Biochar for Carbon Dioxide (CO_2) Capture & Sequestration

A

Seminar Report

Submitted in partial fulfillment of the requirements for the award of the degree

of

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With specialization in

BIOTECHNOLOGY

Under the supervision

Of

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(Assistant Professor)

By

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To

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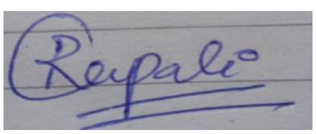
HIMACHAL PRADESH, INDIA

May-2021

STUDENT’S DECLARATION

I hereby declare that the work presented in the Seminar report entitled **“Biochar for Carbon Dioxide Capture & Sequestration”** submitted for partial fulfillment of the requirements for the degree of Master of Science in Biotechnology and Bio Informatics at **Jaypee University of Information Technology, Wakhnaghat** is an authentic record of my work carried out under the supervision of **Dr. ASHOK NADDA**, **Assistant Professor**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my seminar report.



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May-2021

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **“Biochar for Carbon Dioxide Capture & Sequestration”** in partial fulfillment of the requirements for the award of the degree of Master of Science in Biotechnology and submitted to the Department of Biotechnology and Bio Informatics, **Jaypee University of Information Technology, Wakhnaghat** is an authentic record of work carried out by **RUPALI BHARDWAJ (197807)** during a period from January, 2021 to May, 2021 under the supervision of **Dr. ASHOK NADDA**, Department of Biotechnology and Bioinformatics, Jaypee University of Information Technology, Wakhnaghat.

The above statement made is correct to the best of my knowledge.

Date: - ……………………………

Signature of Supervisor | Signature of HOD

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Abstract

As we all know that global warming is increasing at an alarming rate and the contribution of Carbon dioxide (CO_2) is involved at large scale. Thus many scientists are working on how we can reduce CO_2 release that is effecting our environment as well as health of a mankind. We already know that the plants are capable of absorbing CO_2 but looking in the current scenario CO_2 released in environment is much higher than CO_2 absorbed by the plants. Thus one of the way on which scientists are paying attention is Biochar. Biochar is obtained from the waste materials that include plant wastes and other degradable waste. Pyrolysis is a process through which biochar can be obtained and it has various positive effects. Use of biochar is one of the effective ways that can entrap CO_2 and convert it into value added products. Therefore certain modification can be done in a biochar that would ultimately increase the CO_2 absorption and ultimately reduces global warming. Pretreatment of biochar with phosphoric acid has improved carbon retention and sorption ability of biochar. The results by adding phosphoric acid even shows that specific surface area of treated biochar was also increased that would ultimately increase the carbon absorption. Furthermore incorporation of metals such as magnesium chloride, magnesium acetate, and magnesium nitrate and magnesium sulphate in the biochar has lead to enhancement of CO_2 adsorption capacity. Different studies have found that biochar is an effective and eco friendly way to reduce global warming. Various modifications in biochar by adding different chemicals and metals into it has proven to be more effective by increasing CO_2 adsorption to the greater extent. Thus here we will see how effective biochar has proven to be beneficial for our environment and what certain medication can be performed on biochar by adding enzymes or chemicals that would ultimately increase CO_2 adsorption and we can ultimately reduce the presence of CO_2 in our environment.

