viability:** Alternative methods can give farmers the chance to boost their profitability and diversify their income sources. Agroforestry systems, for instance, can produce both timber and agricultural crops, and organic farming can result in higher prices for organic goods [3][18].

Hence, alternative agricultural practices can assist in addressing a variety of difficulties affecting modern agriculture, including water scarcity, soil degradation, and climate change. Alternative farming techniques can contribute to ensuring a better and more resilient food system for future generations by supporting sustainable and regenerative practices [19].

1.21. HYDROPONICS AND ITS POPULARIZATION

In hydroponics, plants are grown in nutrient-rich water solutions rather than in soil. This method is providing plants with a nutrient solution on a regular basis while they are being grown within container filled with a nutrient medium, including such perlite, vermiculite, or coconut coir. Because it has significant advantages over conventional soil-based agriculture, hydroponics has grown in popularity in recent years. These benefits consist of:

- Water efficiency: Compared to conventional soil-based agriculture, hydroponics uses up to 90% less water.
- Space effectiveness: Hydroponic systems can be stacked vertically, which enables the growth of more plants in a smaller area.
- Enhanced plant growth and yield: Compared to plants cultivated in soil, hydroponically grown plants often develop more quickly and yield more.
- Less need for pesticides and herbicides: Because hydroponic systems are usually better controlled than traditional agriculture, less chemical treatment is required.
- Hydroponics makes it possible to grow plants all year round, no matter the weather or the time of year [20].

Several causes, such as the rise in local food consumption, the necessity to preserve water, and the preference for sustainable farming methods, can be blamed for the popularity of hydroponics. Moreover, hydroponics is now more available and simpler to use for backyard gardeners and local farmers thanks to technological and equipment advancements. When there is a strong demand for fresh fruit and there is a lack of available space, hydroponics has gained popularity in urban settings. Also, it has grown in popularity in areas with scarce water supplies where conventional agriculture might not be viable. Given its many benefits, it is anticipated that hydroponics will gain more traction as people look for more efficient and sustainable ways to produce food [21].

1.22. HYDROPONICS AS AN ALTERNATE FORM OF CULTIVATION

An alternate method of cultivation called hydroponics includes growing plants in such a nutrition water solution without the use of soil. In

hydroponics, the plant's stem and leaf are supported by an artificial medium like perlite or coco coir, while the roots are submerged in a nutritional solution. The nutrition solution is continuously pumped to offer a consistent supply of nutrients, and the plant obtains the nutrients it requires from it. Hydroponics is a method of growing plants that enables year-round culture because the plants are grown inside in a controlled environment. As a result, farmers are able to grow crops even in regions where the environment is unfavourable for traditional outdoor agriculture. Some benefits of hydroponic cultivation over conventional soil-based cultivation include:

- More yields: When compared to plants grown in soil, hydroponic can grow more quickly and provide greater yields per unit of space. This is the reason that hydroponic plants can develop more effectively because they have access to a steady intake of nutrients and water.
- Effective use of resources: Since water is recycled inside the hydroponic system, it consumes substantially less water than conventional soil-based farming. The use of less pesticides and fertilizers by hydroponic plants also lessens chemical outflow and soil contamination.
- Space Savings: Hydroponic farming is more suitable for urban areas with limited land because it takes up less room than conventional farming.
- Quality control: Hydroponic farming enables farmers to precisely manage the growth environment, including temperature, humid, and nutrient availability, which produces high-quality, dependable crops.

Hydroponics has several drawbacks in addition to its many positives. A hydroponic system takes technical know-how to maintain and might be expensive to set up. A hydroponic system may not be ideal for all types of plants, and it needs energy constantly to keep the flow of water and nutrients going [18][21].

1.23. MICRO GREEN CULTIVATION

During germination, when genuine leaves grow, Micro-Greens are young, sensitive greens that are harvested. They are raised from various vegetable, herb, and grains seed, and are normally harvested one to two weeks after sowing. Micro-Greens can be found in several different types of foods, including salads, as garnishes, and as a vibrant and tasty accent.

Micro-Greens need very little area to grow and can be cultivated either hydroponically or in soil. In the majority of climates, they may be cultivated both indoors and outdoors and harvested all year round. The correct temperature, moisture, and light levels, as well as other ideal growing circumstances, are essential for growing healthy Micro-Greens.

Start by picking the appropriate seeds for growing Micro-Greens. If you want tender, tasty greens, choose seedlings that are designated for growing Micro-Greens because they will germinate fast. The next step is to select a growing medium such as soil or even a hydroponic system and prepare it in accordance with the directions. The seeds should be sown closely together in the growing medium and lightly covered with soil or the other growing medium. To produce a greenhouse effect, softly mist the seeds with water and cover them with clear plastic wrap or a plastic lid. Set the tray in a warm, well-lit area, like a sunny windowsill or below grow lights. After the seeds have germinated, take off the plastic cover and continue to water the Micro-Greens. The Micro-Greens should be grown until they reach the required size, often 1-2 inches tall. By slicing the Micro-Greens at the stem's base, you can gather them for fresh consumption in salads, sandwich, or as a vibrant garnish for any cuisine [22][23].

1.24. TYPES OF MICRO-GREENS

There are many different kinds of Micro-Greens, including, to name a few, rocket, broccoli, mustard, chives, cilantro, kale and radish. Since each type has a unique flavour and nutritional profile, they can be used as an ingredient in a wide range of cuisines.

- Nutrient-dense: Studies have revealed that Micro-Greens can have as much as forty times higher nutrients per unit of area than mature plants, which is why they are noted for their high level of nutrients. This is due to the fact that Micro-Greens are still able to accumulate nutrients and have not yet depleted their nutrient stores.
- Growing Micro-Greens has various advantages, which are listed below. They are a desirable option for small-scale growers and urban gardening because they are simple to grow and demand few resources. Because to the fact that producers may sell them at a premium price to eateries,

supermarkets, and farmers markets, they can also be a successful commercial venture.

- Growth techniques: There are numerous ways to grow Micro-Greens, including soil-based, hydroponic, and aquaponic systems. Because they are simple to set up and maintain, soil-based systems have become most popular. In contrast to hydroponic systems, which substitute nutrient-rich water for soil, aquaponic systems combine hydroponics and aquaculture to provide a closed-loop system [22][23].

1.25. MICRO-GREENS AND ITS ADVANTAGES

Micro-Greens are grown by sowing their seeds in trays of soil or the other growing medium, and then watching them grow. The trays are then put in a sunny spot or under grow lights, and they receive regular watering. Cutting the Micro-Greens just above the soil level will allow you to harvest them after one to two weeks. In conclusion, growing Micro-Greens is a profitable and sustainable alternative agricultural method that may add taste and nutrients to any meal. Due to the growing demand for Micro-Greens, there are numerous options for producers to sell their produce to eateries, supermarkets, and farmers markets. Micro-Greens are a simple and effective crop to grow that has several advantages, when grown in soil, hydroponic, or aquatic systems. There are some distinctions between Micro-Greens and traditional crops in terms of their growth conditions, nutritional content, and production [1][22].

- Growth requirement: Micro-Greens can be cultivated in constrained areas and need less nutrients and water than traditional crops. Depending on the climate, they can be cultivated indoors, in greenhouses, or outdoors. Conventional crops, on the other hand, are often cultivated outdoors in huge fields and require more land, water, and minerals to grow.
- Nutritional value: Micro-Greens have a higher concentration of vitamins, minerals, and phytonutrients than mature plants, making them more nutrient-dense. They also serve as a good supply of protein and nutritional fiber. Conventional crops, in contrast, have lower levels of essential nutrients.
- Yield: Compared to conventional crops, Micro-Greens have such a shorter maturation period and are able to be harvested in as little as one

to two weeks after sowing. In comparison to regular plants, Micro-Greens can grow in the same amount of space and time while producing numerous harvests.

- Generally, Micro-Greens are superior to conventional crops in a number of ways, including increased nutrient density, reduced resource needs, and higher production potential. They might not work well for intensive farming or for plants that need an extended growing season [22][24].

1.26. MICRO-GREENS AND CONVENTIONAL CROPS IN NON-CONVENTIONAL FARMING:

In non-conventional farming techniques like hydroponics, aeroponics, and aquaponics, traditional crops and Micro-Greens can coexist. These systems use nutrient-rich water or mists to grow plants without the use of soil. Growing Micro-Greens alongside traditional crops has the benefit of making better use of available space. Micro-Greens develop quickly and are able to be harvested in as little as between one two weeks, in contrast to the several months that conventional crops like tomatoes, peppers, and cucumbers might take to mature. Farmers can maximize space use and boost yields by cultivating Micro-Greens alongside traditional crops.

Another benefit is whether Micro-Greens can help to boost the developing system's nutrient content. Studies have revealed that Micro-Greens can contain as much as 40 more nutrients per unit surface area than mature plants, which is why they are noted for their high nutrient content. Farmers can boost the total nutrient content of their producing system by planting Micro-Greens alongside conventional crops. Micro-Greens can also be a lucrative crop for farmers. Although they are well-liked by chefs and consumers who value their health, they can be sold at a premium to restaurants, supermarkets, and farmers markets. It can be grown alongside regular crops, but there are some difficulties as well. Managing infections is one difficulty because Micro-Greens are more prone to disease than mature plants are. To stop illness from spreading across crops, farmers must exercise caution.

Micro-Greens' varied environmental requirements from those of traditional crops present another difficulty. For instance, while normal crops need high light and low humidity, Micro-Greens need high light and low humidity.

Producers need to make sure the crop-growing system can offer the best circumstances for both crops. Overall, using unconventional farming techniques to cultivate Micro-Greens alongside traditional crops can be a feasible and profitable alternative for farmers. It makes good use of available space, boosts the system's general nutrient content, and has the potential to be a successful crop. To manage disease and guarantee ideal growth conditions for both crops, farmers must be aware of the difficulties and take appropriate action [1][16].

CHAPTER 2

LITERATURE REVIEW

- **Savvas, D., & Tsirogiannis, I. L. et al., (2012)** had published the journal in the topic of “Hydroponic lettuce production in a green wall system” Lettuce is a different species that thrives in hydroponic systems. The author claims that hydroponic lettuce may offer yields that are up to 50% more than standard soil-based gardening methods. Hydroponic lettuce produces more quickly and has a more regular shape and size, providing simpler for harvesting and consumers.
- **Tan et al. (2020)** had published the journal in the topic of “Vermicomposting derived from pineapple waste as a hydroponic nutrient supplement for lettuce production” Vermicomposting made from the waste of pineapples was employed as a hydroponic nutrition supplement. According to the study, vermicomposting considerably boosted lettuce output and growth when compared to the typical hydroponic supplement.
- **Kumar, S., Biswas, A. K., & Biswas, P et al., (2018)** had published the journal in the topic of “Agro-waste Bio-Char as a soil amendment to improve soil fertility and crop productivity” The impact of agro waste Bio-Char on soil fertility and productivity of crops were examined in a study done by the author. When compared to compost, the use of agro waste Bio-Char lead to a greater wheat yield and improved fertility of the soil.
- **Hernández et al. (2020)** had published the journal in the topic of a plant extract obtained from *Moringa oleifera* was employed as a hydroponic nutrition supplement. According to the study, the plant extract greatly boosted lettuce yields and growth when compared to the usual hydroponic fertiliser solution.
- **Zhang et al. (2019)** had published the journal in the topic of “Agro-industrial waste materials and wastewater as growth media for microbial bio-flocculants production” A Cu-based homogeneous catalyst was employed to change lignin-based biomass into biofuels. According to the study, the Cu-based catalyst was successful in increasing the cleavage of cellulose, lignin, and the hemicellulose leading to the formation of biofuels.

- **Suwannarach et al. (2020)** had published the journal Compost tea made from banana trash was employed as a hydroponic nutrition supplement. According to the study, compost tea greatly boosted lettuce growth and productivity when compared to the typical hydroponic fertiliser solution.
- **Gutierrez et al., (2020)** had published the journal in the topic of “Design and implementation of an IoT system for monitoring a hydroponic crop in a greenhouse” Hydroponic systems have gained popularity in modern farming because to their multiple advantages over traditional soil-based agriculture. Hydroponics allows for the cultivation of high-quality crops in a controlled environment, resulting in larger yields and faster growth rates. The purpose of this literature study is to investigate the many types of hydroponic systems and their distinguishing qualities.
- **Zhang et al. (2020)** had published the journal in the topic of “Conversion of corn stover to biofuels over mesoporous ZSM-5 zeolite catalyst” Corn stover was converted into biofuels using mesoporous ZSM-5 zeolite as a catalyst. According to the research, the mesoporous ZSM-5 zeolite catalyst demonstrated outstanding catalytic efficiency and selectivity for biofuel synthesis.
- **Mirzaei et al., (2020)** had published the journal in the topic of “Aeroponics hydroponic system: Future of agriculture” The aeroponic system is an advanced hydroponic system that delivers nutrients straight to the roots via spray. This system is extremely efficient, utilising less water and fewer fertilisers than other systems and providing great root oxygenation. It does, however, necessitate more upkeep and specialised equipment than ordinary hydroponic systems.
- **Tyson et al., (2019)** had published the journal in the topic of “Ebb and flow hydroponics” Another common hydroponic technique is the ebb and flow or flood and drain system, which includes regularly flooding the crops with nutrient-rich water and then draining it away. This technique is good for larger plants like tomatoes or cucumbers, as it gives you more control over fertilizer distribution. It is, however, more difficult to install and maintain than conventional hydroponic systems.
- **Resh, H. M. et al., (2013)** had published the journal in the topic of “Hydroponic food production” A definitive guidebook for the advanced home

gardener and the commercial hydroponic grower. Deep water culture (DWC) is a hydroponic method that grows plants in a reservoir of nutrient-rich water. The plants' roots are floating in water, and an air compressor supplies oxygen to the roots. The DWC system, according to the inventor, is simple to set up and maintain, and it can be used to cultivate a variety of plants. However, controlling the pH and nutrient levels in the water might be difficult.

- **Kumar et al. (2020)** had published the journal in the topic of “Synthesis of activated carbon from rice husk for environmental applications” Chemical activation was used to make activated carbon from rice husk. According to the research, activated carbon has a large surface area, making it appropriate for a variety of applications including water treatment, gas retention, and catalysis.
- **Kyriacou and Savvas et al., (2017)** Aeroponic devices supply nutrients to plant roots via mist or fog. The aeroponic system, it can provide higher yields than traditional hydroponic systems. It is also more effective with water and provides updated pH and nutrient control. It is, however, more costly to set up and fix than other hydroponic systems.
- **Yadav et al., (2016)** the drip irrigation system is a hydroponic system that drips nutrient-rich water immediately onto the plant roots. The drip irrigation system, is straightforward to install and operate, and it can be used for growing a range of plants. However, controlling the pH and nutrient levels in the water might be difficult.
- **Mahajan, P., & Tandon, P. et al., (2019)** had published the journal in the topic of “Impact of hydroponic technique on plant growth, fruit yield and quality of cucumber” Cucumbers are a different plant that can thrive in hydroponic systems. According to the author, hydroponic cucumbers can provide crops up to 50% more than standard soil-based growing methods. Hydroponic cucumbers are also superior in texture and possess an extended lifespan, making them more desirable to customers.
- **Wu, L., Wang, C., Zheng, Y., Lin, X., Jiang, X., Wei, D., & Xie, Z et al., (2020)** had published the journal in the topic of “Agro-waste Bio-Char increases grain yield and improves soil fertility in rice-based cropping systems” The authors examined the impact of agro-waste Bio-Char on rice development against no amendment. The study discovered that the use of

agro-waste Bio-Char produced a greater quantity of rice and enhanced soil quality as an alternative to no amendment.

- **Jahan et al. (2020)** had published the journal in the topic of “Biogas slurry as a hydroponic nutrient solution for cucumber cultivation “cow dung biogas slurry was employed as a nutritional supplement in hydroponics. The biogas slurry greatly boosted cucumber growth and yield when compared to the usual hydroponic fertiliser solution, according to the study.
- **Gao et al. (2019)** had published the journal in the topic of “Effect of Light Intensity on the Growth and Yield of Hydroponic Strawberry” Strawberries may also be grown in hydroponic systems, which provide larger yields than typical soil-based agricultural methods. According to the author, hydroponic strawberries can yield up to 25% more than soil-grown strawberries. Hydroponic strawberries also possess a prolonged growth season, which may improve overall yield.
- **Chen, Y., Li, L., Wang, Y., Li, Y., Li, X., Li, Q., & Li, Y et al., (2019)** had published the journal in the topic of “Comparison of agro-waste Bio-Char and chemical fertilization on maize growth, nutrient uptake and soil properties in a saline soil” The authors conducted a study that compared the impact of agro-waste Bio-Char on maize growth to chemical fertiliser. The use of agro-waste Bio-Char gave produce comparable to chemical fertiliser, with the added advantage of enhancing soil fertility and reducing nutrient leaching.
- **Krasnova et al. (2020)** had published the journal in the topic of “Control of pH in hydroponic cultivation” According to his studies, pH acts as one of a significant critical environmental parameters to monitor in hydroponic systems. The research discovered that keeping the pH range around 5.5 and 6.5 is critical for plant development and intake of nutrients.

CHAPTER 3

AIM & SCOPE

3.1. Aim

The ultimate aim of our project titled “SYNTHESIS CHARACTERIZATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS” is to develop an agro waste based nutrient supplement to implement in non-conventional farming technique i.e. hydroponics, by achieving the following objectives.

- Synthesize and Evaluate Bio-Char from an Agricultural Waste.
- Develop a custom Hydroponics Set-up using simple, easily available but effective materials.
- Cultivation of Micro-Greens from the developed hydroponics system and synthesized Bio-Char.
- Nutritional studies on cultivated Micro-Greens and analysis.

3.2. Scope

Alternate farming methods can be a great advantage to conventional farming as it can increase the overall yields and can reduce soil related problems. Requirement of large cultivable land isn't required as non-conventional farming can even be done in terrace or in urban area or even in villages where there is land constraints. Usually water requirement in non-conventional farming is much lesser than conventional farming, so water management is easier. Soil contamination and soil degradation problems doesn't arise in non-conventional technique so nutrition related problems are rare. Agricultural waste which leads to GHG emissions can be greatly reduced in non-conventional methods.

CHAPTER 4

MATERIALS & METHODS

4.1. RAW MATERIAL COLLECTION

Rice Straw is the primary raw material which was used to synthesize Bio-Char. As the primary motive of this project is to synthesize Bio-Char from agro waste. Coco Peat is used as a substrate for growing plants. Acrylic Tubes and PVC Cups for building the Hydroponics System.

4.2. EQUIPMENT USED

Various types of equipment were used in every other aspects. During the synthesis of Bio-Char, Hot Air Oven for moisture removal and Muffle Furnace for achieving one of the main objective i.e. Synthesis of Bio-Char.

While the same Hot Air Oven is used later for determining Moisture Content Property for Bio-Char, Muffle Furnace for Volatile & Ash matter, Bulk Density Apparatus for the same, pH meter for determining pH and Electrical Conductivity Meter for finding the same.

4.3. DEVELOPMENT OF HYDROPONICS SYSTEM

Coming to the next objective, the Hydroponics System. The interesting part here is the entire system is custom made and developed by ourselves inside the Int'l Research Centre which is located inside the University Campus. The System was built using Acrylic Tubes. The main reason for choosing Acrylic Tubes is considering its rigidity. Moreover, these tubes doesn't allow the growth of fungus despite the continuous presence of water and sunlight. The two ends of the tubes are closed tightly with rigid PVC Cups and pasted with a strong adhesive for extra protection. Holes were drilled using drill machine and then sand paper was used to even out the surface.

4.4. BIO-CHAR SYNTHESIS

As stated above, the main motive of this project is to use agro waste. Therefore Rice Straws are chosen. The rice straws are cleaned by hand to remove dirt, sand granules and other impurities. Then the straws are washed and dried for a day. Then, it was placed inside the hot air oven (110 °C for 2

hours) in order to remove moisture. Following this, the straws are cut into small pieces and are split into three parts namely, A, B, and C. These three samples are subjected to three different conditions. The conditions are:-

- A at 200 °C for 2 hours.
- B at 250 °C for 1.5 hours.
- C at 300 °C for 1 hour.

The samples were left all the day for cool-down. Then all the three samples were finely grinded using a hand mortar and neatly stored in an air-tight plastic bag. On the whole the obtained Bio-Char was about 30g. Subsequently, all the samples were tested to find the best one to use it as a nutrient supplement in hydroponics.

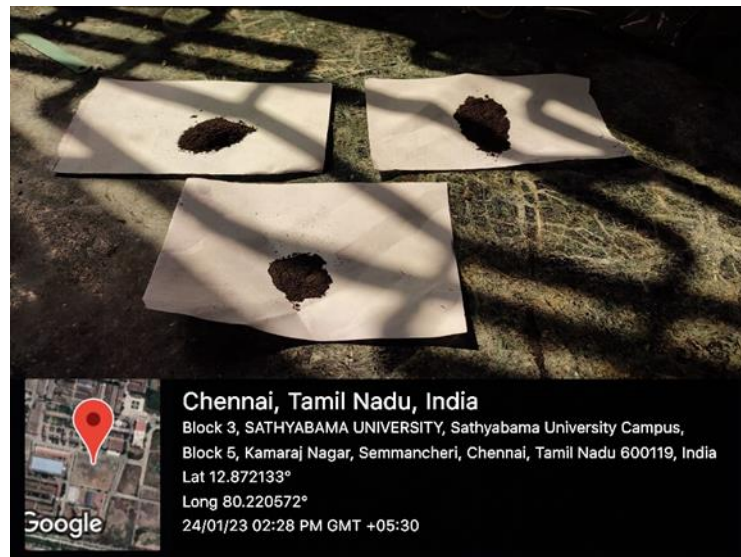


Fig. 4.1: Bio-Char Samples

4.5. PROXIMATE ANALYSIS OF BIO CHAR

Proximate analysis is a technique used to determine the basic composition of a substance. It involves the determination of the amounts of various components of a substance, typically by heating it and measuring the changes that occur. Proximate analysis is commonly used in the analysis of solid fuels like coal and biomass, but it can also be applied to other materials. Proximate analysis is usually conducted by heating a sample of the substance in a controlled environment and measuring the changes that occur. Proximate analysis can provide valuable information about the energy

content and handling properties of solid fuels, and it is commonly used in the evaluation and comparison of different fuels. However, it should be noted that the results of proximate analysis may not provide a complete picture of the fuel's characteristics, and other tests may be necessary for a more detailed analysis. The basic components measured by us for the Bio-Char in proximate analysis are: Moisture Content, Volatile Matter, Ash Content and Bulk Density. Other than these, pH and Electrical Conductivity were also analyzed.