Keywords: Biochar, Pyrolysis, Metals incorporation,

INTRODUCTION

Release of various gases such as CO_2, CH_4 and N_2O is a major environment issues that ultimately leads to global warming (Liu et al., 2019). Various studies have shown that CO_2 is major contributor for increasing global warming (Marescaux et al., 2018). Hence it has become essential to discover such methods which are environmental friendly and will reduce the CO_2 effect leading to increased pollution (Dutcher et al., 2013). Adsorption is one of the techniques that could be effectively used to reduce CO_2 present in atmosphere (Shafeeyan et al., 2010). There are different adsorbents that can be used to absorb CO_2 present in atmosphere which are Zeolites, mesoporous carbon, nonmaterial carbon and activated carbon. Biochar is a charcoal produced by pyrolysis that has potential for absorbing CO_2 present in atmosphere for a greater extent (Ok et al., 2018). As biochar is obtained from different waste such as crop waste, wood waste, food waste, decaying plants, animal manure and sewage waste it is considered eco friendly and also entraps CO_2 to a greater extent (Rajapaksha et al., 2019). As scientists have found that biochar has greater CO_2 adsorption property thus certain modification in biochar can enhance its adsorption property even more (Rajapaksha et al., 2016). By adding different chemicals into biochar it would increase its surface area thus greater carbon retention capacity (Wang et al., 2017). Phosphoric acid can be used as an activating agent in biochar that would lead to greater specific surface area. Incorporation of phosphoric acid to the biochar by total ratio at particular temperature has lead to opening of the pores to the greater extent thus greater capture of CO_2. The pretreatment of biochar with phosphoric acid has various benefits such as greater carbon retention, increase in pore size of biochar and greater specific surface area (Huang et al., 2014). Various methods have been developed for entrapment of CO_2 and technology that is widely preferred is adsorption by amine solutions. Different porous adsorbents that include Zeolites micro porous silica and activated carbons can be used to incorporate into biochar for enhancing its adsorption capacity. Rise in the concentration of stable carbon present biochar is another method that can increase capturing of CO_2. Incorporation of potassium in a biochar has revealed in greater yield of stable carbon (Masek et al., 2019). The structure of biochar incorporated with potassium shows enhanced cross linkage that would ultimately leads to stability (Le Brech et al., 2016). Modification in biochar has proven to provide great benefits for entrapment of CO_2. Phosphoric acid was added in a biochar that increases specific surface area and size and volume of pore (Wang et al., 2017). Biochar pretreated with phosphoric acid shows greater carbon retention and greater carbon yield than the untreated one (Xu et al., 2014). Despite of all these advantages biochar has even proven to be a great medium for amendment of the soil (You et al., 2017). Biochar has helped to improve the soil fertility and added various nutrients (Woolf et al., 2010). These days, the interest for vitality is quickly expanding a direct result of the monetary development around the world. So as to fulfill this developing need, a bounteous measure of non-renewable energy source is required. Non-renewable energy source burning is frequently considered as one of the fundamental dangers to nature in light of the CO_2 discharge in the climate. In this manner, using CO_2 and changing over it into fills and synthetic substances, known as carbon capture and reuse (CCR) process, is a functioning alternative utilized worldwide to change over usable items into important items, and it is utilized to relieve CO_2 emanations which is progressively ideal contrasted with CSS choice. During the most recent years, transformation of CO_2 into value added synthetic compounds utilizing various methods for an incredible consideration from the specialists as it tends to be viewed as an answer for diminish the dangerous atmospheric devation vitality emergency and the capacity of vitality issues. Methanol is a sustainable power source that can be delivered from any crude material containing carbon (fundamentally CO_2), just as it is a perfect wellspring of vitality that can be utilized as transportation fuel. When all is said in done, for a fuel to fulfill the market request, it must be manageable material, clean, and ready to be combined from accessible assets. These days, indeed, the greater part of the creation organizations around the globe use methanol as a crude material to deliver various items. Methanol is utilized in delivering solvents like the acidic corrosive, which speaks to 10% of the worldwide interest. Methanol can likewise be utilized in direct methanol power devices (DMFC), which is utilized for the transformation of substance vitality in methanol straightforwardly to electrical force under surrounding conditions. Methanol is viewed as one of the most significant natural feedstock that can be utilized in the businesses with a yearly creation of 65 million tons around the world