4.5.1. Moisture Content

Moisture content is a key component of proximate analysis, which is a common method used to determine the composition of food and other organic materials. Moisture content is determined by weighing a sample of the material before and after it has been dried to a constant weight. The difference in weight is used to calculate the moisture content as a percentage of the original sample weight. The moisture content of a material can have a significant impact on its properties and suitability for various applications. For example, food products with high moisture content are more susceptible to spoilage and may have shorter shelf lives, while materials with low moisture content may be more stable and easier to store.

In our experimental part, we took ~2g of each sample and followed the procedure. Hot Air Oven was used here. That is 110 °C for 2 hours. After its cooling, the resulting moisture content in % was calculated from the mass difference before and after heating. 1.83%, 1.90%, 1.89% were the moisture content of A, B, C respectively.

$$\text{Moisture Content (\%)} = \frac{\text{Loss in mass of sample}}{\text{Initial mass of the sample}} * 100$$

4.5.2. Volatile Matter

Volatile Matter is one of the components analyzed in the Proximate Analysis of coal, which is a standard method used to determine the quality and composition of coal. The volatile matter is the portion of the

coal that is released as a gas when the coal is heated in a controlled environment. It includes any carbon, hydrogen, and sulfur compounds that are volatilized during the heating process. In the context of Bio-Char production, Volatile Matter refers to the portion of the organic matter in the biomass feedstock that is released as a gas during the process of heating biomass in the absence of oxygen to produce Bio-Char. The amount and composition of the volatile matter in the biomass feedstock can affect the properties of the resulting Bio-Char. Higher levels of volatile matter can result in a more porous Bio-Char with higher surface area, which can be beneficial for soil amendment and other applications. We followed a standard procedure for determining Volatile Matter, i.e. heating the samples at 950 °C for 7 minutes and then using the following formula.

$$\text{Volatile Matter (\%)} = \frac{\text{Loss in mass of sample}}{\text{Initial mass of sample}} * 100$$

Sample C had the maximum amount of Volatile Matter at 69%, followed by Sample A at 66.50% and Sample B at 57%.

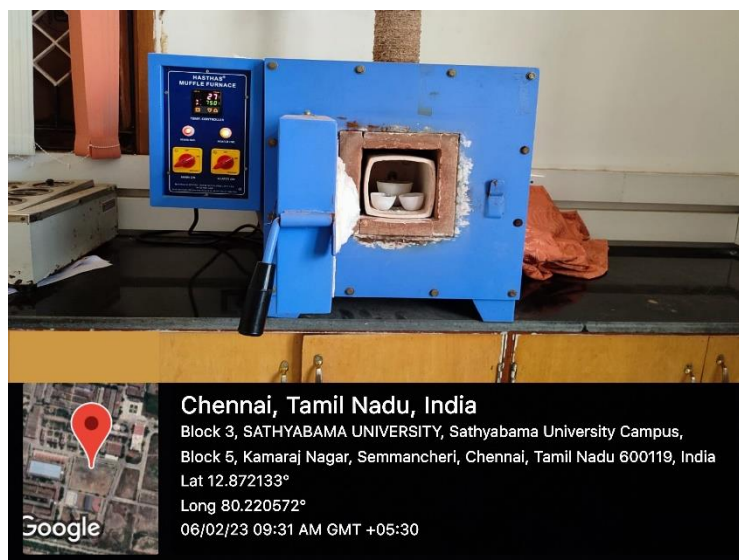


Fig. 4.2: Volatile Matter Determination

4.5.3. Ash Content

The ash content is the amount of inorganic material remaining after a substance has been completely burned. Proximate analysis measures the amount of ash content in a sample by heating the sample to a high

temperature until it is completely burned. The residue that is left behind after burning is then weighed, and the ash content is calculated as a percentage of the original sample weight. Ash content can provide information about the mineral content of a substance, and is often used to measure the quality of fuels such as coal and biomass. It can also be used in food analysis to determine the amount of mineral content in foods such as cereals, grains, and fruits. We've followed a standard procedure for the determination of Ash content i.e. Heating the samples in the muffle furnace for 30 minutes at 750 °C and then the formula below was used.

$$\text{Ash Content (\%)} = \frac{\text{Mass of the ash}}{\text{Initial Mass of Sample}} * 100$$

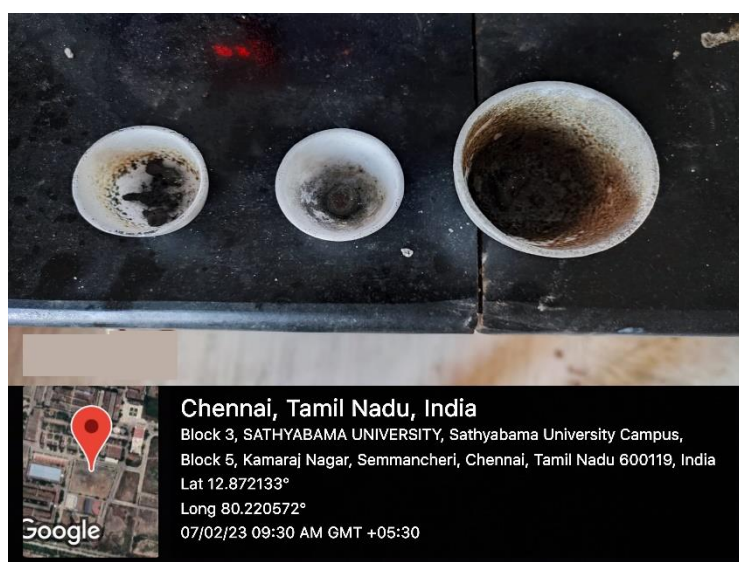


Fig. 4.3: Ash Content Analysis

4.5.4. Bulk Density

Bulk density is an important property for many materials, including powders, granular materials, and soils. There are two main types of bulk density: loose bulk density and packed bulk density. Loose bulk density is the mass of a substance per unit volume when it is poured or dispersed without any compaction. Packed bulk density, on the other hand, is the mass of a substance per unit volume when it is compacted or settled under the weight of its own particles or by external forces. Here, we took 3g of each sample, and loaded it into the bulk density apparatus. Unlike other tests, these samples can be reused so even

more amount of samples can be used for better comparison. The Bulk density apparatus taps the sample for given number of turns and we estimated for sixty turns for better accuracy and in-between at every twenty turns the readings were noted.

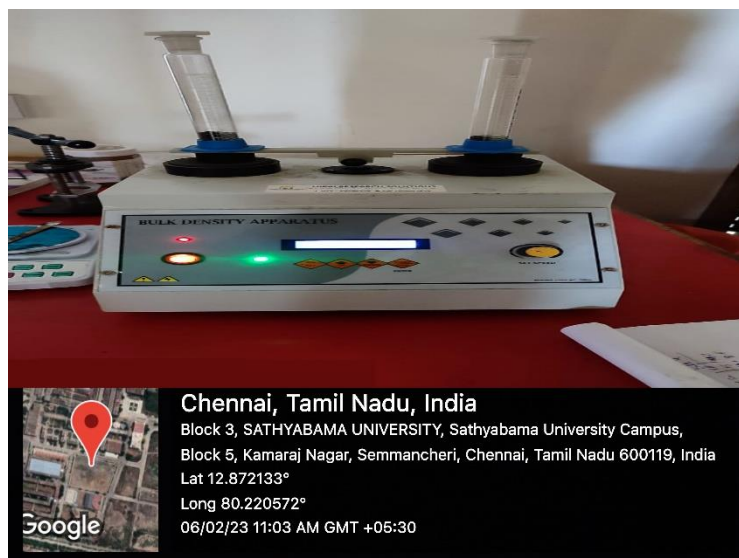


Fig. 4.4: Bulk Density Apparatus

4.5.5. pH and Electrical Conductivity

pH is a measure of the acidity or alkalinity of a solution. It is a logarithmic scale that ranges from 0 to 14, with 0 being the most acidic, 14 being the most alkaline, and 7 being neutral. In general, Bio-Char has a high pH due to the alkaline minerals and metals that are often present in the feedstock material. The pH of Bio-Char is usually in the range of 8 to 10, which is considered slightly alkaline. Since the synthesized Bio-Char is a solid it was mixed with distilled water to test the pH with pH meter. 0.3g of sample is mixed with 40mL of distilled water and tested for each sample using pH meter.

Electrical conductivity is a measure of a material's ability to conduct electric current. It is typically measured in units of Siemens per meter (S/m) or milliSiemens per centimeter (mS/cm). Generally, Bio-Char has a low electrical conductivity due to its high carbon content and low ash content. The electrical conductivity of Bio-Char can be further reduced by washing or leaching to remove any remaining soluble minerals. EC and pH have the same procedure and calibration to test. The only difference is the meter used for its determination.

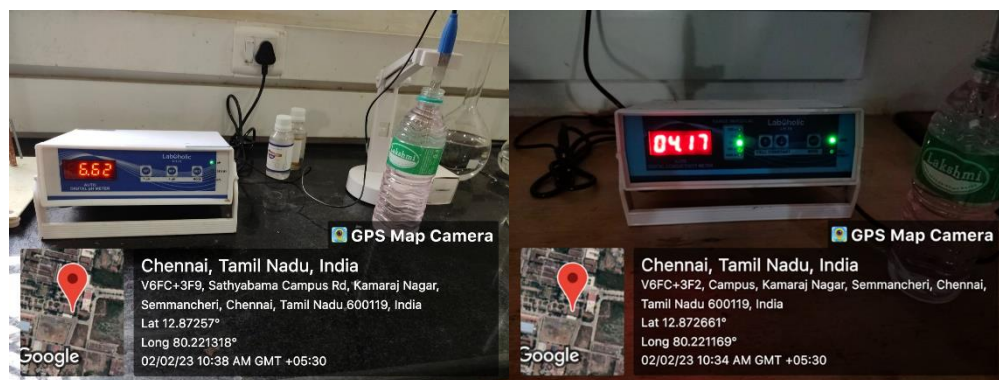


Fig. 4.5: pH & Electrical Conductivity Determination

4.6. FT-IR ANALYSIS

FTIR or Fourier-Transform Infrared Spectroscopy is an easy, simple, fast, suitable, non-invasive and cost-effective method to identify the role of biomolecules. FTIR is an extremely useful technique for confirming the identity of pure compounds, but has limited value if used for mixtures of compounds. The technique is based upon the identification of functional groups within molecules where such groups vibrate (either through stretching or bending in various ways) when irradiated with specific wavelengths of light. These vibrations and their intensity (% transmission) are plotted against the frequency of light (cm^{-1}) to which the sample is exposed to produce an FTIR spectrum. Portions of the FTIR spectrum are unique to the compound under test (this is called the fingerprint region). Infrared analysis is not affected by fluorescence and can be regarded as a powerful technique for investigating aspects of molecular chemistry in Bio-Chars. A range of different methods for performing infrared analysis have been utilized to characterize Bio-Chars: FTIR-PAS (Fourier Transform Mid-Infrared Photo Acoustic) spectroscopy where the samples are placed in a photo acoustic cell and purged with helium prior to analysis; Diffuse Reflectance Infrared Fourier Transform (DRIFT) spectroscopy in absorbance mode where the Bio-Char samples are mixed with KBr to form a wafer; Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy, where the samples are in direct contact with the ATR crystal; Synchrotron-Based Fourier Transform Infrared (FTIR) spectroscopy and, the most commonly used method, transmission mode FTIR, where the samples are mixed with KBr to form a pellet. When applied to a Bio-Char surface, FTIR has been used principally to acquire point spectra. A

disadvantage is that if a material is highly heterogeneous, such as Bio-Char, this can result in sampling bias [25][26].

An infrared spectrum of Bio-Char can be complex, often containing a variety of mineral phases, leading to an extensive variety of chemical bonds in a sample. Another significant challenge for FTIR analysis of Bio-Chars is the opacity of the sample, preventing measurements by transmission without grinding and dispersing the sample, and the low albedo, resulting in poor signal-to-noise in a reflectance FTIR measurement, even with synchrotron sources. In the case of infrared, the response from a Bio-Char sample can be significantly improved by preparing a finely ground solid and using ATR techniques or measuring transmission of infrared light through a KBr disc, where the powdered Bio-Char is dispersed. However, this improvement in spectral quality comes at the cost of spatial information [27].

Laboratory-based FTIR are now relatively widespread and potentially enable the Bio-Char community to better understand the distribution of chemical bonds at micron to millimeter length scales. To have a low-cost, rapid, and easy to use method for non-destructive screening of Bio-Chars, FTIR spectroscopy could be a possible option. Not only has it been used to obtain highly structural information on various Bio-Chars and starting materials, but has also been applied to investigate the structural changes of Bio-Chars as a function of pyrolysis temperatures [26].

4.7. XRD ANALYSIS

XRD or X-Ray Diffraction Analysis is a non-destructive technique that provides detailed information about the crystallographic structure, chemical composition, and physical properties of a material. It is based on the constructive interference of monochromatic X-rays and a crystalline sample. X-rays are shorter wavelength electromagnetic radiation that are generated when electrically charged particles with sufficient energy are decelerated. In XRD, the generated X-rays are collimated and directed to the sample, where the interaction of the incident rays with the sample produces a diffracted ray, which is then detected, processed, and counted. The intensity of the diffracted rays scattered at different angles of material are plotted to display a diffraction pattern. Each phase of the material produces a unique diffraction pattern due to the material's specific chemistry and atomic arrangement. The

diffraction pattern is a simple sum of diffraction patterns of each phase and imperfection in the sample material would affect the pattern of the diffracted signal. Generally, the qualitative phase analysis of the diffraction pattern of XRD characterization will be compared with the standard crystallographic databases such as the International Center for Diffraction Data (ICDD), to ease the phase identification of a material in a large variety of crystalline samples. The peaks of the XRD pattern play a vital role in the identification of the phases as well as the properties of the sample. The intensity of the diffraction peaks in each phase is directly proportional to the amounts of elements present in the sample. The main advantages of XRD is that it is a simple and universally recognized technique. On the other hand, a severe limitation of this technique will be that single conformation and binding state of growing crystals are difficult to identify [28].

4.8. MICRO-GREEN CULTIVATION

After choosing the right Bio-Char sample, three micro-greens plant was chosen after several studies. Those three were Mung Bean, Fenugreek and Mustard. These three were chosen because of easy availability and demanding products in Indian and especially South Indian Cuisine. After selecting fresh and good seeds, the operation were started. The substrate used here was coco-peat. Coco-Peat was carefully chosen as it'll be holding the entire plant till harvest season. If the substrate is either adulterated or old, it'll neither promote the growth nor hold the plant strong enough, but demotes the growth. Since the plants will be placed in water all the time, strength of plant and substrate's holding is very vital. To find the best possible results, seeds are sowed with different Bio-Char concentrations. They're 0.0g (No Bio-Char), 0.2g, 0.4g, 0.6g. In general, three seeds, four concentrations, hence twelve plants (3X4) must be obtained. The pH & EC of Coco-Peat and the water were tested before the initialization of the process. This is done to create a fertile environment can be created. If the pH & EC are high, it affects the growth. So only after ensuring all parameters are apt, the process was started.

- pH of Coco peat cleansed water – 6.17
- Electrical Conductivity – 4.99 (20mS)
- pH of Water inside the System – 6.62

- Electrical Conductivity – 4.17 (20mS)

The samples were monitored for a period of 15 days, typical micro-greens harvest period. Though micro-greens require a good amount of sunlight to grow well, but direct sunlight can sometimes be too intense and may damage the young plants. As a result, direct sunlight was given only during the morning and evening for approximately 4 hours. And during the noon, the system were placed sunlit area but not under the direct sunlight.

In a stagnant micro hydroponic system, the water should be changed more frequently than in larger systems. Ideally, the water should be changed every 3-5 days to ensure that the nutrient solution remains fresh and free from harmful bacteria and algae that can negatively affect plant growth. The smaller size of the system means that the water volume is limited, and there is less water available to dilute any harmful substances that may accumulate in the nutrient solution. Regular water changes help to maintain the pH and nutrient balance in the system, ensuring optimal plant growth and health. So by taking extra care, the water was changed every 3 days. Despite frequent change of water, NPK water was sprayed every day to prevent drying of Coco-peat and to provide extra nutrition. On the first 2 days, there weren't any germination at all. From the 3rd day, there was a steady growth. Out of all Mustard was the fastest and Mung was the tallest. Plants that had the Bio-Char (all three) in them germinated first. The sample without Bio-Char germinated 1-2 days later. The detailed chart and its inferences are discussed in the following sections.

4.9. NUTRITIONAL STUDIES

Out of the three, Mustard is used for further analysis, as mustard was the only micro-green crop from our analysis, lasted for nearly 18 days. Apart from that, mustard micro greens can be used in a variety of dishes, including salads, sandwiches, and soups. Mung gram and fenugreek micro greens may be more limited in their culinary applications. Moreover the yield of the mustard was comparatively more (in all concentrations of Bio-Char) than the other two. This doesn't mean that the other two plants are inferior. In general, even in conventional farming techniques Mustard has very high yields.

In order to prove the influence of Bio-Char on the Micro-Greens, two samples of selected Mustard plants were subjected to analysis. One being the plant cultivated with Bio-Char other being the sample cultivated without Bio-Char. They were tested for Protein, Energy, Carbohydrates, Total Fat, Crude Fiber, Minerals – Sodium, Magnesium, Iron and Calcium.

4.9.1. Proteins

Protein is an essential nutrient that plays a vital role in the growth and maintenance of tissues in the human body. It is important to consume enough protein to support bodily functions and maintain overall health. Mustard greens are a nutritious leafy green vegetable that can provide a range of health benefits. In terms of protein content, Mustard micro-greens are known to be a rich source of protein. The exact protein content in mustard micro-greens can vary depending on various factors such as growing conditions, the age of the micro-greens, and the specific variety of mustard used. Typically the amount of protein found in a 100g serving of Mustard Green is about 2.5g. This value is obtained through conventional farming. It is important to note that the protein content may vary depending on the specific variety of mustard greens and how they are prepared. However, mustard greens can still be a good source of protein as well as other essential vitamins and minerals.

4.9.2. Energy & Carbohydrates

The amount of energy in food is often expressed in calories or joules. The quantity of the food's macronutrients—specifically, its carbohydrate, protein, and fat content—determines how much energy it contains. In general comparison to fats, which have about 9 calories per gram, carbohydrates and proteins have about 4 calories per gram.

Coming to carbohydrates, one of the three macronutrients, along with protein and fat that are present in diet is carbohydrates. The body uses carbohydrates as a source of energy and as a means of ensuring that the nervous system, brain, and other organs continue to work properly. Simple and complex carbohydrates are the two basic types of carbohydrates. Simple carbs are composed of just one or two sugar molecules, and because they are easily absorbed by the body, blood sugar levels rise quickly. Contrarily, complex carbohydrates, which are

composed of lengthy chains of sugar molecules and are absorbed more slowly, give off energy over a longer period of time. In terms of carbs, mustard greens have a tiny quantity of calories and are quite low in calories. One cup of chopped mustard greens (about 100 grams) includes roughly 4 grams of carbs, including 1 gram of dietary fiber and 0.3 grams of sugar, according to the United States Department of Agriculture (USDA). The majority of the carbohydrates in mustard greens are complex carbohydrates like dietary fiber, which can support good health by regulating digestion. Additionally, mustard greens have a low glycemic index, which means that its impact on blood sugar levels is negligible.

4.9.3. Fats

Fats are one of the three macro-nutrients contained in diet, along with carbs and protein. The body uses fats as a source of energy and as a way to maintain healthy skin, hair, and nails. Fats also aid in the body's ability to absorb the fat-soluble vitamins (A, D, E, and K). Unsaturated and saturated fats are the two basic classifications of fats. The majority of animal products, including meat, butter, and cheese, include saturated fats, which are normally solid at room temperature. If ingested in excess, these fats can raise cholesterol levels and raise the risk of developing heart disease.

As opposed to saturated fats, which are usually solid at room temperature, unsaturated fats are present in plant-based foods including nuts, seeds, and oils. When used in moderation, these fats can help lower cholesterol and minimize the risk of heart disease. When choosing healthy fats for a balanced diet, it's crucial to minimize saturated and Trans fats while consuming foods that are high in unsaturated fats.

In terms of total fats, mustard micro-greens are a very low-fat food. According to the United States Department of Agriculture (USDA), one cup of chopped mustard micro-greens (about 100 grams) contains only 0.9 gram of total fat, including both saturated and unsaturated fats. The fats in mustard greens are primarily unsaturated fats, which are considered healthy fats that can help to reduce inflammation and lower the risk of heart disease when consumed in moderation. Mustard greens

are a good source of omega-3 fatty acids, which are important for brain health and reducing inflammation.

4.9.4. Crude Fibers

The indigestible part of plant-based meals such fruits, vegetables, grains, and legumes is referred to as "crude fiber" in nutritional analysis. It is a way to gauge how much fiber, both soluble and insoluble, is present in a given diet. The body cannot absorb crude fiber, in contrast to other nutrients like protein or fat. Instead, it mostly completes its journey through the digestive system, giving stools more volume and assisting in controlling bowel motions.

There are around 2 grams of crude fiber per 100 grams of fresh weight in mustard micro-greens, which is a relatively significant amount. The quantity of crude fiber that can be gained by consuming mustard micro-greens, however, is probably fairly minimal because they are normally eaten in small amounts. It is important to remember that the precise crude fiber content of mustard micro-greens might vary based on elements including the type of mustard plant, the growing environment, and the time of harvest.

4.9.5. Minerals:

Our bodies require minerals as necessary nutrients to perform a number of tasks, such as constructing strong bones, sending nerve signals, and controlling our metabolism. Foods based on both plant-based and animal-based sources can provide minerals.

Sodium - Sodium is a mineral that is essential for human health in small amounts. It plays a vital role in maintaining the balance of fluids in the body, transmitting nerve impulses, and contracting and relaxing muscles. Only about 40 milligrams of sodium are found in one cup of chopped raw mustard greens, which is a comparatively low sodium concentration for a green vegetable. As a tasty, nutrient-dense crop that can be utilized in a variety of meals, mustard greens are a fantastic option for people who are seeking to limit their intake of sodium. However, consuming too much sodium can be harmful to health and has been linked to an increased risk of high blood pressure, stroke, and heart

disease. The recommended daily intake of sodium for adults is less than 23 grams per day, which is about one teaspoon of salt. It's important to keep in mind that the sodium concentration of mustard greens might change based on things like the growth environment and the cooking process. For instance, pickled or canned mustard greens could contain more sodium than raw or fresh greens.

Magnesium - Magnesium is an essential mineral that plays a crucial role in numerous bodily functions, including energy production, muscle and nerve function, bone health, and regulating blood sugar levels. Magnesium is an important mineral that is necessary for many body processes, and mustard greens are a rich source of it. One cup (about 100 grams) of chopped, cooked mustard greens has roughly 30 mg of magnesium, according to the United States Department of Agriculture (USDA). This amounts to around 6% of the adult magnesium recommended daily intake. However, it's important to keep in mind that various sources may give somewhat varying figures for the amount of magnesium in mustard greens.

Iron - The creation of red blood cells and the delivery of oxygen to cells are only two examples of the important roles that iron plays in the body. Stating Iron as the most vital mineral in the human body wouldn't be wrong. Iron levels in the body should be kept at healthy levels by eating meals high in this mineral. Dietary iron comes in two forms: heme iron, which is present in foods derived from animals, and non-heme iron, which is present in foods derived from plants. Although heme iron is more easily absorbed by the body than non-heme iron, both forms can add to the total amount of iron consumed. The body's capacity to absorb iron can be impacted by a variety of different elements, including the availability of specific nutrients (such as vitamin C), drugs, and medical disorders. A 100-gram serving of mustard greens contains around 7% of the adult recommended daily value (DV) for iron. Mustard greens are a good source of iron. It's important to keep in mind, though, that various sources may give slightly varying figures for the iron concentration of mustard greens.

Calcium - The mineral calcium is essential for numerous body processes, such as blood clotting, muscle and nerve function, the growth and maintenance of healthy bones and teeth, and many more. Depending on age and gender, the recommended daily intake of calcium for people ranges from 1.0-1.3 grams. The amount of calcium in 100 grams of cooked, chopped mustard greens is around 104 milligrams. This amounts to around 10% of the adult recommended daily intake (DV) for calcium. Various elements, including the type of mustard greens grown, the growth environment, and the soil quality, might affect the precise calcium content of mustard greens. However, mustard greens are typically regarded as a good source of calcium [29][30].

CHAPTER 5

RESULTS & DISCUSSION

5.1. PROXIMATE ANALYSIS FINDINGS

Sample C was chosen as the nutrient supplement for the hydroponics system inferring from these results. The moisture content was suitable than the other samples. At the same time the electrical conductivity was least with Sample C. If EC is very high, it leads to formation of salts in long run, which in-turn affects the growth of the plants. pH was the least with Sample C as NPK(Nitrogen-Phosphorous-Potassium) and Bio-Char will be added to the system which can even more alter the pH. So having pH close to Neutral is better for the hydroponics system. As mentioned earlier if the percentage of Volatile Matter is high, it results in more porous Bio-Char which is best suitable. Sample C which had highest percentage of Volatile Matter i.e. 69% when compared to Sample A & Sample B (which had 66.5% & 57.0% respectively) is another factor for choosing Sample C. Coming to the Ash Content, excessive amounts of ash can reduce the effectiveness of Bio-Char as it can increase soil pH and reduce the availability of certain nutrients. Sample C had the least amount of Ash Content. Even the Bulk Density (Loose as well as packed) was at the moderate level. Keeping in mind all these factors, Sample C was chosen as it was the most suitable.

Table 5.1: Proximate Analysis of Bio-Char

PROPERTIES	SAMPLE A	SAMPLE B	SAMPLE C
MOISTURE CONTENT (%)	1.83	1.90	1.89
ELECTRICAL CONDUCTIVITY (2MS/CM)	0.778	1.342	0.718
PH	9.71	10.17	8.29
ASH CONTENT	55	60	45

(%)			
VOLATILE MATTER (%)	66.5	57.0	69.0
LOOSE BULK DENSITY (G/ML)	0.231	0.186	0.200
PACKED BULK DENSITY (G/ML)	0.30	0.25	0.28

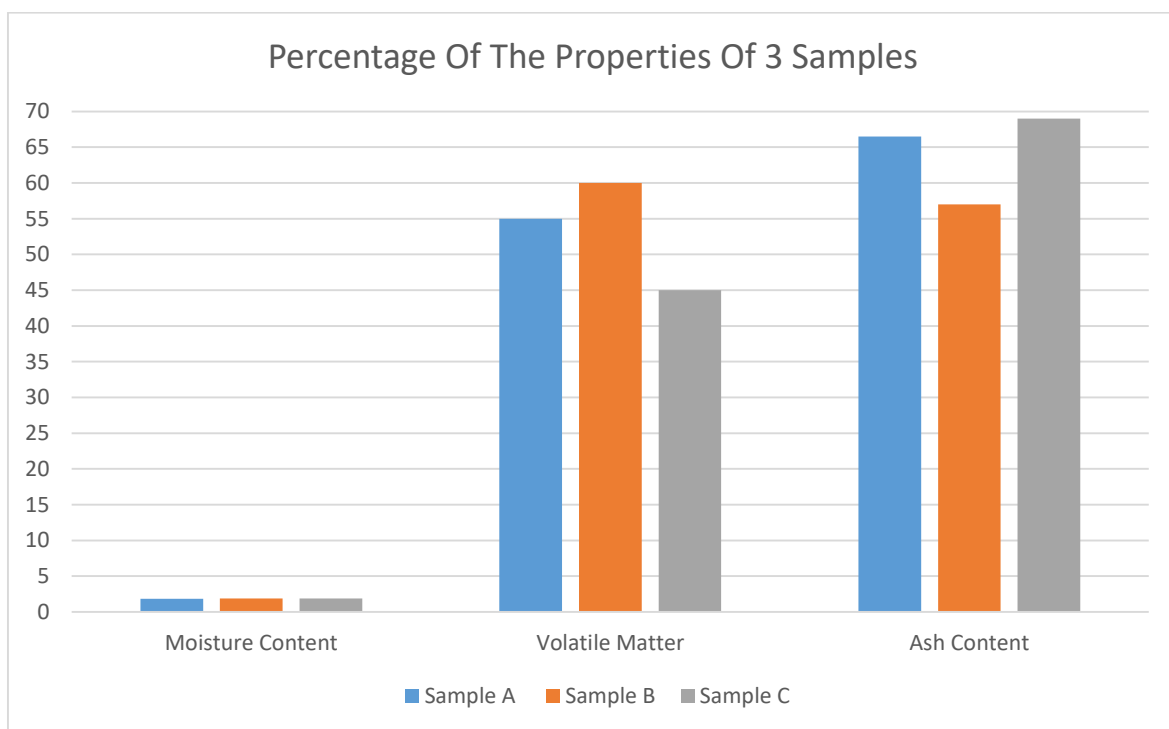


Fig. 5.1: Graph – Moisture Content, Volatile Matter, Ash Content

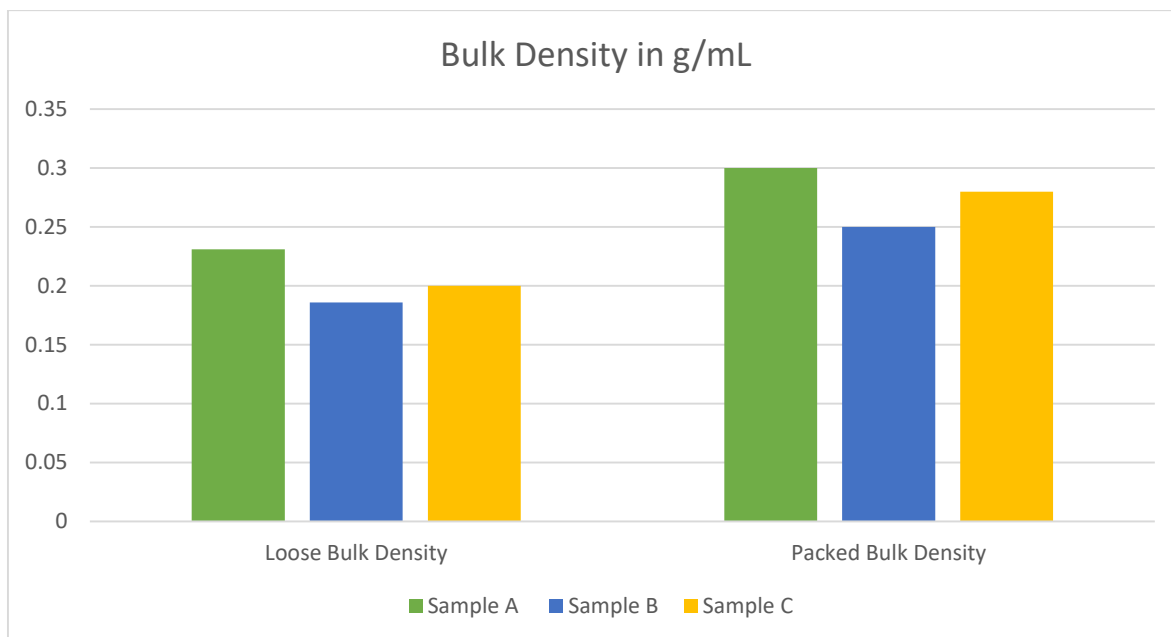


Fig. 5.2: Graph – Bulk Density (Loose and Packed)

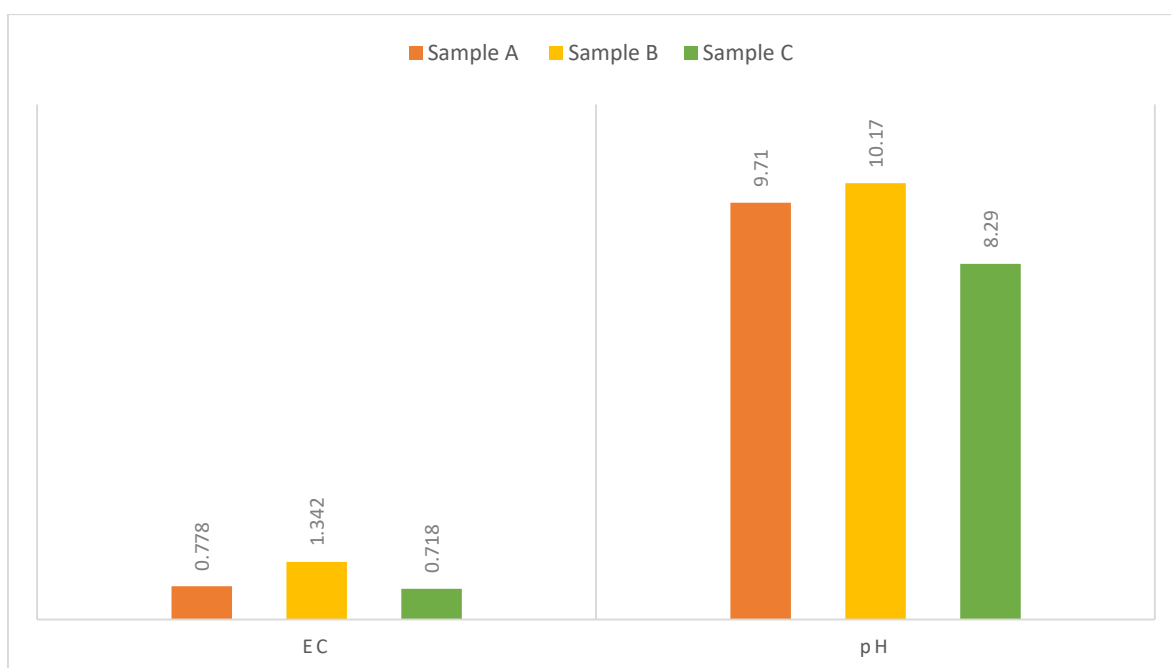


Fig. 5.3: Graph – pH and Electrical Conductivity

The plants Mung Bean, Fenugreek and Mustard were monitored for a period of 12 days. In that period, the growth rate were measured daily and the effect of Bio-Char were analyzed. The germination was quick in the presence of Bio-Char. To be precise, plants germinated only after the germination of plants with Bio-Char. Even the difference in concentration Bio-Char did have some effects. That is, the growth rate were more on the sample with highest

amount i.e. 0.6g. But the difference was only about $\sim 0.1\text{cm}$. This can be associated with two reasons, since the cultivated crops are Micro-Greens, this difference is significant. Moreover, since the system is developed in small scale, it is challenging to produce more difference. If the system is developed on a large scale, there will definitely be an even greater difference.

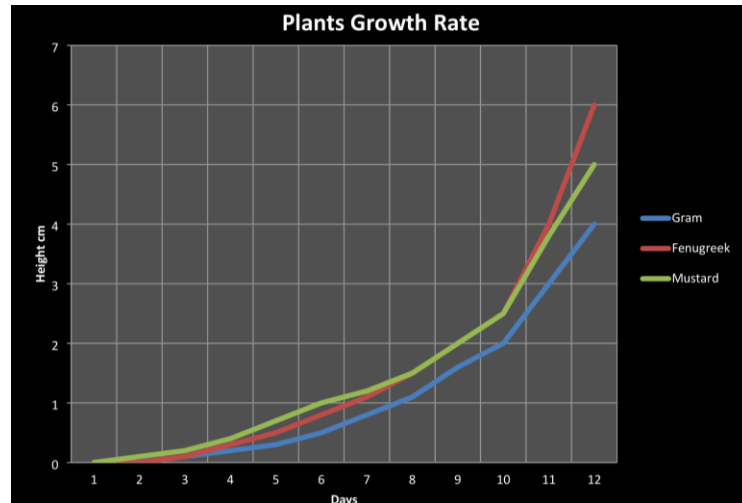


Fig. 5.4: Plants Growth Rate

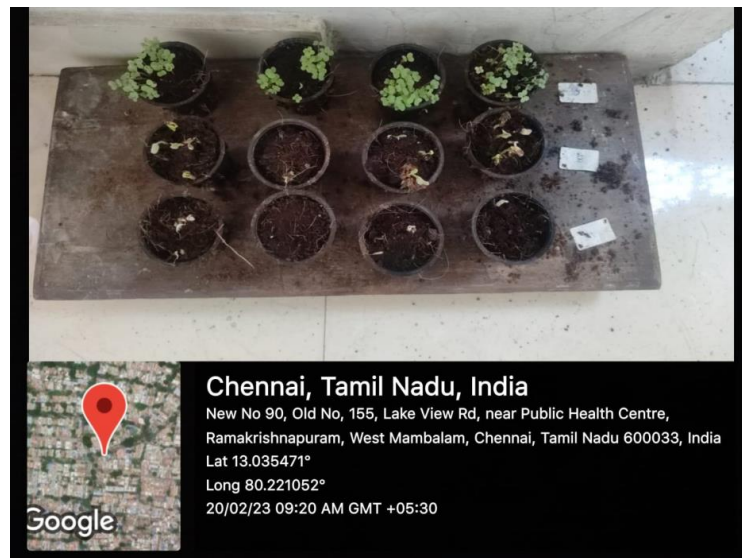


Fig. 5.5: Germination



Fig.5.6: Plant Growth

5.2. FTIR Analysis

Agilent Resolutions Pro

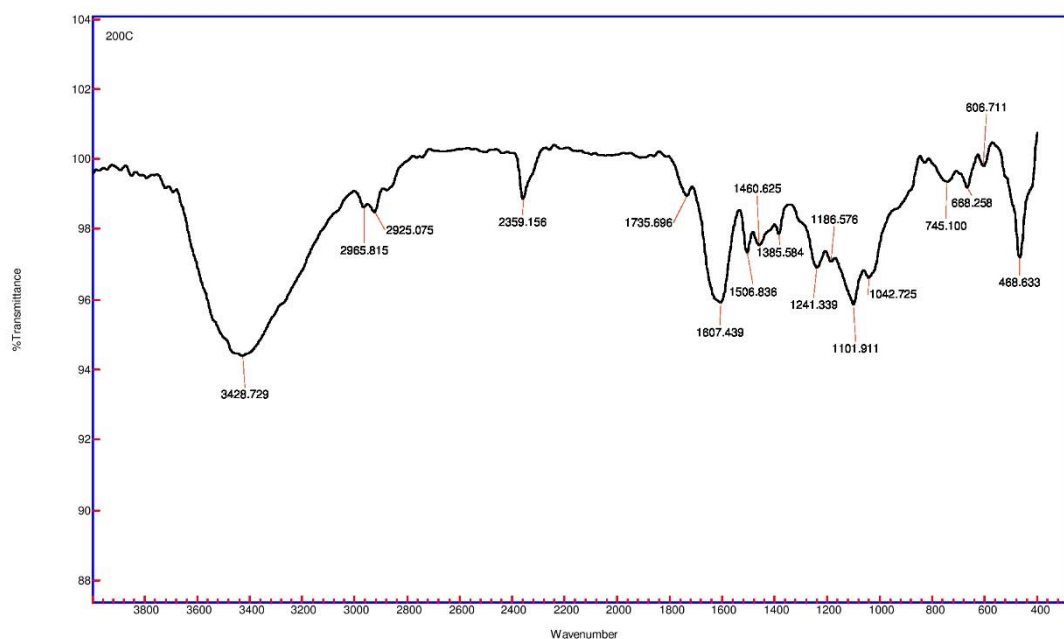


Fig.5.7: FTIR Spectrum of Bio-Char Sample

The above figure (Fig.5.6) shows the FTIR spectrum of the produced Bio-Char sample (Sample C). The table below elaborates the findings from the FTIR spectrum.

Table 5.2 FTIR Analysis

Frequency Range (cm⁻¹)	Observed Range (cm⁻¹)	Functional Group
4000 - 3000	3428.729	O-H stretching vibration Presence of Alcohol
3000 - 2500	2965.815	C-H stretching vibration Presence of Alkane
3000 - 2500	2925.075	C-H stretching vibration Presence of Alkane
1670 - 1600	1607.439	C=C shorting vibration Presence of Conjugated Alkane
1600 - 1300	1506.836	N-O stretching vibration Presence of Nitro Compound
1400 - 1000	1241.339	C-O stretching vibration Presence of Alkyl Ether
1400 - 1000	1101.911	C-O stretching vibration Presence of Secondary Alcohol
1000 - 650	668.258	C=C stretching vibration Presence of Alkene
600 - 650	606.711	C-Br stretching vibration Presence of Halo Compound

5.3. XRD Findings

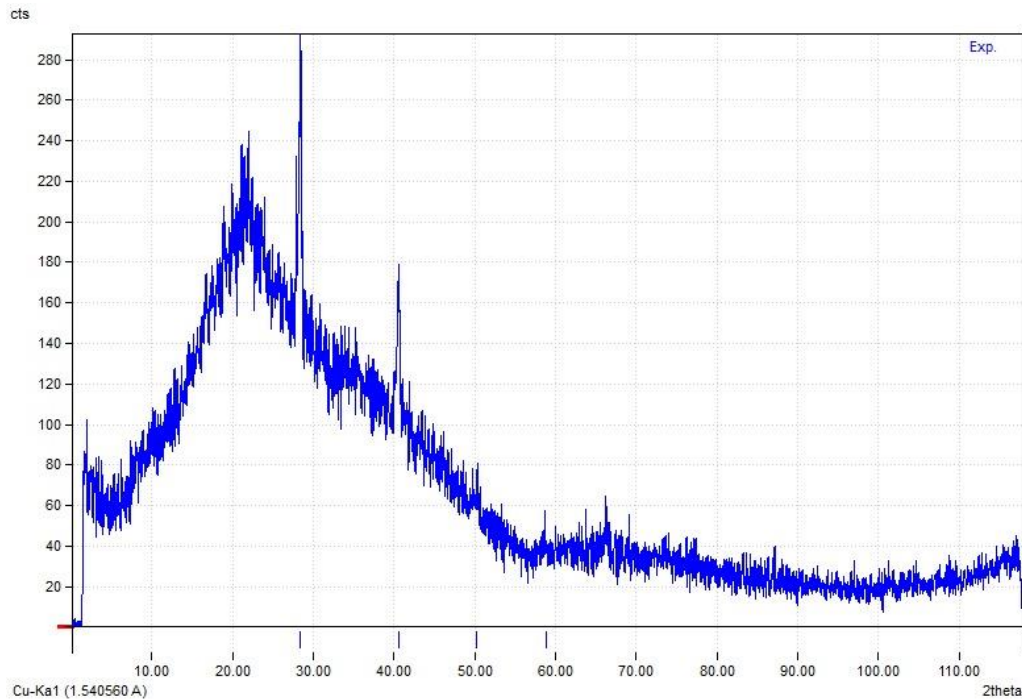


Fig.5.8: X-Ray Diffraction

As stated earlier, XRD states crystal structure, which can be inferred from finding HKL. The HKL system is based on the Miller indices, which are a set of three integers used to describe the orientation of a plane within a crystal lattice. The HKL system is used to calculate the positions of diffraction peaks in X-ray diffraction patterns, which can be used to determine the crystal structure of a material. The lattice in X-ray crystallography refers to the regular arrangement of atoms within a crystal. The lattice is described by a set of lattice parameters, which include the length of the unit cell edges and the angles between them. The lattice parameters can be used to calculate the volume of the unit cell and the density of the crystal.

Computing HKL,

Here $2\theta = 110^\circ$, therefore $\theta = 55^\circ$ or 0.96 radians, $\lambda = 1.54 \times (10^{-10})$ m.

Bragg's Rule must be used to compute HKL.

$$n\lambda = 2d \sin \theta$$

Where,

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

Here, d is the distance between crystal planes, n is an integer ($n=1$), θ is angle of incidence of X-Rays on the sample, λ is wavelength of X-Rays, a is lattice constant ($a = 10 \times (10^{-10})$ m). Now equating the above equations, we find HKL.

From Bragg's Rule,

$h = 7, k = 8, l = 0$ or $h = 0, k = 7, l = 8$ or $h = 8, k = 0, l = 7$.

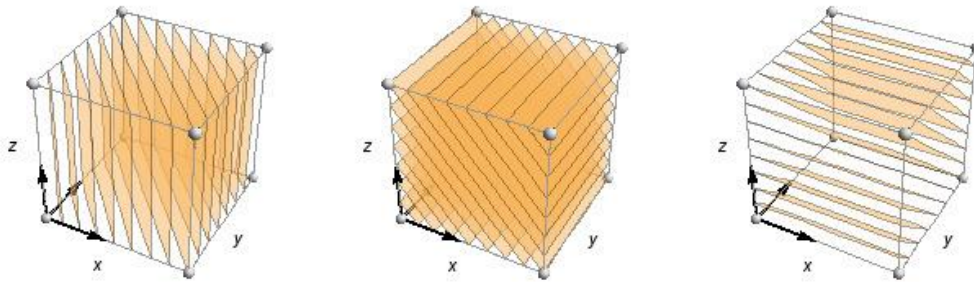


Fig.5.9: HKL Crystal Structure

5.4. NUTRIENT ANALYSIS

And the tests concluded our purpose. These tests proved that, Bio-Char did have a significant influence on the plant, as the nutritional numbers were higher on sample with Bio-Char (Sample A) than with the sample without Bio-Char (Sample B). These are elaborated in a table below.

There is a significant difference in Energy Content as we should multiply the grams of each macronutrient by the associated caloric value per gram to determine the amount of energy in a food item by adding the resulting numbers. A dietary item's total energy content, for instance, would be: if it comprises 10 grams of carbohydrates, 5 grams of protein, and 2 grams of fat. 40 calories come from 10 grams of carbs, which have 4 calories per gram. 20 calories are equivalent to 5 grams of protein at 4 calories per gram. 9 calories per gram of fat, divided by 2 grams, equals 18 calories. $40 + 20 + 18$ calories make up the entire amount of energy. That is 78 calories in total. It's worth noting that the energy content of a food item can also be affected by factors such as its fiber content and how it's prepared or cooked.

Mustard greens are a good source of several important nutrients, including fiber, vitamins A, C, and K, and minerals such as calcium and iron. They are also relatively low in calories, with approximately 15 calories per 100 grams of raw mustard greens. The energy content of mustard greens comes primarily from

their carbohydrate content, which is about 3 grams per 100 grams of raw mustard greens. This provides approximately 12 calories. Mustard greens also contain small amounts of protein (about 2 gram per 100 grams) and fat (about 1 gram per 100 grams), which contribute a small amount of additional calories. It's worth noting that the energy content of cooked mustard greens may be slightly different than raw mustard greens, as cooking can affect the bioavailability of some nutrients and may alter the overall energy content.

The same procedure can be used to calculate Energy Content from our sample,

With Bio-Char (per 100g),

Amount of Protein = 2.29g = $(2.29 \times 4) = \underline{9.16 \text{ cal}}$

Amount of Carbohydrates = 3.61g = $(3.61 \times 4) = \underline{14.44 \text{ cal}}$

Amount of Fats = 1.10g = $(1.10 \times 9) = \underline{9.90 \text{ cal}}$

Total Energy = $\underline{9.16 \text{ cal}} + \underline{14.44 \text{ cal}} + \underline{9.90 \text{ cal}} = \mathbf{33.50 \text{ cal}}$

Similarly,

Without Bio-Char (per 100g),

Total Energy = $\underline{7.36 \text{ cal}} + \underline{12.00 \text{ cal}} + \underline{9.72 \text{ cal}} = \mathbf{29.08 \text{ cal}}$

Table 5.3: Nutritional Parameters

TEST PARAMETERS	UNIT	RESULTS	
		SAMPLE A	SAMPLE B
<i>PROTEIN</i>	g/100g	2.29	1.84
<i>ENERGY</i>	cal	33.5	29.08
<i>CARBOHYDRATE</i>	g/100g	3.61	3.00

<i>TOTAL FAT</i>	g/100g	1.10	1.08
<i>CRUDE FIBER</i>	g/100g	2.01	1.10
<i>SODIUM – Na</i>	mg/100g	45.828	40.657
<i>MAGNESIUM – Mg</i>	mg/100g	35.780	30.476
<i>IRON – Fe</i>	mg/100g	9.044	6.328
<i>CALCIUM – Ca</i>	mg/100g	51.481	45.279

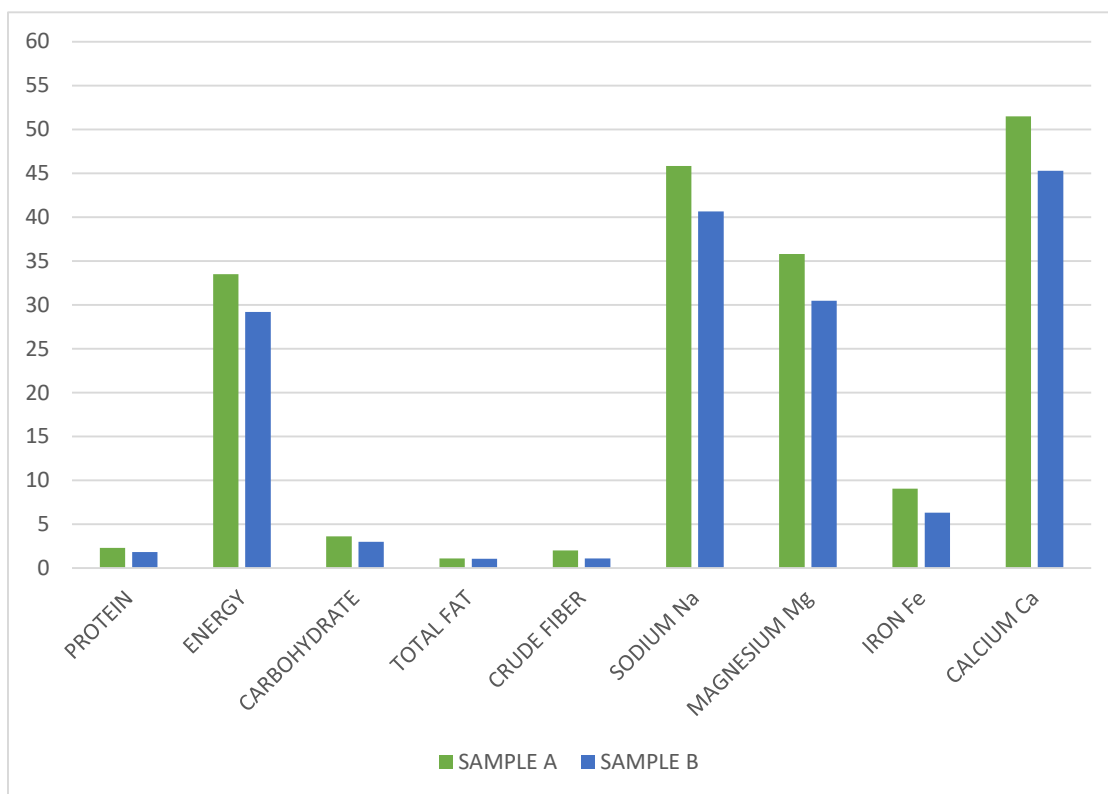


Fig. 5.10: Graph – Nutritional Parameters

CHAPTER 6

SUMMARY & CONCLUSION

Agro waste can be a sustainable resource if managed properly, since it is a renewable resource, as it comes from crops, forests, and other natural sources that can be replanted and regrown. By using agro waste, we can reduce the amount of waste that is sent to landfills or burned in open fields, which can release harmful pollutants into the atmosphere. Agro waste can be used to generate energy, such as through the production of biofuels or through the burning of biomass for electricity production. When agro waste is returned to the soil, it can help to improve soil health by increasing organic matter and nutrient availability. That is the main reason for choosing agro waste as our raw material. Bio-Char can be synthesized from various raw material, but nothing would be as perfect as agro waste, as this simply implies best out of waste. The agro waste is again used for agriculture. And utilizing the same for non-conventional farming (here Hydroponics) is the need of the hour. However, it is important to manage agro waste in a sustainable way, such as through composting, conversion into Bio-Char or biofuels, or incorporation into soil. Improper management of agro waste can lead to environmental problems such as air pollution, water pollution, and soil degradation. Anyways, agro waste can yield numerous benefits if properly used and maximum of it can be extracted in the future.

When compared to plants cultivated on soil, the nutritional value of hydroponically grown plants can vary. Plants cultivated hydroponically are grown in a soil-free media and frequently receive fertilizer solutions that are given right to their roots. It is possible to precisely regulate this nutrient solution to provide the plant the right amount of nutrients, water, and oxygen. In comparison to conventional soil-based farming, hydroponic systems' controlled environment can result in better water and space utilization as well as less pesticide use. However, a number of variables, such as the type and quality of the nutrient solution, the solution's pH level, the temperature of the growing environment, and the particular crop being produced, can affect the nutrient content of plants grown in hydroponics.

For instance, according to some research, lettuce cultivated hydroponically may have more of a number of vitamins and minerals than lettuce grown conventionally. Other research, however, suggests that tomatoes produced hydroponically may contain less of some nutrients than tomatoes grown in soil. It is crucial to remember that these changes may instead show that different growing techniques may result in variations in nutrient content rather than necessarily showing that one growing technique is better or worse than the other.

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SYNTHESIS CHARACTERIZATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS

by Mani Vannan

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Submitted in partial fulfilment of the requirement for the award of

Bachelor of Technology Degree in

Chemical Engineering

by

MANIVANNAN U S (39190016)

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**DEPARTMENT OF CHEMICAL ENGINEERING
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BONAFIDE CERTIFICATE

This is to certify that this project report is the bonafide work of MANIVANNAN U.S. (39190016) and RAGURAM N. (39190024) who carried out the project entitled "SYNTHESIS CHARACTERIZATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS" under my supervision from November 2022 to April 2023

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DATE:

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATES

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ABSTRACT

Hydroponics – a technique, where plants are grown without soil using a water-based fertiliser solution. Growing medium can be used in this method, which includes aggregate substrates like vermiculite, coconut coir, or perlite. Small farmers, amateurs, and business enterprises all use hydroponic production systems. Bio-Char is a charcoal-like material that is generated from plant materials such as grass, agricultural and forest residues that are decomposed at high temperatures, commonly during renewable energy production. The procedure transforms the plant material's physical and chemical qualities into Bio-Char, a highly porous, stable, carbon-rich substance. Bio-Char produced from agricultural (agro) waste is studied and supported by various factors (pH, Electrical Conductivity, Bulk Density, Volatile Matter, Ash Content and Moisture Content) to be used as a nutrient supplement in the hydroponics system. One or more variety of seeds are chosen and different amounts of Bio-Char are added with corresponding plants with their respective system. That is, Bio-Char will be used at different concentration and one sample in each system will have no Bio-Char. As a result, the growth rates of the different plants are analysed and the influence of Bio-Char on those plants will also be studied. Therefore we can draw a conclusion on the ideal amount of nutrient supplement that is best suited for growing plants in the hydroponics system. At the same time studying the Nutrient Contents (including Protein, Carbohydrates, Fat, Crude Fiber, Energy and Minerals) gives a clear picture on the influence of the Bio-Char on the plants in various aspects with the data from FTIR and XRD.

Keywords: Bio-Char, Hydroponics, Nutrient.

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LIST OF ABBREVIATION

MSW	-	Municipal Solid Waste
TLUD	-	Top Lift Up-Draft
CHNS/O	-	Carbon Hydrogen Nitrogen Sulphur/Oxygen
TGA	-	Thermo Gravimetric Analysis
CEC	-	Cation Exchange Capacity
PVC	-	Poly Vinyl Chloride
FTIR	-	Fourier-Transform Infrared (Spectroscopy)
PAS	-	Photo Acoustic
ATR	-	Attenuated Total Reflectance
DRIFT	-	Diffuse Reflectance Infrared Fourier Transform
NPK	-	Nitrogen Phosphorus Potassium
USDA	-	United States Department of Agriculture
EC	-	Electrical Conductivity
XRD	-	X-Ray Diffraction

CHAPTER 1 – INTRODUCTION

1.1. WASTE GENERATION

Waste generation is the process of producing resources that eventually become unwanted or unusable and need to be disposed of. This covers a range of solid waste types, including garbage from homes, industrial waste, electronic waste, and hazardous waste. Garbage generation is a major problem that affects society, the environment, and the economy [1].

Population growth, urbanization, consumerism, industrialization, and lack of waste disposal and recycling are all contributing factors to the increase in trash production worldwide. Urbanization brings about a greater population, consumerism produces more items, industrialization produces waste from industrial activity, and lack of waste disposal and recycling increases trash production [2].

1.2. IMPACTS OF WASTE PRODUCTION

The generation of waste has a substantial impact on the economy, the environment, and human health. The air, water, and soil can get contaminated by improper trash disposal. For instance, burning garbage releases noxious gases and pollutants into the environment, causing respiratory issues and climate change. Hazardous waste disposal errors can also contaminate soil and water, harming plant and animal life. The creation of waste has financial effects as well. It can be expensive to correctly dispose of waste, and communities, corporations, and governments may incur higher costs as a result of improper waste management. Additionally, garbage that is not recycled or reused represents a lost chance for resource recovery and can aid in the depletion of natural resources. Finally, there are social effects of trash generation. Inadequate waste management can result in a rise in disease-carrying pests like rats and mosquitoes, which is bad for public health. Additionally, it may have a detrimental effect on local communities' quality of life, resulting in falling property values and a general loss in wellbeing. Overall, trash creation has negative effects that highlight the significance of good waste management practices, which include lowering waste production, improving recycling and reuse, and assuring safe and environmentally friendly disposal techniques. By implementing these

actions, we can protect the environment, public health, economy and other factors by reducing the negative effects of trash creation.

Any object or element that is thrown away, useless, or undesirable is considered as waste. It can come from a multitude of sources which may be solid, liquid, or gaseous. For the sake of preserving both the environment and human health, waste management must be done properly. The various waste types and how they affect the environment will be described below [3].

1.3. TYPE OF WASTES

1.3.1. Municipal Solid Waste (MSW)

Trash produced by homes, businesses, and companies is referred to as municipal solid waste (MSW). It consists of industrial, commercial, and domestic garbage. Hazardous substances like battery, electronics, and chemicals can be found in MSW.

1.3.2. Electronic Waste

Often known as e-waste, this kind of waste includes old computers, televisions, and mobile phones. Because to the accelerating speed of technological innovation and the rising demand for electronic gadgets, e-waste is an issue that is spreading around the globe.

1.3.3. Hazardous waste

Trash that could be hazardous to the environment or human health is referred to as hazardous waste. It can be produced by households, medical facilities, and industrial operations. Chemicals, insecticides, batteries, and radioactive substances are examples of hazardous waste.

1.3.4. Biodegradable Waste

Any trash that may be organically broken down by microorganisms is considered biodegradable. Waste that degrades naturally includes plant matter, paper, and food scraps. Waste that degrades can be composted and added to the soil as a soil amendment.

1.3.5. Non-biodegradable Waste

Anything that cannot decompose spontaneously is considered non-biodegradable waste. Polymers, metals, and glass are a few non-biodegradable garbage examples. Pollution from non-biodegradable garbage can build up in the ecosystem.

1.3.6. Organic Waste

Any garbage that contains organic components is referred to as organic waste. Food trash, yard waste, and animal waste are a few examples of organic waste. Composting organic waste allows for soil amendment [3].

1.4. WASTE DISPOSAL

The act of gathering, moving, and safely getting rid of waste in an environmentally friendly way is known as waste disposal. As the world's population and urbanization continue to rise, it is more crucial than ever to dispose of waste properly. Inadequate waste disposal can have detrimental effects on the environment and human health, including air and water pollution, soil and groundwater contamination, and the spread of infectious illnesses.

Waste management refers to the control of waste products which are no longer be required or desired. It entails gathering, moving, processing, and disposal of garbage in a secure and environmentally responsible way.

Waste disposal and waste management are closely related concepts that involve the proper handling and disposal of waste materials. Waste disposal explicitly refers to the last stage of the waste management process, where waste is disposed of in a safe and responsible manner. Waste management generally refers to the handling, transporting, and disposal of waste. The steps of effective waste management include waste reduction, recycling, composting, and disposal. While recycling entails gathering, classifying, and processing materials that can be reused or repurposed, waste reduction focuses on reducing the amount of garbage generated in the first place. While garbage disposal refers to the final disposition of waste that cannot be recycled or composted, composting entails the breakdown of organic materials into nutrient-rich soil [4].

1.5. TYPES OF WASTE DISPOSAL

1.5.1. Landfills

The most common method of waste disposal is to bury the trash underground in landfills. The garbage is crushed and covered with an outer layer of dirt to suppress odour and prevent the spread of illness. Landfills are appropriate for non-hazardous waste material, but if they are

not adequately managed, they can lead to environmental contamination and health risks.

1.5.2. Incineration

Incineration is the technique of lowering the volume of waste by burning it at high temperatures and turning it into ash and gases. Hazardous trash, medical waste, and industrial waste can all be incinerated. Yet, it has the potential to produce dangerous greenhouse gases and hazardous pollutants that can harm human health and the environment [5].

1.5.3. Recycling

Recycling is the practice of reusing discarded materials to create new goods. It is appropriate for substances including paper, plastic, glass, and metal. Recycling can save resources, cut waste volume, and lessen the effects of trash disposal on the environment.

1.5.4. Composting

The act of turning organic waste, like food scraps and garden waste, into nutrition soil is known as composting. It is appropriate for organic waste and it has agricultural and gardening applications. Composting can provide a beneficial soil amendment and cut down the amount of trash dumped in landfills

1.5.5. Waste-To-Energy

Burning waste to produce heat or power is known as waste-to-energy. It is appropriate for non-recyclable garbage, including industrial and municipal solid waste. Waste-to-energy can decrease the amount of waste transported to landfills and generate electricity, but it can also have negative health and environmental effects.

1.5.6. Plasma Gasification

Gasification is the process of dissolving garbage into its component parts by employing hot temperatures and a gasification agent. It is appropriate for both hazardous and medical waste. Although plasma gasification is an expensive and complicated technique, it can reduce the amount of garbage that is dumped in landfills and generate electricity.

1.5.7. Pyrolysis

Pyrolysis is the heating of waste without the presence of oxygen to create a gaseous and a solid residue. It is appropriate for rubber, plastics, as well as other organic materials. Pyrolysis can provide energy and reduce waste volume, but it can also create harmful pollutants [3].

1.5.8. Mechanical Biological Treatment

Waste is separated and processed mechanically and biologically by mechanical biodegradation. It works well for mixed garbage and can make compost, fuel, and recyclables. Mechanical biological treatment is an expensive and complicated technique, but it can reduce the quantity of trash dumped in landfills and generate energy.

1.5.9. Land Application

Application of trash to the ground as fertilizer or a soil supplement is known as "land application." It can increase soil fertility and is appropriate for organic waste. Applying garbage to the land can provide a beneficial soil amendment and cut down on the amount of waste transported to landfills.

1.5.10. Ocean Dumping:

Ocean dumping is the practice of discarding waste products in the ocean. It is suitable for dredging debris and other non-hazardous garbage. Ocean dumping, however, can destroy marine life and produce environmental contamination.

1.5.11. Sanitary Landfilling:

Sanitary landfilling is the practice of burying garbage in a landfill that is intended to reduce health risks and environmental degradation. It is appropriate for non-hazardous solid waste, but if it is not controlled, it can lead to environmental contamination and health risks [1].

1.6. AGRICULTURAL WASTE

Any waste produced by agricultural practices, such as crop cultivation, animal husbandry, and forestry, is referred to as agricultural waste. This trash can come in a variety of shapes and sizes, including agricultural residue, manure, animal remains, and wood chips. Agricultural waste poses a serious threat to the environment because it can contaminate streams, release greenhouse gases, and spread disease. Agricultural waste can be

used in a variety of ways and is a valuable resource that can be recycled. Crop residue, for instance, might be utilized as fuel, bedding, or animal food. Wood chips can be utilized to provide electricity, and manure can be used as fertilizer. Additionally, various types of agricultural waste are utilized to make biofuels, including leftover cooking oil and animal fat.

However, improper handling of agricultural waste can lead to environmental and health problems. For instance, manure runoff can contaminate waterways and lead to eutrophication, a process in which excess nutrients promote the growth of harmful algae and deplete oxygen levels in water bodies. Therefore, it is important to manage agricultural waste properly through appropriate storage, treatment, and disposal methods [5][6][7].

1.7. APPLICATION OF AGRO WASTE

Agricultural waste is the term used to describe the leftovers and by-products produced during agricultural processes like cultivation, harvesting, and processing. These wastes are frequently burned or disposed of, which pollutes the environment. They have historically been seen as an annoyance. Agro-waste, however, is now being acknowledged as a significant resource that may be used for a variety of reasons, from producing energy to soil enhancement, as a consequence of increasing concern for sustainability. We will go into great detail about the numerous applications for agro-waste are as follows:

1.7.1. Bio Fuel

A type of fuel known as biofuel is created from organic material, such as agricultural residues. Ethanol and biodiesel are the two different kinds of biofuels. Whereas biodiesel is made using vegetable oil and animal fats, ethanol is made from crops like corn, wheat and sugarcane. We shall talk about the creation of biofuel from agricultural waste in this article [8].

1.7.2. Corn Stover

When the corn has indeed been harvested, waste material known as corn stover is left behind. Ethanol can be made from this substance. The cellulose inside the maize stover is converted into simple sugars in the process, which are subsequently fermented to produce ethanol.

1.7.3. Sugarcane Bagasse

The fibrous residue that remains when sugarcane has been collected and the juices have been drawn out is known as sugarcane bagasse. Both ethanol and biofuel can be made from this substance [9].

1.7.4. Wheat Straw

Wheat is the residue left over after harvesting wheat. Ethanol can be made from this substance. The method is comparable to that used to make ethanol from corn stover.

1.7.5. Rice Husk

The outer layer of the grain of rice is known as the husk. Both ethanol and biofuel can be made from this substance [6].

1.7.6. Energy Production

Biogas production, combustion, and gasification are a few of the methods that can be used to turn agricultural waste into renewable energy. Because it lowers greenhouse gas emissions, biomass energy using agro-waste is regarded as an environmentally benign substitute for fossil fuels.

1.7.7. Animal Feed

Using agro-waste as animal feed is an economical way to recycle the trash and give animals a wholesome diet.

1.7.8. Organic Fertility

Agro-waste can be used to create organic fertilizers, including crop leftovers and animal manure. Natural fertilizers increase soil fertility and are rich in nutrients, which lessens the need to use synthetic fertilizers that are bad for the environment.

1.7.9. Soil Improvement

Agro-waste may be utilized to enhance the structure and quality of the soil. Increased agricultural productivity may result from its ability to improve soil fertility, reduce erosion, and retain moisture.

1.7.10. Construction Material

Agro-waste can be utilized as a building material to create lightweight bricks and panels, including such rice husk and bagasse. As a result, less conventional building materials are used, which lowers carbon emissions.

1.7.11. Production Of Paper

Paper pulp can be created using agricultural waste, including rice straw and sugarcane bagasse. As a result, there is less demand need virgin pulp, which also is made by felling trees [10].

1.8. BIO CHAR

Bio-Char is a type of charcoal that is produced from organic materials such as wood chips, agricultural waste, or other biomass. It is created through a process called pyrolysis, which involves heating the organic material in the absence of oxygen. The resultant Bio-Char is a very porous, carbon-rich substance. In crop and garden applications, it can be used as a soil conditioner to enhance fertilization, water holding capacity, and nutrient availability. A sustainable and eco-friendly substitute for conventional fertilizers and soil additions is Bio-Char. It may be made from a variety of organic waste products, which lessens the demand for landfills and encourages the circular economy.

There are numerous advantages of Bio-Char for healthy soil and plant growth. By enhancing the soil's capacity to hold onto water, minerals, and organic matter, it can raise soil fertility. This may result in better plant health and higher crop production. Moreover, Bio-Char can aid in soil carbon sequestration, which lowers greenhouse gas emissions and may assist to slow down the effects of climate change. Also, it may lessen the demand for synthetic fertilizer, which can be costly to create and deliver. Bio-Char has been demonstrated to always have potential uses in the treatment of water and the removal of pollution, in additional to its advantages for the health of the soil and plant growth. It can be used to clean up soil and water of impurities like organic pollutants and heavy metals [11].

1.9. SOURCES OF BIO CHAR

Depending on the area and the accessibility of biomass materials, the precise cause of Bio-Char can vary greatly. There are several different organic resources that can be used to make Bio-Char, such as:

- Agriculture waste: Crop wastes, including maize stalks, wheat straw, rice straw, sugarcane bagasse, and other plant materials left behind after harvesting, can be utilized to make Bio-Char.

- Forest trash: In addition to using sawdust as a feedstock, Bio-Char can also be produced using wood chips, bark, branches, and other types of forest waste.
- Livestock manure, poultry litter, and bone meal are a few types of animal waste that can be used to make Bio-Char.
- Urban green waste: Grass trimmings, leaves, yard debris, and other organic waste products from gardening and landscaping projects can be utilized to generate Bio-Char.
- Aquatic plants: The manufacturing of Bio-Char can also use water hyacinth, water lettuce, and other aquatic plants as feedstock.
- Industrial waste: Bio-Char can be produced using coconut shells, rice husks, nut shells, and other leftovers from processes including rice milling, nut breaking, and coconut processing.
- Energy Crops: Switch-grass, miscanthus, bamboo, and other quickly expanding plants cultivated expressly for the production of bioenergy can also be used to generate Bio-Char.

The chemical make-up, porosity, surface area, and stability of Bio-Char can all be impacted by the feedstock used. For instance, some feedstock, like hardwoods, create Bio-Char with a high carbon content and a high degree of stability, whereas others, like agricultural waste, might produce Bio-Char with a high nutrient content and a high degree of porosity. The choice of feedstock is also influenced by accessibility, price, and regional laws. When producing Bio-Char, waste materials that would otherwise be wasted can sometimes be used, reducing waste and possibly benefiting farmers, loggers, and other businesses economically [12].

1.10. APPLICATION OF BIO-CHAR

1.10.1. Soil amendment:

Bio-Char is capable of serving as a soil supplement to strengthen the soil, boost crop yields, and lessen the need for fertilizer. Bio-Char's porous structure can store water and nutrients while enhancing soil aeration and lowering soil compaction. Bio-Char can also boost the activity of soil microbes, which aids in the decomposition of organic materials and the release of nutrients for plant growth.

1.10.2. Fuel source

Using Bio-Char as fuel is possible both on its own and in mixtures with other fuels like woody biomass or sawdust. Because of its high energy content, Bio-Char may produce both heat and electricity when burnt in stoves or boilers. Using Bio-Char as a source of fuel can aid in decreasing emissions of greenhouse gases and advancing the production of sustainable energy [10].

1.10.3. Carbon sequestration

Bio-Char, a stable form of carbon that can linger inside the soil for a number of years, is a form of carbon sequestration. Carbon may be held in the soil and kept away from the atmosphere by adding Bio-Char, which helps to slow down global warming.

1.10.4. Water filtering

Bio-Char's porous structure makes it a useful water filtration and purification tool. Bio-Char is a useful technique for water purification and purification because it may remove toxins from water, including heavy metals, pesticides, and medicines.

1.10.5. Supplemental feed for livestock

Activated carbon could be put to pet food to help livestock digest and assimilate nutrients. In addition, Bio-Char can assist with odour control and air quality improvement in animal quality housing [5].

Ultimately, Bio-Char has the possibility to have major positive effects on the environment and the economy. The use of Bio-Char may become a crucial tool in the battle against global warming and environmental deterioration with further study and development.

1.11. SYNTHESIS OF BIO-CHAR

Pyrolysis is a method for creating Bio-Char that includes heating organic materials without oxygen. There are numerous ways to make Bio-Char, and each has benefits and drawbacks. Typical techniques include:

1.11.1. Traditional Pit Kilns

This process entails excavating a pit in the earth, putting organic materials inside of it, and then covering the pit with soil. The ingredients are then slowly burnt over a number of days to create charcoal. While

this process is straightforward and inexpensive, it has the potential to be ineffective and yield substandard Bio-Char.

1.11.2. Improved Top-Lit Updraft (TLUD) Stoves

This technique involves burning organic materials in a stove that has a combustion chamber and a chimney. The TLUD stove produces high-quality Bio-Char and lowers pollution by burning the ingredients top to bottom.

1.11.3. Gasification

In the gasification process, organic materials are heated in a confined container to generate gases that can be collected and burned as fuel. Bio-Char makes up the remaining solid matter. Although this approach can be effective and yield high-quality Bio-Char, it may also be more expensive and need more equipment [11][10].

1.11.4. Microwave Pyrolysis

By heating organic materials with microwave energy, Bio-Char is produced swiftly and effectively. Although though this technique is still being refined and isn't yet commonly utilized, it's got the ability to be a cheap and energy-effective way to make Bio-Char.

The organic materials used, as well as the heating temperature, time and the oxygen level during the pyrolysis process, all have an impact on the quality of Bio-Char produced, regardless of the method. Bio-Char of the highest level need to be stable, black, porous, and contain little ash or volatile material. Overall, the production of Bio-Char is a crucial field for study and development because it has the possibility to have a wide range of positive effects on the environment and the economy [13].

1.12. BIO CHAR SYNTHESIS AND LIMITATIONS

1.12.1. Advantages

- Mitigation of climate change: By removing carbon from the environment, Bio-Char can be utilized to lessen the consequences of global warming.
- Adding Bio-Char to soil can help it retain nutrients, hold more water, and improve its structure, which will enhance plant growth and crop production.

- Waste management: The production of Bio-Char from a variety of naturally occurring waste materials offers a way to lessen waste while also creating a useful product.
- Energy derived from renewable sources: It is possible to collect and burn the gases released during the synthesis of Bio-Char [14].

1.12.2. Limitations

- Cost: Making high-quality char can be costly, especially when specialized equipment is needed.
- Scale: Since Bio-Char is primarily produced on a tiny scale, its influence on major environmental issues may be constrained.
- Energy usage: Producing Bio-Char can demand a lot of energy, especially if complex machinery is employed.
- Emissions: The creation of Bio-Char can lower greenhouse gas emissions, but it can also result in the generation of other pollutants such as particulates and organic compounds that are volatile.

Overall, the advantages and limitations of Bio-Char synthesis depend on a variety of factors, including the specific method used, the quality of the Bio-Char produced, and the intended application of the Bio-Char. While Bio-Char synthesis is not a panacea for environmental problems, it has the potential to provide numerous benefits when produced and used appropriately [14].

1.13. CHARACTERIZATION OF BIO-CHAR

- Analysing The Elements: The hydrogen, nitrogen, oxygen, carbon, hydrogen, and sulphur content of Bio-Char is examined. Techniques like combustion analysis or elemental analysis with a CHNS/O analyser can be used for this.
- Surface Area And Pore Size Distribution: Using methods like nitrogen adsorption using a BET analyser, the particular area of surface of Bio-Char can be determined. Mercury intrusion porosimetry can be used to determine the distribution of pore sizes.
- Ash Content: The cation exchange capacity and nutritional content of Bio-Char are both impacted by the ash content of the material. By

- ⁵⁹ weighing the residue after ashing the charcoal in a furnace, it can be calculated.
- pH: After mixing it in distilled water, you can use a pH metre to determine the pH of Bio-Char.
 - Functional Groups: Methods like ²⁰ Fourier-transform infrared (FTIR) spectroscopic can be used to examine the existence of functional groups like carboxyl, hydroxyl, and phenolic groups.
 - Thermal Stability: Thermo gravimetric analysis (TGA), which analyses the weight loss of Bio-Char with raising temperatures, can be used to identify the thermal stability of Bio-Char.
 - Cation Exchange Capacity (CEC): A crucial characteristic that affects Bio-Char's potential to store and release nutrients is its CEC. Ammonium acetate or sodium chloride extraction can be used to find out.
 - Microbial Activity: Depending on its characteristics and pace of application, Bio-Char can have a variety of effects on soil microbial activity. Utilizing techniques like respiration or DNA analysis, microbial activity can be assessed.

These methods can enlighten researchers about the physical and chemical characteristics of Bio-Char, allowing them to better understand its potential uses in carbon sequestration, water purification, soil remediation, and as a feedstock for bioenergy generation [15].

1.14. BIO CHAR AS NUTRIENT SUPPLIMENT

An efficient soil fertilizer addition is Bio-Char. In the absence of oxygen, organic material, including such wood pellets or agricultural residues, is heated to create Bio-Char, a type of charcoal. Bio-Char ²³ can be used to amend soil to increase soil fertility, increase the soil water-holding ability, and improve soil structure. Nitrogen, potassium, and phosphorus, can all be absorbed and retained by Bio-Char, which is rich in carbon. Also, it offers a home for helpful soil microbes, which may aid in fostering plant health and growth.

By storing carbon in the soil, Bio-Char can aid in lowering greenhouse gas emissions in addition to its capacity to hold nutrients. Hence, there will be less carbon dioxide in the atmosphere, which can assist to slow down

climate change. It is crucial to take into account both the particular requirements of both the plants being grown and the purity of the Bio-Char when utilizing it as a nutritional supplement. The best quantity of Bio-Char to utilize will depend on the soil types, climate, and other variables. Certain forms of Bio-Char may be better at retaining specific nutrients than others [13].

1.15. FARMING AND CULTIVATION

Agriculture includes two key components: formation and cultivation. Farming is the process of preparing land for planting, whereas cultivating is the control of crops as they grow and develop.

In general, the term "farming" refers to the broader idea of managing agricultural output, which encompasses a variety of tasks like the cultivation, harvesting, processing, and marketing of crops or livestock. To create food, fiber, fuel, and other goods, it makes use of land, labor, capital, and technology. Farming can be a full-time profession, and it frequently requires a sizable time and financial commitment.

On the other hand, the term "cultivation" explicitly refers to the procedure of preparing the soil, sowing seeds, and growing crops or plants until they are fully mature. It is a branch of farming that focuses on the particular techniques used to cultivate crops, like irrigation, fertilization, and pest control. Growing crops can be a seasonal or part-time job, and it isn't always necessary to make substantial financial commitments.

1.15.1. Farming

The act of forming involves preparing the ground for agricultural planting.

There are multiple steps involved, including:

- Soil preparation: In order to loosen the soil and facilitate root growth, it is tilled, ploughed, or otherwise turned.
- Fertilization: To give crops the necessary nutrients, fertilizers are incorporated into the soil.
- Irrigation: The soil is moistened by the addition of water.
- Planting: To start the growth process, seeds or seedlings are buried in the ground.

1.15.2. Cultivation

Crops are grown and developed while being managed through cultivation. There are numerous steps involved, such as:

- Crop maintenance: Pest and disease infestations are tracked down and treated as necessary.
- Irrigation: Crops are irrigated as necessary to keep them moist.
- Fertilization: Extra fertilizers are put into the soil as necessary to supply the crops' crops with nutrients.
- Harvest: When a crop is fully developed and prepared for consumption, it is harvested.

A successful agricultural industry depends on both farming and cultivation. While efficient cultivation techniques can assist optimize agricultural yields and reduce losses due to pests and diseases, proper soil preparations and planting procedures can help assure healthy growth and development of crops. Agricultural can be a profitable and sustainable business that feeds people all over the world with the right management.

In agriculture, there are various different forms of cultivation, such as:

- Intensive cultivation: In order to get high yields, this style of farming uses a lot of effort, money, and resources, such pesticides and fertilizers. In order to cultivate crops on a big scale while maximizing earnings, intensive cultivation is frequently used in commercial farming.
- Extensive cultivation: Many inputs of labor, money, and resources are used in small amounts during extensive cultivation, resulting in low yields. In subsistence farming, when crops are largely cultivated for the farmer's personal consumption, extensive cultivation is frequently practiced [5].
- Organic cultivation: In this style of farming, natural pest control techniques like crop rotation and companion planting are used together with natural fertilizers like compost. Due to worries about the effects that conventional agricultural practices have on the

environment and human health, organic farming is growing in popularity.

- Precision cultivation: This method of farming maximize yield while minimizing waste by using technology, including such GPS and remote sensing, to accurately regulate the application of inputs, such as fertilizers and pesticides.
- Hydroponic cultivation: This method of growth uses a nutritionally water solution to produce plants without utilizing soil. Due to its water efficiency and storage space, hydroponic farming is becoming more and more popular.
- Mixed cultivation: In this method of farming, several crops are grown side by side in the same field. By fostering biodiversity, mixed farming can help minimize pest and disease issues and enhance soil health.

For various crops, geographical locations, and farming techniques, several forms of cultivation could be preferable. To satisfy their objectives and the needs of their markets, farmers may decide to combine these different farming techniques [16].

1.16. CONVENTIONAL FARMING TECHNIQUES

The term "conventional farming," usually referred to as "traditional farming," is an agricultural practice that relies on the application of artificial fertilizers, pesticides, and herbicides to manage crops and control pests. Large-scale monoculture, or the cultivation of a single crop over a considerable amount of land, is a common practice in conventional farming. Chemical inputs are employed in traditional agriculture to increase crop yields and safeguard crops against pests and illnesses. Contrary to popular belief, traditional farming can have a negative influence on the environment due to the extensive use of synthetic chemicals, which can lead to soil erosion, water pollution, and biodiversity loss. In addition to being extremely mechanized, conventional farming typically uses tractors and other equipment to prepare the soil, plant crops, and harvest the crop's output. This can result in soil compaction, erosion, a rise in energy consumption, and a rise in greenhouse gas emissions. Despite the fact that conventional farming has been successful in producing plenty food to satisfy the world's expanding

population, organic farming and agro ecology are increasingly being recognized as more environmentally friendly alternatives [15].

1.17. ALTERNATIVE FARMING TECHNIQUES

A wide range of farming strategies that are different from traditional farming techniques are included in alternate farming, commonly referred to as alternative farming. These techniques frequently focus on conserving soil health and biodiversity and are more environmentally friendly and sustainable. Here are a few instances of alternative farming techniques:

- Organic Farming: Using natural pesticides and fertilizers as opposed to synthetic ones is what is meant by organic farming.
- Agro Ecology: Agro ecology is a farming method that aims to resemble natural ecosystems. It places a strong emphasis on the use of crop rotation, intercropping, and other techniques that support biodiversity and ecological harmony.
- Permaculture is an all-encompassing method of farming that places a focus on creating self-sufficient, low-input agricultural systems.
- Regenerative Agriculture: A farming strategy that aims to enhance soil health, boost biodiversity, and store carbon in the soil with a focus on long-term sustainability.
- Aqua-Ponics: Aqua-Ponics is a farming technique that combines hydroponics (plant growth in water) and aquaculture (raising fish) to produce a closed-loop system that reduces waste and increases output.

The popularity of alternative farming techniques is rising as a result of their emphasis on biodiversity, soil health, and sustainability. These methods present a viable substitute for conventional farming, which can be resource-intensive and have detrimental effects on the environment [15].

1.18. ADVANTAGES OF ALTERNATIVE FARMING

Alternative farming techniques have a number of benefits over traditional agricultural techniques, such as:

1.18.1. Environmental Sustainability

Alternative farming practices, such as organic farming, agroecology, and regenerative agriculture, place an emphasis on using natural inputs and

preserving soil health and biodiversity, which results in a more resilient and sustainable farming system.

1.18.2. Synthetic Chemicals

The use of artificial fertilizers, pesticides, and herbicides, which can have detrimental effects on the environment and human health, is reduced by alternative farming techniques.

1.18.3. Food Safety & Soil Health

Alternative agricultural practices put a priority on food safety by reducing the use of chemical inputs and highlighting organic means of preventing pests and diseases. Agro ecology and regenerative agriculture, as well as alternative farming techniques, prioritize soil health through techniques including crop rotation, cover crops, and reduced tillage, which can enhance soil fertility, lower erosion, and boost water retention.

1.18.4. Increased Biodiversity

The preservation of biodiversity is a top priority for alternative farming techniques like agro ecology and permaculture, which encourage the coexistence of many plants, animals, and wildlife on the farm.

Overall, alternative farming techniques prioritize food safety, soil health, and biodiversity while also providing a more sustainable and environmentally friendly approach to agriculture.

1.19. ALTERNATE FORMS OF CULTIVATION

Agriculture uses a variety of alternative farming methods. These are a few instances:

- Organic Farming: It's a method of cultivation that uses organic pest and fertilizer management techniques rather than artificial chemicals. Crop rotation as well as utilizing cover crops are common practices in organic farming to enhance soil health.
- Hydroponics: Using a nutrient-rich fluid in place of dirt, hydroponic farming entails cultivating plants. Crops can be grown using this technique both inside and in regions with inadequate soil.
- Agroforestry: Agroforestry is a technique of land use management that blends trees with livestock or agricultural products. By using this

technique, you can increase soil fertility, lessen erosion, and give plants and animals shade and protection.

- Precision Farming: To maximize crop yield, precision farming employs technology such as GPS and sensors. Farmers can increase yields, boost efficiency, and minimize waste by using this technique.
- Permaculture: Permaculture is a development method that imitates natural ecosystems in order to develop agricultural systems that are sustainable. This approach places an emphasis on regenerative methods, healthy soil, and biodiversity.

These are only a few instances of alternative agricultural growing methods. Depending on their requirements and objectives, farmers may decide to combine these strategies since each has advantages and disadvantages of its own [15][17].

1.20. NECCESITY OF ALTERNATIVE FARMING

⁶² Due to a number of environmental, economic, and societal issues, alternative farming approaches are becoming more and more significant. Alternative agricultural methods are essential for a number of reasons, including:

- Climate Change: Climate change is causing weather patterns to shift, including rising temperatures and irregular rainfall, which can result in crop failure and lower yields. By enhancing soil health and water retention, alternative agricultural techniques like intercropping and agroforestry can assist to lessen the consequences of climate change.
- Environmental Sustainability: Traditional agricultural practices frequently consume a lot of water, fertilizer, and pesticides, which can have detrimental effects on the environment such soil erosion, water pollution, and biodiversity loss. Utilizing natural resources, cutting down on waste and pollution, and maintaining biodiversity are the main focuses of alternative farming methods including agro ecology, conservation agriculture, and organic farming. Regenerative agriculture and organic farming are two examples of alternative farming practices that work to enhance soil health and encourage biodiversity.

- **Water Scarcity:** Traditional irrigation practices are frequently wasteful and ineffective, and water scarcity is a problem that is becoming more and more urgent in many regions of the world. Water usage can be decreased and water efficiency can be increased by using alternative farming techniques like irrigation water and conservation agriculture.
- **Health Issues:** Chemical pesticides and fertilizers are frequently used widely in conventional farming method, which can have a harmful impact on both the environment and human health. By using fewer chemicals and promoting the production of sustainable and healthful foods, alternative farming techniques like organic agriculture and integrated pest control attempt to limit the usage of chemicals.
- **Food Security:** To meet the needs of a growing world population, more food must be produced with fewer resources. Alternative methods, such as aquaponics, hydroponics, and vertical farming, offer solutions to grow food in cities and other places with limited access to land, water, and other resources.
- **Social Equity:** Alternative approaches can aid in addressing social challenges such as rural poverty, gender inequality, and problems with land tenure. For instance, agro ecology places an emphasis on farmers' stewardship of their land and can give women and communities who are marginalized the power to take charge of their own food production.
- **Economic Viability:** Alternative methods can give farmers the chance to boost their profitability and diversify their income sources. Agroforestry systems, for instance, can produce both timber and agricultural crops, and organic farming can result in higher prices for organic goods [3][18].

Hence, alternative agricultural practices can assist in addressing a variety of difficulties affecting modern agriculture, including water scarcity, soil degradation, and climate change. Alternative farming techniques can contribute to ensuring a better and more resilient food system for future generations by supporting sustainable and regenerative practices [19].

1.21. HYDROPONICS AND ITS POPULARIZATION

In hydroponics, plants are grown in nutrient-rich water solutions rather than in soil. This method is providing plants with a nutrient solution on a regular basis while they are being grown within container filled with a nutrient medium, including such perlite, vermiculite, or coconut coir. Because it has significant advantages over conventional soil-based agriculture, hydroponics has grown in popularity in recent years. These benefits consist of:

- Water efficiency: Compared to conventional soil-based agriculture, hydroponics uses up to 90% less water.
- Space effectiveness: Hydroponic systems can be stacked vertically, which enables the growth of more plants in a smaller area.
- Enhanced plant growth and yield: Compared to plants cultivated in soil, hydroponically grown plants often develop more quickly and yield more.
- Less need for pesticides and herbicides: Because hydroponic systems are usually better controlled than traditional agriculture, less chemical treatment is required.
- Hydroponics makes it possible to grow plants all year round, no matter the weather or the time of year [20].

Several causes, such as the rise in local food consumption, the necessity to preserve water, and the preference for sustainable farming methods, can be blamed for the popularity of hydroponics. Moreover, hydroponics is now more available and simpler to use for backyard gardeners and local farmers thanks to technological and equipment advancements. When there is a strong demand for fresh fruit and there is a lack of available space, hydroponics has gained popularity in urban settings. Also, it has grown in popularity in areas with scarce water supplies where conventional agriculture might not be viable. Given its many benefits, it is anticipated that hydroponics will gain more traction as people look for more efficient and sustainable ways to produce food [21].

1.22. HYDROPONICS AS AN ALTERNATE FORM OF CULTIVATION

An alternate method of cultivation called hydroponics includes growing plants in such a nutrition water solution without the use of soil. In

hydroponics, the plant's stem and leaf are supported by an artificial medium like perlite or coco coir, while the roots are submerged in a nutritional solution. The nutrition solution is continuously pumped to offer a consistent supply of nutrients, and the plant obtains the nutrients it requires from it. Hydroponics is a method of growing plants that enables year-round culture because the plants are grown inside in a controlled environment. As a result, farmers are able to grow crops even in regions where the environment is unfavourable for traditional outdoor agriculture. Some benefits of hydroponic cultivation over conventional soil-based cultivation include:

- More yields: When compared to plants grown in soil, hydroponic can grow more quickly and provide greater yields per unit of space. This is the reason that hydroponic plants can develop more effectively because they have access to a steady intake of nutrients and water.
- Effective use of resources: Since water is recycled inside the hydroponic system, it consumes substantially less water than conventional soil-based farming. The use of less pesticides and fertilizers by hydroponic plants also lessens chemical outflow and soil contamination.
- Space Savings: Hydroponic farming is more suitable for urban areas with limited land because it takes up less room than conventional farming.
- Quality control: Hydroponic farming enables farmers to precisely manage the growth environment, including temperature, humid, and nutrient availability, which produces high-quality, dependable crops.

Hydroponics has several drawbacks in addition to its many positives. A hydroponic system takes technical know-how to maintain and might be expensive to set up. A hydroponic system may not be ideal for all types of plants, and it needs energy constantly to keep the flow of water and nutrients going [18][21].

1.23. MICRO GREEN CULTIVATION

During germination, when genuine leaves grow, Micro-Greens are young, sensitive greens that are harvested. They are raised from various vegetable, herb, and grains seed, and are normally harvested one to two weeks after sowing. Micro-Greens can be found in several different types of foods, including salads, as garnishes, and as a vibrant and tasty accent.

Micro-Greens need very little area to grow and can be cultivated either hydroponically or in soil. In the majority of climates, they may be cultivated both indoors and outdoors and harvested all year round. The correct temperature, moisture, and light levels, as well as other ideal growing circumstances, are essential for growing healthy Micro-Greens.

Start by picking the appropriate seeds for growing Micro-Greens. If you want tender, tasty greens, choose seedlings that are designated for growing Micro-Greens because they will germinate fast. The next step is to select a growing medium such as soil or even a hydroponic system and prepare it in accordance with the directions. The seeds should be sown closely together in the growing medium and lightly covered with soil or the other growing medium. To produce a greenhouse effect, softly mist the seeds with water and cover them with clear plastic wrap or a plastic lid. Set the tray in a warm, well-lit area, like a sunny windowsill or below grow lights. After the seeds have germinated, take off the plastic cover and continue to water the Micro-Greens. The Micro-Greens should be grown until they reach the required size, often 1-2 inches tall. By slicing the Micro-Greens at the stem's base, you can gather them for fresh consumption in salads, sandwich, or as a vibrant garnish for any cuisine [22][23].

1.24. TYPES OF MICRO-GREENS

There are many different kinds of Micro-Greens, including, to name a few, rocket, broccoli, mustard, chives, cilantro, kale and radish. Since each type has a unique flavour and nutritional profile, they can be used as an ingredient in a wide range of cuisines.

- Nutrient-dense: Studies have revealed that Micro-Greens can have as much as forty times higher nutrients per unit of area than mature plants, which is why they are noted for their high level of nutrients. This is due to the fact that Micro-Greens are still able to accumulate nutrients and have not yet depleted their nutrient stores.
- Growing Micro-Greens has various advantages, which are listed below. They are a desirable option for small-scale growers and urban gardening because they are simple to grow and demand few resources. Because to the fact that producers may sell them at a premium price to eateries,

supermarkets, and farmers markets, they can also be a successful commercial venture.

- Growth techniques: There are numerous ways to grow Micro-Greens, including soil-based, hydroponic, and aquaponic systems. Because they are simple to set up and maintain, soil-based systems have become most popular. In contrast to hydroponic systems, which substitute nutrient-rich water for soil, aquaponic systems combine hydroponics and aquaculture to provide a closed-loop system [22][23].

1.25. MICRO-GREENS AND ITS ADVANTAGES

Micro-Greens are grown by sowing their seeds in trays of soil or the other growing medium, and then watching them grow. The trays are then put in a sunny spot or under grow lights, and they receive regular watering. Cutting the Micro-Greens just above the soil level will allow you to harvest them after one to two weeks. In conclusion, growing Micro-Greens is a profitable and sustainable alternative agricultural method that may add taste and nutrients to any meal. Due to the growing demand for Micro-Greens, there are numerous options for producers to sell their produce to eateries, supermarkets, and farmers markets. Micro-Greens are a simple and effective crop to grow that has several advantages, when grown in soil, hydroponic, or aquatic systems. There are some distinctions between Micro-Greens and traditional crops in terms of their growth conditions, nutritional content, and production [1][22].

- Growth requirement: Micro-Greens can be cultivated in constrained areas and need less nutrients and water than traditional crops. Depending on the climate, they can be cultivated indoors, in greenhouses, or outdoors. Conventional crops, on the other hand, are often cultivated outdoors in huge fields and require more land, water, and minerals to grow.
- Nutritional value: Micro-Greens have a higher concentration of vitamins, minerals, and phytonutrients than mature plants, making them more nutrient-dense. They also serve as a good supply of protein and nutritional fiber. Conventional crops, in contrast, have lower levels of essential nutrients.
- Yield: Compared to conventional crops, Micro-Greens have such a shorter maturation period and are able to be harvested in as little as one

to two weeks after sowing. In comparison to regular plants, Micro-Greens can grow in the same amount of space and time while producing numerous harvests.

- Generally, Micro-Greens are superior to conventional crops in a number of ways, including increased nutrient density, reduced resource needs, and higher production potential. They might not work well for intensive farming or for plants that need an extended growing season [22][24].

1.26. MICRO-GREENS AND CONVENTIONAL CROPS IN NON-CONVENTIONAL FARMING:

In non-conventional farming techniques like hydroponics, aeroponics, and aquaponics, traditional crops and Micro-Greens can coexist. These systems use nutrient-rich water or mists to grow plants without the use of soil. Growing Micro-Greens alongside traditional crops has the benefit of making better use of available space. Micro-Greens develop quickly and are able to be harvested in as little as between one two weeks, in contrast to the several months that conventional crops like tomatoes, peppers, and cucumbers might take to mature. Farmers can maximize space use and boost yields by cultivating Micro-Greens alongside traditional crops.

Another benefit is whether Micro-Greens can help to boost the developing system's nutrient content. Studies have revealed that Micro-Greens can contain as much as 40 more nutrients per unit surface area than mature plants, which is why they are noted for their high nutrient content. Farmers can boost the total nutrient content of their producing system by planting Micro-Greens alongside conventional crops. Micro-Greens can also be a lucrative crop for farmers. Although they are well-liked by chefs and consumers who value their health, they can be sold at a premium to restaurants, supermarkets, and farmers markets. It can be grown alongside regular crops, but there are some difficulties as well. Managing infections is one difficulty because Micro-Greens are more prone to disease than mature plants are. To stop illness from spreading across crops, farmers must exercise caution.

Micro-Greens' varied environmental requirements from those of traditional crops present another difficulty. For instance, while normal crops need high light and low humidity, Micro-Greens need high light and low humidity.

Producers need to make sure the crop-growing system can offer the best circumstances for both crops. Overall, using unconventional farming techniques to cultivate Micro-Greens alongside traditional crops can be a feasible and profitable alternative for farmers. It makes good use of available space, boosts the system's general nutrient content, and has the potential to be a successful crop. To manage disease and guarantee ideal growth conditions for both crops, farmers must be aware of the difficulties and take appropriate action [1][16].

CHAPTER 2

LITERATURE REVIEW

- **Savvas, D., & Tsirogiannis, I. L. et al., (2012)** had published the journal in the topic of “Hydroponic lettuce production in a green wall system” Lettuce is a different species that thrives in hydroponic systems. The author claims that hydroponic lettuce may offer yields that are up to 50% more than standard soil-based gardening methods. Hydroponic lettuce produces more quickly and has a more regular shape and size, providing simpler for harvesting and consumers.
- **Tan et al. (2020)** had published the journal in the topic of “Vermicomposting derived from pineapple waste as a hydroponic nutrient supplement for lettuce production” Vermicomposting made from the waste of pineapples was employed as a hydroponic nutrition supplement. According to the study, vermicomposting considerably boosted lettuce output and growth when compared to the typical hydroponic supplement.
- **Kumar, S., Biswas, A. K., & Biswas, P et al., (2018)** had published the journal in the topic of “Agro-waste Bio-Char as a soil amendment to improve soil fertility and crop productivity” The impact of agro waste Bio-Char on soil fertility and productivity of crops were examined in a study done by the author. When compared to compost, the use of agro waste Bio-Char lead to a greater wheat yield and improved fertility of the soil.
- **Hernández et al. (2020)** had published the journal in the topic of a plant extract obtained from *Moringa oleifera* was employed as a hydroponic nutrition supplement. According to the study, the plant extract greatly boosted lettuce yields and growth when compared to the usual hydroponic fertiliser solution.
- **Zhang et al. (2019)** had published the journal in the topic of “Agro-industrial waste materials and wastewater as growth media for microbial bio-flocculants production” A Cu-based homogeneous catalyst was employed to change lignin-based biomass into biofuels. According to the study, the Cu-based catalyst was successful in increasing the cleavage of cellulose, lignin, and the hemicellulose leading to the formation of biofuels.

- **Suwannarach et al. (2020)** had published the journal Compost tea made from banana trash was employed as a hydroponic nutrition supplement. According to the study, compost tea greatly boosted lettuce growth and productivity when compared to the typical hydroponic fertiliser solution.
- **Gutierrez et al., (2020)** had published the journal in the topic of “Design and implementation of an IoT system for monitoring a hydroponic crop in a greenhouse” Hydroponic systems have gained popularity in modern farming because to their multiple advantages over traditional soil-based agriculture. Hydroponics allows for the cultivation of high-quality crops in a controlled environment, resulting in larger yields and faster growth rates. The purpose of this literature study is to investigate the many types of hydroponic systems and their distinguishing qualities.
- **Zhang et al. (2020)** had published the journal in the topic of “Conversion of corn stover to biofuels over mesoporous ZSM-5 zeolite catalyst” Corn stover was converted into biofuels using mesoporous ZSM-5 zeolite as a catalyst. According to the research, the mesoporous ZSM-5 zeolite catalyst demonstrated outstanding catalytic efficiency and selectivity for biofuel synthesis.
- **Mirzaei et al., (2020)** had published the journal in the topic of “Aeroponics hydroponic system: Future of agriculture” The aeroponic system is an advanced hydroponic system that delivers nutrients straight to the roots via spray. This system is extremely efficient, utilising less water and fewer fertilisers than other systems and providing great root oxygenation. It does, however, necessitate more upkeep and specialised equipment than ordinary hydroponic systems.
- **Tyson et al., (2019)** had published the journal in the topic of “Ebb and flow hydroponics” Another common hydroponic technique is the ebb and flow or flood and drain system, which includes regularly flooding the crops with nutrient-rich water and then draining it away. This technique is good for larger plants like tomatoes or cucumbers, as it gives you more control over fertilizer distribution. It is, however, more difficult to install and maintain than conventional hydroponic systems.
- **Resh, H. M. et al., (2013)** had published the journal in the topic of “Hydroponic food production” A definitive guidebook for the advanced home

gardener and the commercial hydroponic grower. Deep water culture (DWC) is a hydroponic method that grows plants in a reservoir of nutrient-rich water. The plants' roots are floating in water, and an air compressor supplies oxygen to the roots. The DWC system, according to the inventor, is simple to set up and maintain, and it can be used to cultivate a variety of plants. However, controlling the pH and nutrient levels in the water might be difficult.

- **Kumar et al. (2020)** had published the journal in the topic of "Synthesis of activated carbon from rice husk for environmental applications" Chemical activation was used to make activated carbon from rice husk. According to the research, activated carbon has a large surface area, making it appropriate for a variety of applications including water treatment, gas retention, and catalysis.
- **Kyriacou and Savvas et al., (2017)** Aeroponic devices supply nutrients to plant roots via mist or fog. The aeroponic system, it can provide higher yields than traditional hydroponic systems. It is also more effective with water and provides updated pH and nutrient control. It is, however, more costly to set up and fix than other hydroponic systems.
- **Yadav et al., (2016)** the drip irrigation system is a hydroponic system that drips nutrient-rich water immediately onto the plant roots. The drip irrigation system, is straightforward to install and operate, and it can be used for growing a range of plants. However, controlling the pH and nutrient levels in the water might be difficult.
- **Mahajan, P., & Tandon, P. et al., (2019)** had published the journal in the topic of "Impact of hydroponic technique on plant growth, fruit yield and quality of cucumber" Cucumbers are a different plant that can thrive in hydroponic systems. According to the author, hydroponic cucumbers can provide crops up to 50% more than standard soil-based growing methods. Hydroponic cucumbers are also superior in texture and possess an extended lifespan, making them more desirable to customers.
- **Wu, L., Wang, C., Zheng, Y., Lin, X., Jiang, X., Wei, D., & Xie, Z et al., (2020)** had published the journal in the topic of "Agro-waste Bio-Char increases grain yield and improves soil fertility in rice-based cropping systems" The authors examined the impact of agro-waste Bio-Char on rice development against no amendment. The study discovered that the use of

agro-waste Bio-Char produced a greater quantity of rice and enhanced soil quality as an alternative to no amendment.

- **Jahan et al. (2020)** had published the journal in the topic of “Biogas slurry as a hydroponic nutrient solution for cucumber cultivation” “cow dung biogas slurry was employed as a nutritional supplement in hydroponics. The biogas slurry greatly boosted cucumber growth and yield when compared to the usual hydroponic fertiliser solution, according to the study.
- **Gao et al. (2019)** had published the journal in the topic of “Effect of Light Intensity on the Growth and Yield of Hydroponic Strawberry” Strawberries may also be grown in hydroponic systems, which provide larger yields than typical soil-based agricultural methods. According to the author, hydroponic strawberries can yield up to 25% more than soil-grown strawberries. Hydroponic strawberries also possess a prolonged growth season, which may improve overall yield.
- **Chen, Y., Li, L., Wang, Y., Li, Y., Li, X., Li, Q., & Li, Y et al., (2019)** had published the journal in the topic of “Comparison of agro-waste Bio-Char and chemical fertilization on maize growth, nutrient uptake and soil properties in a saline soil” The authors conducted a study that compared the impact of agro-waste Bio-Char on maize growth to chemical fertiliser. The use of agro-waste Bio-Char gave produce comparable to chemical fertiliser, with the added advantage of enhancing soil fertility and reducing nutrient leaching.
- **Krasnova et al. (2020)** had published the journal in the topic of “Control of pH in hydroponic cultivation” According to his studies, pH acts as one of a significant critical environmental parameters to monitor in hydroponic systems. The research discovered that keeping the pH range around 5.5 and 6.5 is critical for plant development and intake of nutrients.

CHAPTER 3

AIM & SCOPE

3.1. Aim

The ultimate aim of our project titled “SYNTHESIS CHARACTERIZATION AND EVALUATION OF AGRO WASTE BIO-CHAR AS A NUTRIENT SUPPLEMENT IN HYDROPONICS” is to develop an agro waste based nutrient supplement to implement in non-conventional farming technique i.e. hydroponics, by achieving the following objectives.

- Synthesize and Evaluate Bio-Char from an Agricultural Waste.
- Develop a custom Hydroponics Set-up using simple, easily available but effective materials.
- Cultivation of Micro-Greens from the developed hydroponics system and synthesized Bio-Char.
- Nutritional studies on cultivated Micro-Greens and analysis.

3.2. Scope

Alternate farming methods can be a great advantage to conventional farming as it can increase the overall yields and can reduce soil related problems. Requirement of large cultivable land isn't required as non-conventional farming can even be done in terrace or in urban area or even in villages where there is land constraints. Usually water requirement in non-conventional farming is much lesser than conventional farming, so water management is easier. Soil contamination and soil degradation problems doesn't arise in non-conventional technique so nutrition related problems are rare. Agricultural waste which leads to GHG emissions can be greatly reduced in non-conventional methods.

CHAPTER 4

MATERIALS & METHODS

4.1. RAW MATERIAL COLLECTION

Rice Straw is the primary raw material which was used to synthesize Bio-Char. As the primary motive of this project is to synthesize Bio-Char from agro waste. Coco Peat is used as a substrate for growing plants. Acrylic Tubes and PVC Cups for building the Hydroponics System.

4.2. EQUIPMENT USED

Various types of equipment were used in every other aspects. During the synthesis of Bio-Char, Hot Air Oven for moisture removal and Muffle Furnace for achieving one of the main objective i.e. Synthesis of Bio-Char.

While the same Hot Air Oven is used later for determining Moisture Content Property for Bio-Char, Muffle Furnace for Volatile & Ash matter, Bulk Density Apparatus for the same, pH meter for determining pH and Electrical Conductivity Meter for finding the same.

4.3. DEVELOPMENT OF HYDROPONICS SYSTEM

Coming to the next objective, the Hydroponics System. The interesting part here is the entire system is custom made and developed by ourselves inside the Int'l Research Centre which is located inside the University Campus. The System was built using Acrylic Tubes. The main reason for choosing Acrylic Tubes is considering its rigidity. Moreover, these tubes doesn't allow the growth of fungus despite the continuous presence of water and sunlight. The two ends of the tubes are closed tightly with rigid PVC Cups and pasted with a strong adhesive for extra protection. Holes were drilled using drill machine and then sand paper was used to even out the surface.

4.4. BIO-CHAR SYNTHESIS

As stated above, the main motive of this project is to use agro waste. Therefore Rice Straws are chosen. The rice straws are cleaned by hand to remove dirt, sand granules and other impurities. Then the straws are washed and dried for a day. Then, it was placed inside the hot air oven (110 °C for 2

hours) in order to remove moisture. Following this, the straws are cut into small pieces and are split into three parts namely, A, B, and C. These three samples are subjected to three different conditions. The conditions are:-

- A at 200 °C for 2 hours.
- B at 250 °C for 1.5 hours.
- C at 300 °C for 1 hour.

The samples were left all the day for cool-down. Then all the three samples were finely grinded using a hand mortar and neatly stored in an air-tight plastic bag. On the whole the obtained Bio-Char was about 30g. Subsequently, all the samples were tested to find the best one to use it as a nutrient supplement in hydroponics.

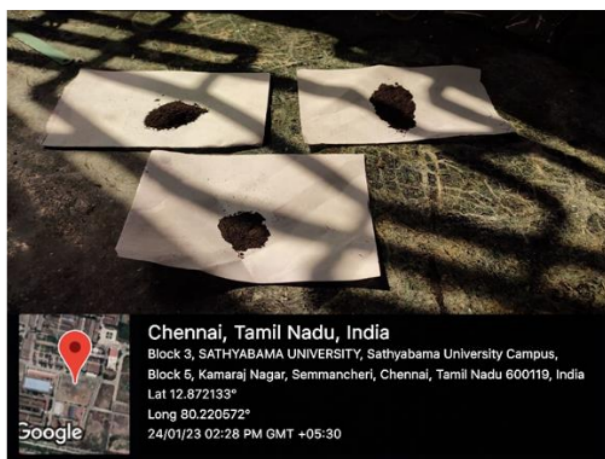


Fig. 4.1: Bio-Char Samples

4.5. PROXIMATE ANALYSIS OF BIO CHAR

Proximate analysis is a technique used to determine the basic composition of a substance. It involves the determination of the amounts of various components of a substance, typically by heating it and measuring the changes that occur. Proximate analysis is commonly used in the analysis of solid fuels like coal and biomass, but it can also be applied to other materials. Proximate analysis is usually conducted by heating a sample of the substance in a controlled environment and measuring the changes that occur. Proximate analysis can provide valuable information about the energy

content and handling properties of solid fuels, and it is commonly used in the evaluation and comparison of different fuels. However, it should be noted that the results of proximate analysis may not provide a complete picture of the fuel's characteristics, and other tests may be necessary for a more detailed analysis. The basic components measured by us for the Bio-Char in proximate analysis are: Moisture Content, Volatile Matter, Ash Content and Bulk Density. Other than these, pH and Electrical Conductivity were also analyzed.

4.5.1. Moisture Content

Moisture content is a key component of proximate analysis, which is a common method used to determine the composition of food and other organic materials. Moisture content is determined by weighing a sample of the material before and after it has been dried to a constant weight. The difference in weight is used to calculate the moisture content as a percentage of the original sample weight. The moisture content of a material can have a significant impact on its properties and suitability for various applications. For example, food products with high moisture content are more susceptible to spoilage and may have shorter shelf lives, while materials with low moisture content may be more stable and easier to store.

In our experimental part, we took ~2g of each sample and followed the procedure. Hot Air Oven was used here. That is 110 °C for 2 hours. After its cooling, the resulting moisture content in % was calculated from the mass difference before and after heating. 1.83%, 1.90%, 1.89% were the moisture content of A, B, C respectively.

$$\text{Moisture Content (\%)} = \frac{\text{Loss in mass of sample}}{\text{Initial mass of the sample}} * 100$$

4.5.2. Volatile Matter

Volatile Matter is one of the components analyzed in the Proximate Analysis of coal, which is a standard method used to determine the quality and composition of coal. The volatile matter is the portion of the

coal that is released as a gas when the coal is heated in a controlled environment. It includes any carbon, hydrogen, and sulfur compounds that are volatilized during the heating process. In the context of Bio-Char production, Volatile Matter refers to the portion of the organic matter in the biomass feedstock that is released as a gas during the process of heating biomass in the absence of oxygen to produce Bio-Char. The amount and composition of the volatile matter in the biomass feedstock can affect the properties of the resulting Bio-Char. Higher levels of volatile matter can result in a more porous Bio-Char with higher surface area, which can be beneficial for soil amendment and other applications. We followed a standard procedure for determining Volatile Matter, i.e. heating the samples at 950 °C for 7 minutes and then using the following formula.

$$\text{Volatile Matter (\%)} = \frac{\text{Loss in mass of sample}}{\text{Initial mass of sample}} * 100$$

Sample C had the maximum amount of Volatile Matter at 69%, followed by Sample A at 66.50% and Sample B at 57%.



Fig. 4.2: Volatile Matter Determination

4.5.3. Ash Content

The ash content is the amount of inorganic material remaining after a substance has been completely burned. Proximate analysis measures the amount of ash content in a sample by heating the sample to a high

temperature until it is completely burned. The residue that is left behind after burning is then weighed, and the ash content is calculated as a percentage of the original sample weight. Ash content can provide information about the mineral content of a substance, and is often used to measure the quality of fuels such as coal and biomass. It can also be used in food analysis to determine the amount of mineral content in foods such as cereals, grains, and fruits. We've followed a standard procedure for the determination of Ash content i.e. Heating the samples in the muffle furnace for 30 minutes at 750 °C and then the formula below was used.

$$\text{Ash Content (\%)} = \frac{\text{Mass of the ash}}{\text{Initial Mass of Sample}} * 100$$

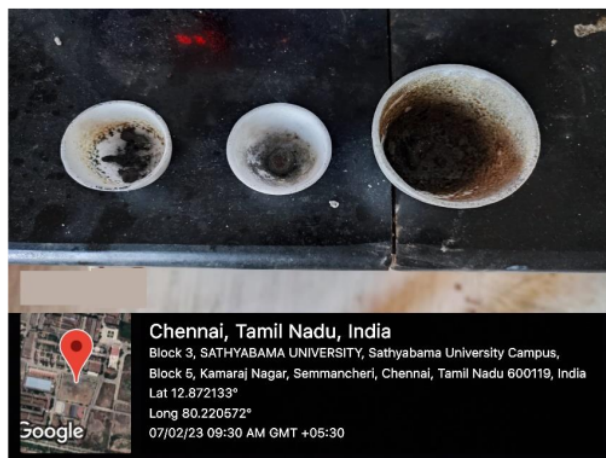


Fig. 4.3: Ash Content Analysis

4.5.4. Bulk Density

Bulk density is an important property for many materials, including powders, granular materials, and soils. There are two main types of bulk density: loose bulk density and packed bulk density. Loose bulk density is the mass of a substance per unit volume when it is poured or dispersed without any compaction. Packed bulk density, on the other hand, is the mass of a substance per unit volume when it is compacted or settled under the weight of its own particles or by external forces. Here, we took 3g of each sample, and loaded it into the bulk density apparatus. Unlike other tests, these samples can be reused so even

more amount of samples can be used for better comparison. The Bulk density apparatus taps the sample for given number of turns and we estimated for sixty turns for better accuracy and in-between at every twenty turns the readings were noted.



Fig. 4.4: Bulk Density Apparatus

4.5.5. pH and Electrical Conductivity

pH is a measure of the acidity or alkalinity of a solution. It is a logarithmic scale that ranges from 0 to 14, with 0 being the most acidic, 14 being the most alkaline, and 7 being neutral. In general, Bio-Char has a high pH due to the alkaline minerals and metals that are often present in the feedstock material. The pH of Bio-Char is usually in the range of 8 to 10, which is considered slightly alkaline. Since the synthesized Bio-Char is a solid it was mixed with distilled water to test the pH with pH meter. 0.3g of sample is mixed with 40mL of distilled water and tested for each sample using pH meter.

Electrical conductivity is a measure of a material's ability to conduct electric current. It is typically measured in units of Siemens per meter (S/m) or milliSiemens per centimeter (mS/cm). Generally, Bio-Char has a low electrical conductivity due to its high carbon content and low ash content. The electrical conductivity of Bio-Char can be further reduced by washing or leaching to remove any remaining soluble minerals. EC and pH have the same procedure and calibration to test. The only difference is the meter used for its determination.

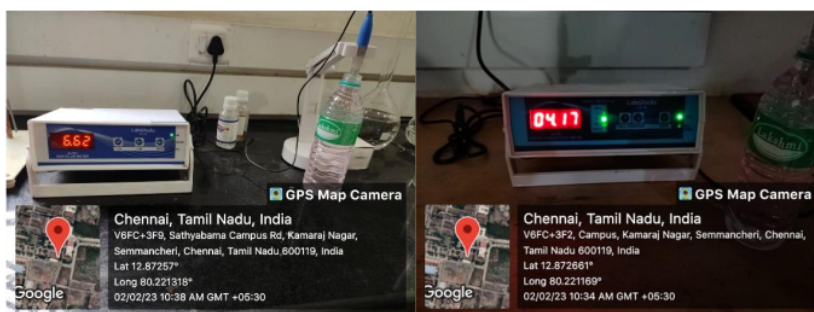


Fig. 4.5: pH & Electrical Conductivity Determination

4.6. FT-IR ANALYSIS

FTIR or Fourier-Transform Infrared Spectroscopy is an easy, simple, fast, suitable, non-invasive and cost-effective method to identify the role of biomolecules. FTIR is an extremely useful technique for confirming the identity of pure compounds, but has limited value if used for mixtures of compounds. The technique is based upon the identification of functional groups within molecules where such groups vibrate (either through stretching or bending in various ways) when irradiated with specific wavelengths of light. These vibrations and their intensity (% transmission) are plotted against the frequency of light (cm^{-1}) to which the sample is exposed to produce an FTIR spectrum. Portions of the FTIR spectrum are unique to the compound under test (this is called the fingerprint region). Infrared analysis is not affected by fluorescence and can be regarded as a powerful technique for investigating aspects of molecular chemistry in Bio-Chars. A range of different methods for performing infrared analysis have been utilized to characterize Bio-Chars: FTIR-PAS (Fourier Transform Mid-Infrared Photo Acoustic) spectroscopy where the samples are placed in a photo acoustic cell and purged with helium prior to analysis; Diffuse Reflectance Infrared Fourier Transform (DRIFT) spectroscopy in absorbance mode where the Bio-Char samples are mixed with KBr to form a wafer; Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy, where the samples are in direct contact with the ATR crystal; Synchrotron-Based Fourier Transform Infrared (FTIR) spectroscopy and, the most commonly used method, transmission mode FTIR, where the samples are mixed with KBr to form a pellet. When applied to a Bio-Char surface, FTIR has been used principally to acquire point spectra. A

disadvantage is that if a material is highly heterogeneous, such as Bio-Char, this can result in sampling bias [25][26].

An infrared spectrum of Bio-Char can be complex, often containing a variety of mineral phases, leading to an extensive variety of chemical bonds in a sample. Another significant challenge for FTIR analysis of Bio-Chars is the opacity of the sample, preventing measurements by transmission without grinding and dispersing the sample, and the low albedo, resulting in poor signal-to-noise in a reflectance FTIR measurement, even with synchrotron sources. In the case of infrared, the response from a Bio-Char sample can be significantly improved by preparing a finely ground solid and using ATR techniques or measuring transmission of infrared light through a KBr disc, where the powdered Bio-Char is dispersed. However, this improvement in spectral quality comes at the cost of spatial information [27].

Laboratory-based FTIR are now relatively widespread and potentially enable the Bio-Char community to better understand the distribution of chemical bonds at micron to millimeter length scales. To have a low-cost, rapid, and easy to use method for non-destructive screening of Bio-Chars, FTIR spectroscopy could be a possible option. Not only has it been used to obtain highly structural information on various Bio-Chars and starting materials, but has also been applied to investigate the structural changes of Bio-Chars as a function of pyrolysis temperatures [26].

4.7. XRD ANALYSIS

XRD or X-Ray Diffraction Analysis is a non-destructive technique that provides detailed information about the crystallographic structure, chemical composition, and physical properties of a material. It is based on the constructive interference of monochromatic X-rays and a crystalline sample. X-rays are shorter wavelength electromagnetic radiation that are generated when electrically charged particles with sufficient energy are decelerated. In XRD, the generated X-rays are collimated and directed to the sample, where the interaction of the incident rays with the sample produces a diffracted ray, which is then detected, processed, and counted. The intensity of the diffracted rays scattered at different angles of material are plotted to display a diffraction pattern. Each phase of the material produces a unique diffraction pattern due to the material's specific chemistry and atomic arrangement. The

diffraction pattern is a simple sum of diffraction patterns of each phase and imperfection in the sample material would affect the pattern of the diffracted signal. Generally, the qualitative phase analysis of the diffraction pattern of XRD characterization will be compared with the standard crystallographic databases such as the International Center for Diffraction Data (ICDD), to ease the phase identification of a material in a large variety of crystalline samples. The peaks of the XRD pattern play a vital role in the identification of the phases as well as the properties of the sample. The intensity of the diffraction peaks in each phase is directly proportional to the amounts of elements present in the sample. The main advantages of XRD is that it is a simple and universally recognized technique. On the other hand, a severe limitation of this technique will be that single conformation and binding state of growing crystals are difficult to identify [28].

4.8. MICRO-GREEN CULTIVATION

After choosing the right Bio-Char sample, three micro-greens plant was chosen after several studies. Those three were Mung Bean, Fenugreek and Mustard. These three were chosen because of easy availability and demanding products in Indian and especially South Indian Cuisine. After selecting fresh and good seeds, the operation were started. The substrate used here was coco-peat. Coco-Peat was carefully chosen as it'll be holding the entire plant till harvest season. If the substrate is either adulterated or old, it'll neither promote the growth nor hold the plant strong enough, but demotes the growth. Since the plants will be placed in water all the time, strength of plant and substrate's holding is very vital. To find the best possible results, seeds are sowed with different Bio-Char concentrations. They're 0.0g (No Bio-Char), 0.2g, 0.4g, 0.6g. In general, three seeds, four concentrations, hence twelve plants (3X4) must be obtained. The pH & EC of Coco-Peat and the water were tested before the initialization of the process. This is done to create a fertile environment can be created. If the pH & EC are high, it affects the growth. So only after ensuring all parameters are apt, the process was started.

- pH of Coco peat cleansed water – 6.17
- Electrical Conductivity – 4.99 (20mS)
- pH of Water inside the System – 6.62

- Electrical Conductivity – 4.17 (20mS)

The samples were monitored for a period of 15 days, typical micro-greens harvest period. Though micro-greens require a good amount of sunlight to grow well, but direct sunlight can sometimes be too intense and may damage the young plants. As a result, direct sunlight was given only during the morning and evening for approximately 4 hours. And during the noon, the system were placed sunlit area but not under the direct sunlight.

In a stagnant micro hydroponic system, the water should be changed more frequently than in larger systems. Ideally, the water should be changed every 3-5 days to ensure that the nutrient solution remains fresh and free from harmful bacteria and algae that can negatively affect plant growth. The smaller size of the system means that the water volume is limited, and there is less water available to dilute any harmful substances that may accumulate in the nutrient solution. Regular water changes help to maintain the pH and nutrient balance in the system, ensuring optimal plant growth and health. So by taking extra care, the water was changed every 3 days. Despite frequent change of water, NPK water was sprayed every day to prevent drying of Coco-peat and to provide extra nutrition. On the first 2 days, there weren't any germination at all. From the 3rd day, there was a steady growth. Out of all Mustard was the fastest and Mung was the tallest. Plants that had the Bio-Char (all three) in them germinated first. The sample without Bio-Char germinated 1-2 days later. The detailed chart and its inferences are discussed in the following sections.

4.9. NUTRITIONAL STUDIES

Out of the three, Mustard is used for further analysis, as mustard was the only micro-green crop from our analysis, lasted for nearly 18 days. Apart from that, mustard micro greens can be used in a variety of dishes, including salads, sandwiches, and soups. Mung gram and fenugreek micro greens may be more limited in their culinary applications. Moreover the yield of the mustard was comparatively more (in all concentrations of Bio-Char) than the other two. This doesn't mean that the other two plants are inferior. In general, even in conventional farming techniques Mustard has very high yields.

In order to prove the influence of Bio-Char on the Micro-Greens, two samples of selected Mustard plants were subjected to analysis. One being the plant cultivated with Bio-Char other being the sample cultivated without Bio-Char. They were tested for Protein, Energy, Carbohydrates, Total Fat, Crude Fiber, Minerals – Sodium, Magnesium, Iron and Calcium.

4.9.1. Proteins

Protein is an essential nutrient ¹ that plays a vital role in the growth and maintenance of tissues in the human body. It is important to consume enough protein to support bodily functions and maintain overall health. Mustard greens are a nutritious leafy green vegetable that can provide a range of health benefits. In terms of protein content, Mustard micro-greens are known to be a rich source of protein. The exact protein content in mustard micro-greens can ¹⁰ vary depending on various factors such as growing conditions, the age of the micro-greens, and the specific variety of mustard used. Typically the amount of protein found in a 100g serving of Mustard Green is about 2.5g. This value is obtained through conventional farming. It is important to note that the protein content may vary depending on the specific variety of mustard greens and how they are prepared. However, mustard greens can still be a good source of protein as well as other essential vitamins and minerals.

4.9.2. Energy & Carbohydrates

The amount of energy in food is often expressed in calories or joules. The quantity of the food's macronutrients—specifically, its carbohydrate, protein, and fat content—determines ³⁹ how much energy it contains. In general comparison to fats, which have about 9 calories per gram, carbohydrates and proteins have about 4 calories per gram.

Coming to carbohydrates, one of the three macronutrients, along with protein and fat that are present in diet is carbohydrates. The body uses carbohydrates as a source of energy and as a means of ensuring that the nervous system, brain, and other organs continue to work properly. Simple and complex carbohydrates are the two basic types of carbohydrates. Simple carbs are composed of just one or two sugar molecules, and because they are easily absorbed by the body, blood sugar levels rise quickly. Contrarily, complex carbohydrates, which are

composed of lengthy chains of sugar molecules and are absorbed more slowly, give off energy over a longer period of time. In terms of carbs, mustard greens have a tiny quantity of calories and are quite low in calories. One cup of chopped mustard greens (about 100 grams) includes roughly 4 grams of carbs, including 1 gram of dietary fiber and 0.3 grams of sugar, according to the United States Department of Agriculture (USDA). The majority of the carbohydrates in mustard greens are complex carbohydrates like dietary fiber, which can support good health by regulating digestion. Additionally, mustard greens have a low glycemic index, which means that its impact on blood sugar levels is negligible.

4.9.3. Fats

Fats are one of the three macro-nutrients contained in diet, along with carbs and protein. The body uses fats as a source of energy and as a way to maintain healthy skin, hair, and nails. Fats also aid in the body's ability to absorb the fat-soluble vitamins (A, D, E, and K). Unsaturated and saturated fats are the two basic classifications of fats. The majority of animal products, including meat, butter, and cheese, include saturated fats, which are normally solid at room temperature. If ingested in excess, these fats can raise cholesterol levels and raise the risk of developing heart disease.

As opposed to saturated fats, which are usually solid at room temperature, unsaturated fats are present in plant-based foods including nuts, seeds, and oils. When used in moderation, these fats can help lower cholesterol and minimize the risk of heart disease. When choosing healthy fats for a balanced diet, it's crucial to minimize saturated and Trans fats while consuming foods that are high in unsaturated fats.

In terms of total fats, mustard micro-greens are a very low-fat food. According to the United States Department of Agriculture (USDA), one cup of chopped mustard micro-greens (about 100 grams) contains only 0.9 gram of total fat, including both saturated and unsaturated fats. The fats in mustard greens are primarily unsaturated fats, which are considered healthy fats that can help to reduce inflammation and lower the risk of heart disease when consumed in moderation. Mustard greens

³³ are a good source of omega-3 fatty acids, which are important for brain health and reducing inflammation.

4.9.4. Crude Fibers

The indigestible part of plant-based meals such fruits, vegetables, grains, and legumes is referred to as "crude fiber" in nutritional analysis. It is a way to gauge how much fiber, both soluble and insoluble, is present in a given diet. The body cannot absorb crude fiber, in contrast to other nutrients like protein or fat. Instead, it mostly completes its journey through the digestive system, giving stools more volume and assisting in controlling bowel motions.

There are around 2 grams of crude fiber per 100 grams of fresh weight in mustard micro-greens, which is a relatively significant amount. The quantity of crude fiber that can be gained by consuming mustard micro-greens, however, is probably fairly minimal because they are normally eaten in small amounts. It is important to remember that the precise crude fiber content of mustard micro-greens might vary based on elements including the type of mustard plant, the growing environment, and the time of harvest.

4.9.5. Minerals:

Our bodies require minerals as necessary nutrients to perform a number of tasks, such as constructing strong bones, sending nerve signals, and controlling our metabolism. Foods based on both plant-based and animal-based sources can provide minerals.

Sodium - Sodium is a mineral that is essential for human health in small amounts. It plays a vital role in maintaining the balance of fluids in the body, transmitting nerve impulses, and contracting and relaxing muscles. Only about 40 milligrams of sodium are found in one cup of chopped raw mustard greens, which is a comparatively low sodium concentration for a green vegetable. As a tasty, nutrient-dense crop that can be utilized in a variety of meals, mustard greens are a fantastic option for people who are seeking to limit their intake of sodium. However, consuming too much sodium can be harmful to health and has been linked to an increased risk of high blood pressure, stroke, and heart

disease. The recommended daily intake of sodium for adults is less than 23 grams per day, which is about one teaspoon of salt. It's important to keep in mind that the sodium concentration of mustard greens might change based on things like the growth environment and the cooking process. For instance, pickled or canned mustard greens could contain more sodium than raw or fresh greens.

Magnesium - Magnesium is an essential mineral that plays a crucial role in numerous bodily functions, including energy production, muscle and nerve function, bone health, and regulating blood sugar levels. Magnesium is an important mineral that is necessary for many body processes, and mustard greens are a rich source of it. One cup (about 100 grams) of chopped, cooked mustard greens has roughly 30 mg of magnesium, according to the United States Department of Agriculture (USDA). This amounts to around 6% of the adult magnesium recommended daily intake. However, it's important to keep in mind that various sources may give somewhat varying figures for the amount of magnesium in mustard greens.

Iron - The creation of red blood cells and the delivery of oxygen to cells are only two examples of the important roles that iron plays in the body. Stating Iron as the most vital mineral in the human body wouldn't be wrong. Iron levels in the body should be kept at healthy levels by eating meals high in this mineral. Dietary iron comes in two forms: heme iron, which is present in foods derived from animals, and non-heme iron, which is present in foods derived from plants. Although heme iron is more easily absorbed by the body than non-heme iron, both forms can add to the total amount of iron consumed. The body's capacity to absorb iron can be impacted by a variety of different elements, including the availability of specific nutrients (such as vitamin C), drugs, and medical disorders. A 100-gram serving of mustard greens contains around 7% of the adult recommended daily value (DV) for iron. Mustard greens are a good source of iron. It's important to keep in mind, though, that various sources may give slightly varying figures for the iron concentration of mustard greens.

Calcium - The mineral calcium is essential for numerous body processes, such as blood clotting, muscle and nerve function, the growth and maintenance of healthy bones and teeth, and many more. Depending on age and gender, the recommended daily intake of calcium for people ranges from 1.0-1.3 grams. The amount of calcium in 100 grams of cooked, chopped mustard greens is around 104 milligrams. This amounts to around 10% of the adult recommended daily intake (DV) for calcium. Various elements, including the type of mustard greens grown, the growth environment, and the soil quality, might affect the precise calcium content of mustard greens. However, mustard greens are typically regarded as a good source of calcium [29][30].

CHAPTER 5

RESULTS & DISCUSSION

5.1. PROXIMATE ANALYSIS FINDINGS

Sample C was chosen as the nutrient supplement for the hydroponics system inferring from these results. The moisture content was suitable than the other samples. At the same time the electrical conductivity was least with Sample C. If EC is very high, it leads to formation of salts in long run, which in-turn affects the growth of the plants. pH was the least with Sample C as NPK(Nitrogen-Phosphorous-Potassium) and Bio-Char will be added to the system which can even more alter the pH. So having pH close to Neutral is better for the hydroponics system. As mentioned earlier if the percentage of Volatile Matter is high, it results in more porous Bio-Char which is best suitable. Sample C which had highest percentage of Volatile Matter i.e. 69% when compared to Sample A & Sample B (which had 66.5% & 57.0% respectively) is another factor for choosing Sample C. Coming to the Ash Content, excessive amounts of ash can reduce the effectiveness of Bio-Char as it can increase soil pH and reduce the availability of certain nutrients. Sample C had the least amount of Ash Content. Even the Bulk Density (Loose as well as packed) was at the moderate level. Keeping in mind all these factors, Sample C was chosen as it was the most suitable.

Table 5.1: Proximate Analysis of Bio-Char

PROPERTIES	SAMPLE A	SAMPLE B	SAMPLE C
MOISTURE CONTENT (%)	1.83	1.90	1.89
ELECTRICAL CONDUCTIVITY (2MS/CM)	0.778	1.342	0.718
PH	9.71	10.17	8.29
ASH CONTENT	55	60	45

(%)			
VOLATILE MATTER (%)	66.5	57.0	69.0
LOOSE BULK DENSITY (G/ML)	0.231	0.186	0.200
PACKED BULK DENSITY (G/ML)	0.30	0.25	0.28

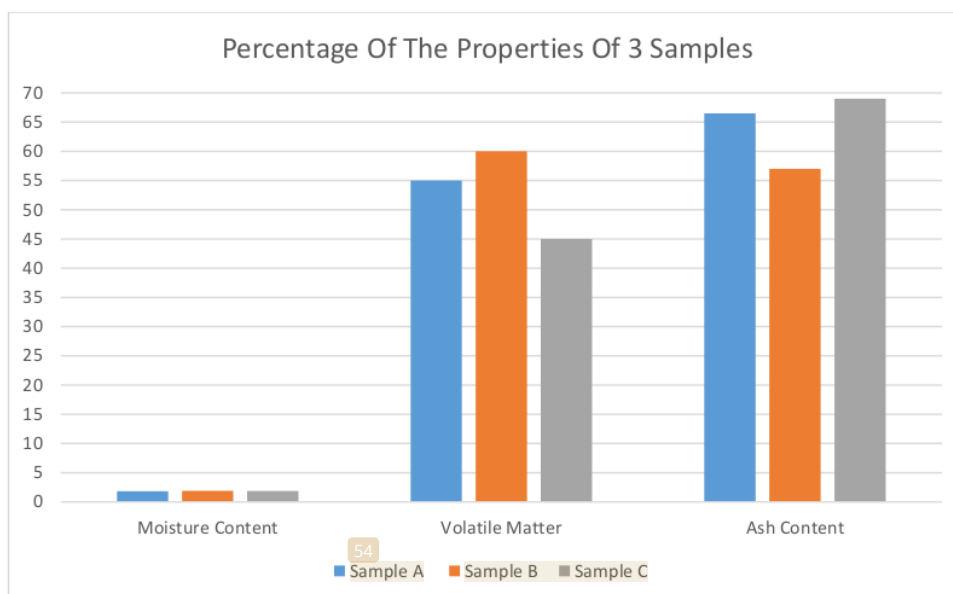


Fig. 5.1: Graph – Moisture Content, Volatile Matter, Ash Content

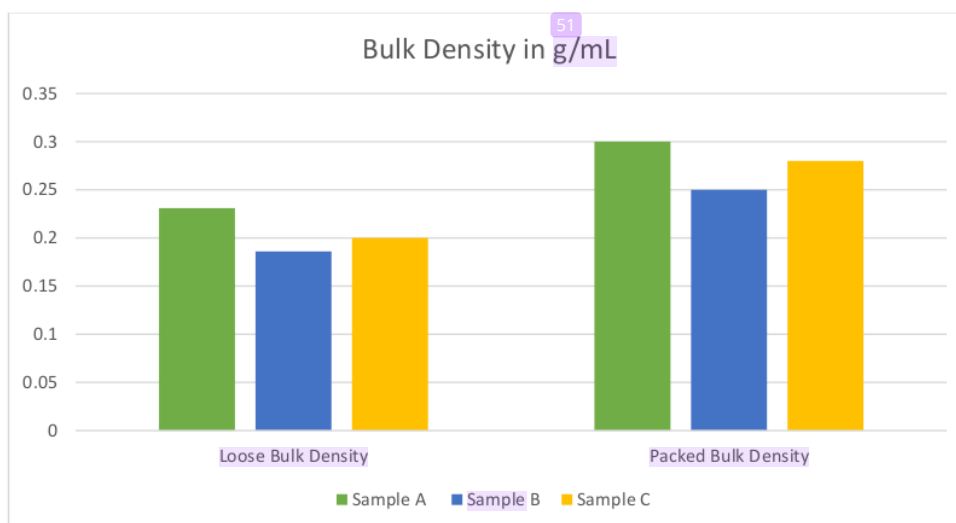


Fig. 5.2: Graph – Bulk Density (Loose and Packed)

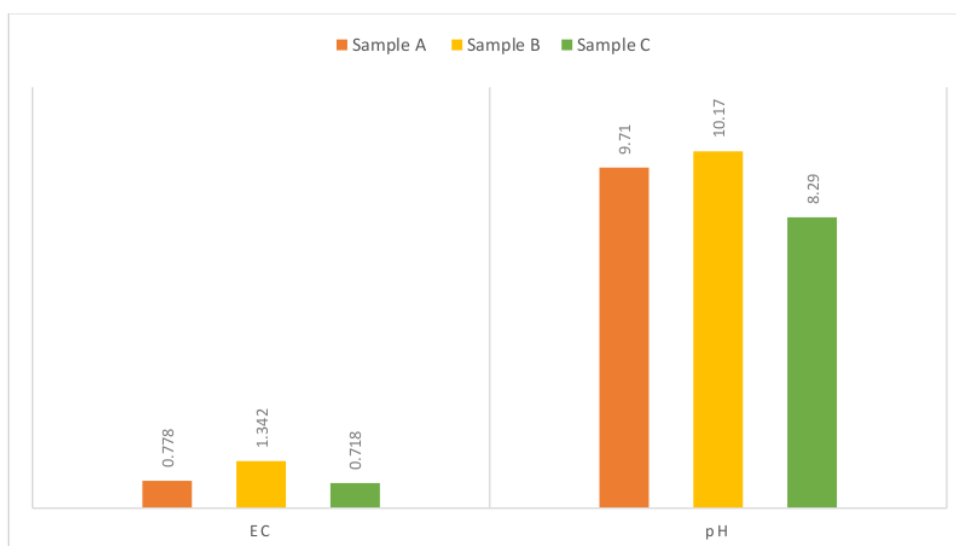


Fig. 5.3: Graph – pH and Electrical Conductivity

The plants Mung Bean, Fenugreek and Mustard were monitored for a period of 12 days. In that period, the growth rate were measured daily and the effect of Bio-Char were analyzed. The germination was quick in the presence of Bio-Char. To be precise, plants germinated only after the germination of plants with Bio-Char. Even the difference in concentration Bio-Char did have some effects. That is, the growth rate were more on the sample with highest

amount i.e. 0.6g. But the difference was only about ~ 0.1 cm. This can be associated with two reasons, since the cultivated crops are Micro-Greens, this difference is significant. Moreover, since the system is developed in small scale, it is challenging to produce more difference. If the system is developed on a large scale, there will definitely be an even greater difference.

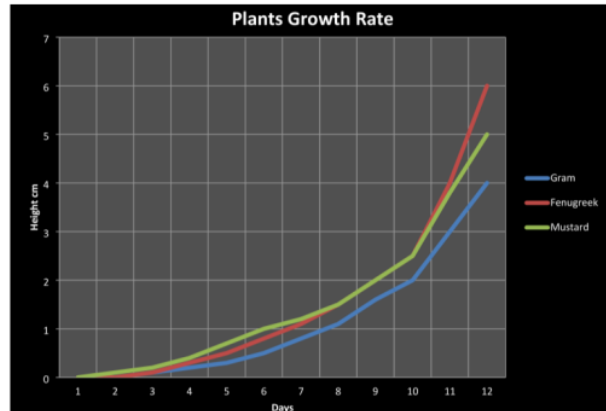


Fig. 5.4: Plants Growth Rate

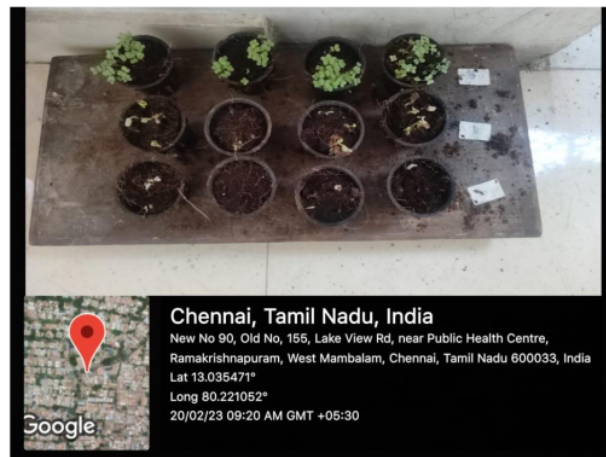


Fig. 5.5: Germination



Fig.5.6: Plant Growth

5.2. FTIR Analysis

Agilent Resolutions Pro

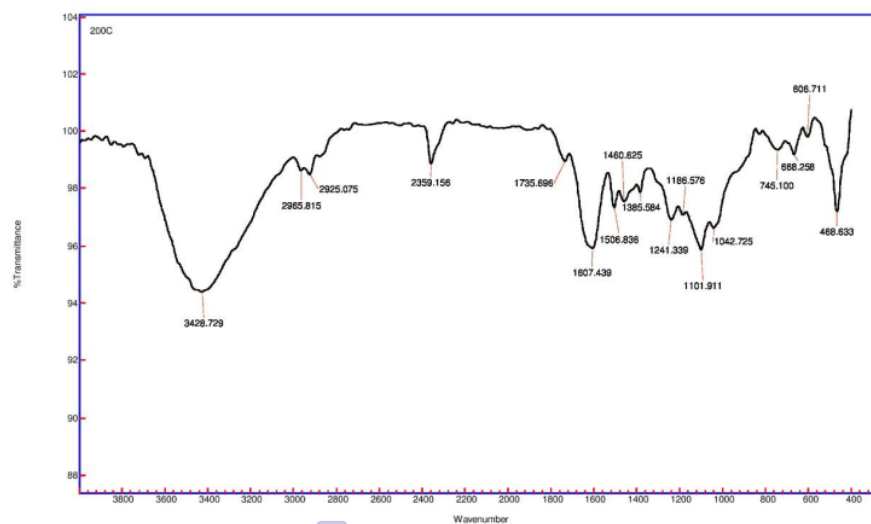


Fig.5.7: FTIR Spectrum of Bio-Char Sample

The above figure (Fig.5.6) shows the FTIR spectrum of the produced Bio-Char sample (Sample C). The table below elaborates the findings from the FTIR spectrum.

Table 5.2 FTIR Analysis

Frequency Range (cm ⁻¹)	Observed Range (cm ⁻¹)	Functional Group
4000 - 3000	3428.729	¹¹ O-H stretching vibration Presence of Alcohol
3000 - 2500	2965.815	¹¹ C-H stretching vibration Presence of Alkane
3000 - 2500	2925.075	¹¹ C-H stretching vibration Presence of Alkane
1670 - 1600	1607.439	⁴³ C=C shorting vibration Presence of Conjugated Alkane
1600 - 1300	1506.836	¹⁸ N-O stretching vibration Presence of Nitro Compound
1400 - 1000	1241.339	¹¹ C-O stretching vibration Presence of Alkyl Ether
1400 - 1000	1101.911	¹⁸ C-O stretching vibration Presence of Secondary Alcohol
1000 - 650	668.258	⁴³ C=C stretching vibration Presence of Alkene
600 - 650	606.711	¹⁸ C-Br stretching vibration Presence of Halo Compound

5.3. XRD Findings

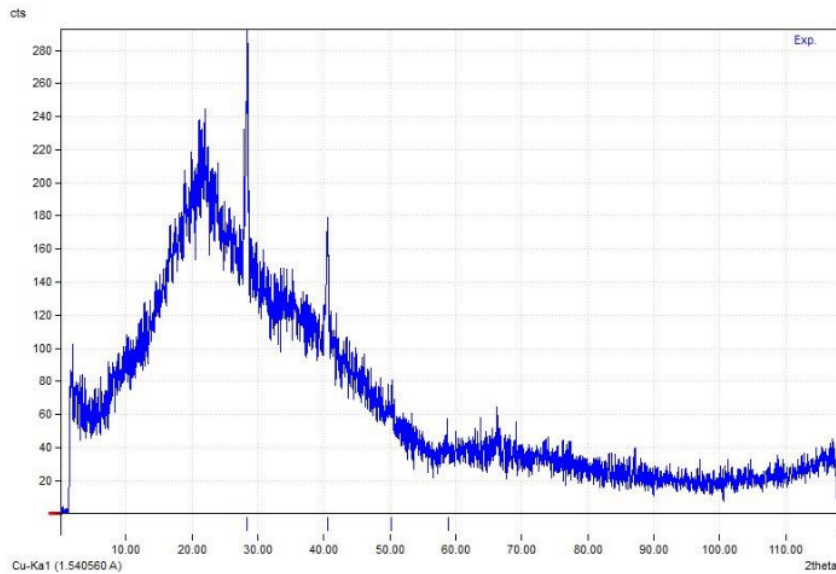


Fig.5.8: X-Ray Diffraction

As stated earlier, XRD states crystal structure, which can be inferred from finding HKL. The HKL system is based on the Miller indices, which are a set of three integers used to describe the orientation of a plane within a crystal lattice. The HKL system is used to calculate the positions of diffraction peaks in X-ray diffraction patterns, which can be used to determine the crystal structure of a material. The lattice in X-ray crystallography refers to the regular arrangement of atoms within a crystal. The lattice is described by a set of lattice parameters, which include the length of the unit cell edges and the angles between them. The lattice parameters can be used to calculate the volume of the unit cell and the density of the crystal.

Computing HKL,

Here $2\theta = 110^\circ$, therefore $\theta = 55^\circ$ or 0.96 radians, $\lambda = 1.54 \times (10^{-10})$ m.

Bragg's Rule must be used to compute HKL.

$$n\lambda = 2d \sin \theta$$

Where,

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

Here, d is the distance between crystal planes, n is an integer ($n=1$), θ is angle of incidence of X-Rays on the sample, λ is wavelength of X-Rays, a is lattice constant ($a = 10^{-10}$ m). Now equating the above equations, we find HKL.

From Bragg's Rule,

$h = 7, k = 8, l = 0$ or $h = 0, k = 7, l = 8$ or $h = 8, k = 0, l = 7$.

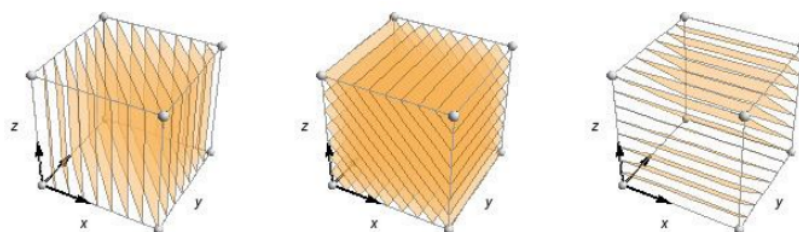


Fig.5.9: HKL Crystal Structure

5.4. NUTRIENT ANALYSIS

And the tests concluded our purpose. These tests proved that, Bio-Char did have a significant influence on the plant, as the nutritional numbers were higher on sample with Bio-Char (Sample A) than with the sample without Bio-Char (Sample B). These are elaborated in a table below.

There is a significant difference in Energy Content as we should multiply the grams of each macronutrient by the associated caloric value per gram to determine the amount of energy in a food item by adding the resulting numbers. A dietary item's total energy content, for instance, would be: if it comprises 10 grams of carbohydrates, 5 grams of protein, and 2 grams of fat. 40 calories come from 10 grams of carbs, which have 4 calories per gram. 20 calories are equivalent to 5 grams of protein at 4 calories per gram. 9 calories per gram of fat, divided by 2 grams, equals 18 calories. 40 + 20 + 18 calories make up the entire amount of energy. That is 78 calories in total. It's worth noting that the energy content of a food item can also be affected by factors such as its fiber content and how it's prepared or cooked.

Mustard greens are a good source of several important nutrients, including fiber, vitamins A, C, and K, and minerals such as calcium and iron. They are also relatively low in calories, with approximately 15 calories per 100 grams of raw mustard greens. The energy content of mustard greens comes primarily from

their carbohydrate content, which is about 3 grams per 100 grams of raw mustard greens. This provides approximately 12 calories. Mustard greens also contain small amounts of protein (about 2 gram per 100 grams) and fat (about 1 gram per 100 grams), which contribute a small amount of additional calories. It's worth noting that the energy content of cooked mustard greens may be slightly different than raw mustard greens, as cooking can affect the bioavailability of some nutrients and may alter the overall energy content.

The same procedure can be used to calculate Energy Content from our sample,

With Bio-Char (per 100g),

Amount of Protein = 2.29g = $(2.29 \times 4) = \underline{9.16 \text{ cal}}$

Amount of Carbohydrates = 3.61g = $(3.61 \times 4) = \underline{14.44 \text{ cal}}$

Amount of Fats = 1.10g = $(1.10 \times 9) = \underline{9.90 \text{ cal}}$

Total Energy = $\underline{9.16 \text{ cal}} + \underline{14.44 \text{ cal}} + \underline{9.90 \text{ cal}} = \underline{33.50 \text{ cal}}$

Similarly,

Without Bio-Char (per 100g),

Total Energy = $\underline{7.36 \text{ cal}} + \underline{12.00 \text{ cal}} + \underline{9.72 \text{ cal}} = \underline{29.08 \text{ cal}}$

Table 5.3: Nutritional Parameters

TEST PARAMETERS	UNIT	RESULTS	
		SAMPLE A	SAMPLE B
<i>PROTEIN</i>	g/100g	2.29	1.84
<i>ENERGY</i>	cal	33.5	29.08
<i>CARBOHYDRATE</i>	g/100g	3.61	3.00

<i>TOTAL FAT</i>	⁵⁶ g/100g	1.10	1.08
<i>CRUDE FIBER</i>	g/100g	2.01	1.10
<i>SODIUM – Na</i>	mg/100g	45.828	40.657
<i>MAGNESIUM – Mg</i>	mg/100g	35.780	30.476
<i>IRON – Fe</i>	mg/100g	9.044	6.328
<i>CALCIUM – Ca</i>	mg/100g	51.481	45.279

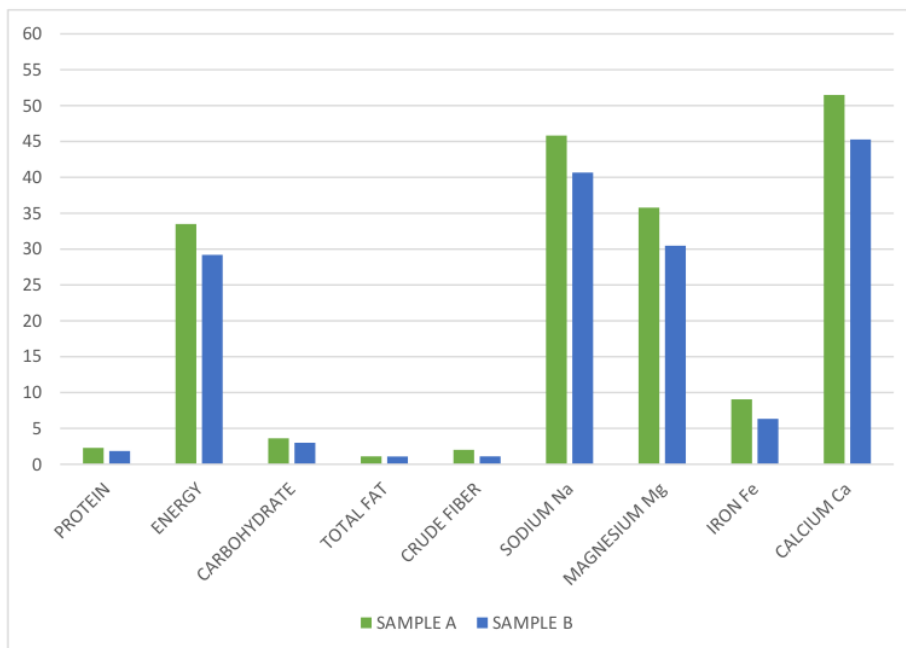


Fig. 5.10: Graph – Nutritional Parameters

CHAPTER 6

SUMMARY & CONCLUSION

Agro waste can be a sustainable resource if managed properly, since it is a renewable resource, as it comes from crops, forests, and other natural sources that can be replanted and regrown. By using agro waste, we can reduce the amount of waste that is sent to landfills or burned in open fields, which can release harmful pollutants into the atmosphere. Agro waste can be used to generate energy, such as through the production of biofuels or through the burning of biomass for electricity production. When agro waste is returned to the soil, it can help to improve soil health by increasing organic matter and nutrient availability. That is the main reason for choosing agro waste as our raw material. Bio-Char can be synthesized from various raw material, but nothing would be as perfect as agro waste, as this simply implies best out of waste. The agro waste is again used for agriculture. And utilizing the same for non-conventional farming (here Hydroponics) is the need of the hour. However, it is important to manage agro waste in a sustainable way, such as through composting, conversion into Bio-Char or biofuels, or incorporation into soil. Improper management of agro waste can lead to environmental problems such as air pollution, water pollution, and soil degradation. Anyways, agro waste can yield numerous benefits if properly used and maximum of it can be extracted in the future.

When compared to plants cultivated on soil, the nutritional value of hydroponically grown plants can vary. Plants cultivated hydroponically are grown in a soil-free media and frequently receive fertilizer solutions that are given right to their roots. It is possible to precisely regulate this nutrient solution to provide the plant the right amount of nutrients, water, and oxygen. In comparison to conventional soil-based farming, hydroponic systems' controlled environment can result in better water and space utilization as well as less pesticide use. However, a number of variables, such as the type and quality of the nutrient solution, the solution's pH level, the temperature of the growing environment, and the particular crop being produced, can affect the nutrient content of plants grown in hydroponics.

For instance, according to some research, lettuce cultivated hydroponically may have more of a number of vitamins and minerals than lettuce grown conventionally. Other research, however, suggests that tomatoes produced hydroponically may contain less of some nutrients than tomatoes grown in soil. It is crucial to remember that these changes may instead show that different growing techniques may result in variations in nutrient content rather than necessarily showing that one growing technique is better or worse than the other.

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