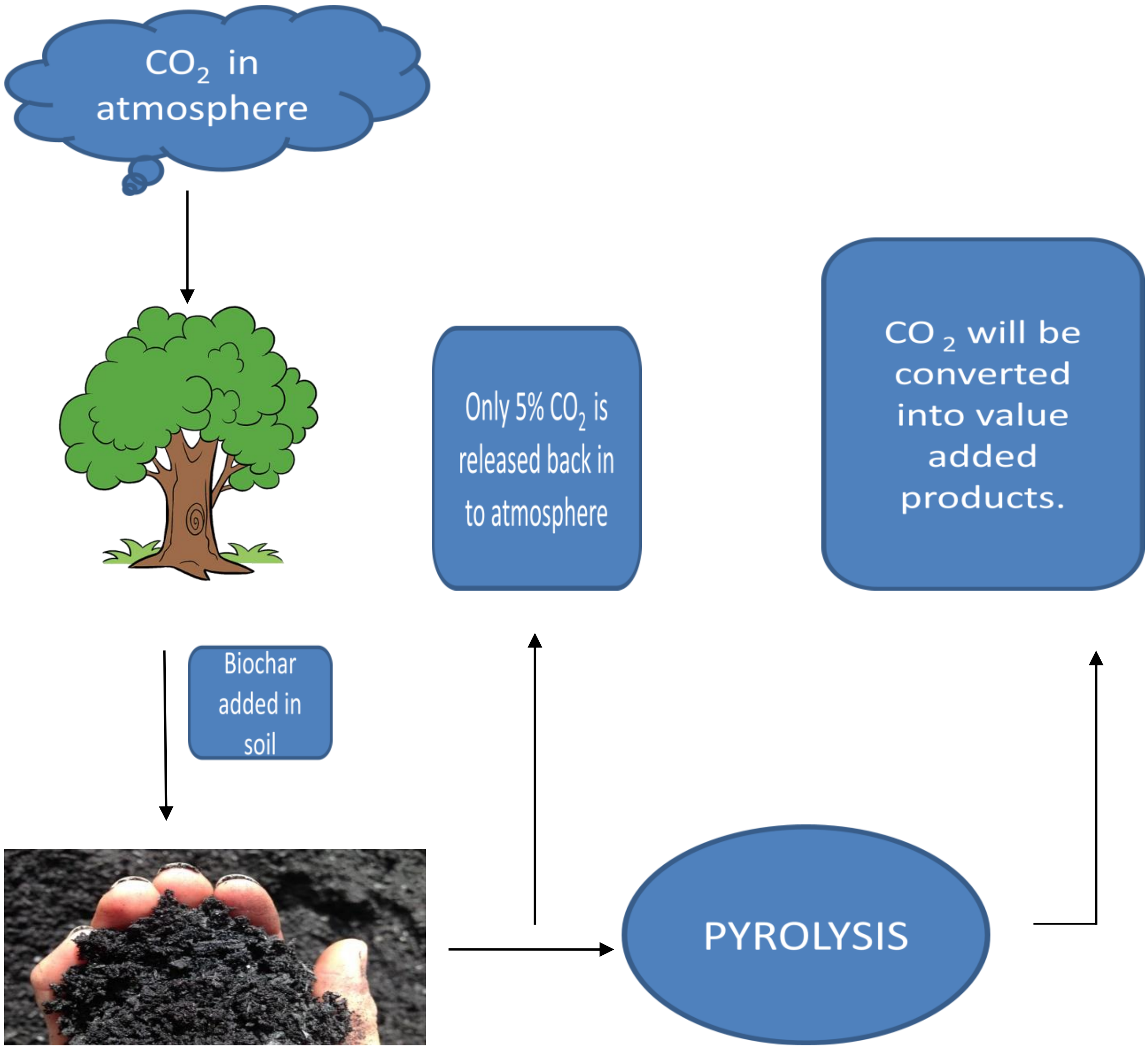

Fig1. CO_2 present in environment used to convert into Bioenergy using biochar

1. Use of biochar for CO_2 sequestration

CO_2 sequestration can also be refereed as capture of CO_2 from the environment where various technologies helps to capture CO_2 and store it that can further helps in making environment friendly products that can be ethanol or methanol. It is beneficial for environment as it reduces the carbon dioxide content in environment and in addition from this carbon dioxide we can get various important fuels that can be helpful in long term. Thus biochar is an effective way for CO_2 capture and its sequestration.

Soil is the major source that store greater amount of carbon that is even greater than CO_2 present in environment. Plant through the process of photosynthesis absorbs the CO_2 thus getting captured in the soil but ultimately it is further added back into the environment with the help of biological process performed by micro organisms. Therefore here CO_2 sequestration comes into role. As we can add biochar into the soil that has a potential for capturing greater amount of CO_2 in the soil that would ultimately reduce the release of CO_2 into the environment.

2. Use of Potassium for increasing the efficiency of biochar for CO_2 sequestration

Several studies and experiments performed by scientists show the results that various alkali metals including K, Na, Ca, Mg has shown the positive results for increasing biochar yield for CO_2 sequestration. Therefore use of such metals can be beneficial as it would enhance the absorption capacity of CO_2 in the biochar. In addition these metals are easily available and economically feasible.

2.1. Potassium doping in biochar

According to the experiment performed by Masek et al., 2019 on Miscanthus the biomass shows the positive results by adding alkali metals. There results shows that when doping of potassium was done the yield of biochar came out to be increased by 10.5% to 21.1% as compared to untreated biomass. According to then two other main criteria also include stable carbon yield. Therefore they use hydrogen peroxide for determining the stable carbon content thus showing the positive effect. Thus all alkali metal treatment results increase in stable carbon yield (Nowakowski et al., 2007).

The steps followed in potassium doping for biochar are as follow:

- Alkali metal loaded Miscanthus with 1% and 2% w/w content potassium was added by spraying potassium acetate on oven dried Miscanthus. [Fuentes et al., 2008]
- The potassium was added and moisture of biomass has been resorted.
- 1% potassium doped Miscanthus was pyrolysis at 350 to 750 degree Celsius.
- Hence, at last biochar structure was examined through Raman spectroscopy and X-ray diffraction.

Therefore the comparison was done between Potassium doped biochar versus untreated biochar the results that were observed were very positive. The potassium doped biochar has greater CO_2 adsorption capacity and the volume of pores was also increased as compared to untreated biochar. Thus doping of potassium found to appropriate can be used as a modification for biochar that would give us better CO_2 adsorption.

2.3 Affect of potassium doping on microstructure and carbon stability of biochar

The increased stability was determined by enhanced cross linking reaction (Le Brech et al., 2016). Structure was observed through Raman spectroscopy that can help to easily differentiate between Potassium doped and untreated biochar. The results that were observed includes that potassium doped biochar shows grater cross linkage which means greater absorption of CO_2 as well as increase in volume and size of pores were observed as compared to that of untreated biochar (Liu et al., 2015).

2.4. Potassium doping increases carbon sequestration

Earlier it was observed that biochar can store 0.7-1.8 Gt CO_2 but after performing the experiment of doping biochar with potassium it was found that biochar can store 45% more CO_2 (Smith et al., 2016). Another benefit that was added is majority of potassium treated biochar is that it also helps in soil amendment that means increasing the soil fertility through $Cacl_2$ extraction (Peter et al., 2015). Thus it was concluded that potassium doping has increased CO_2 sequestration as well as better slow release potassium fertilizer.

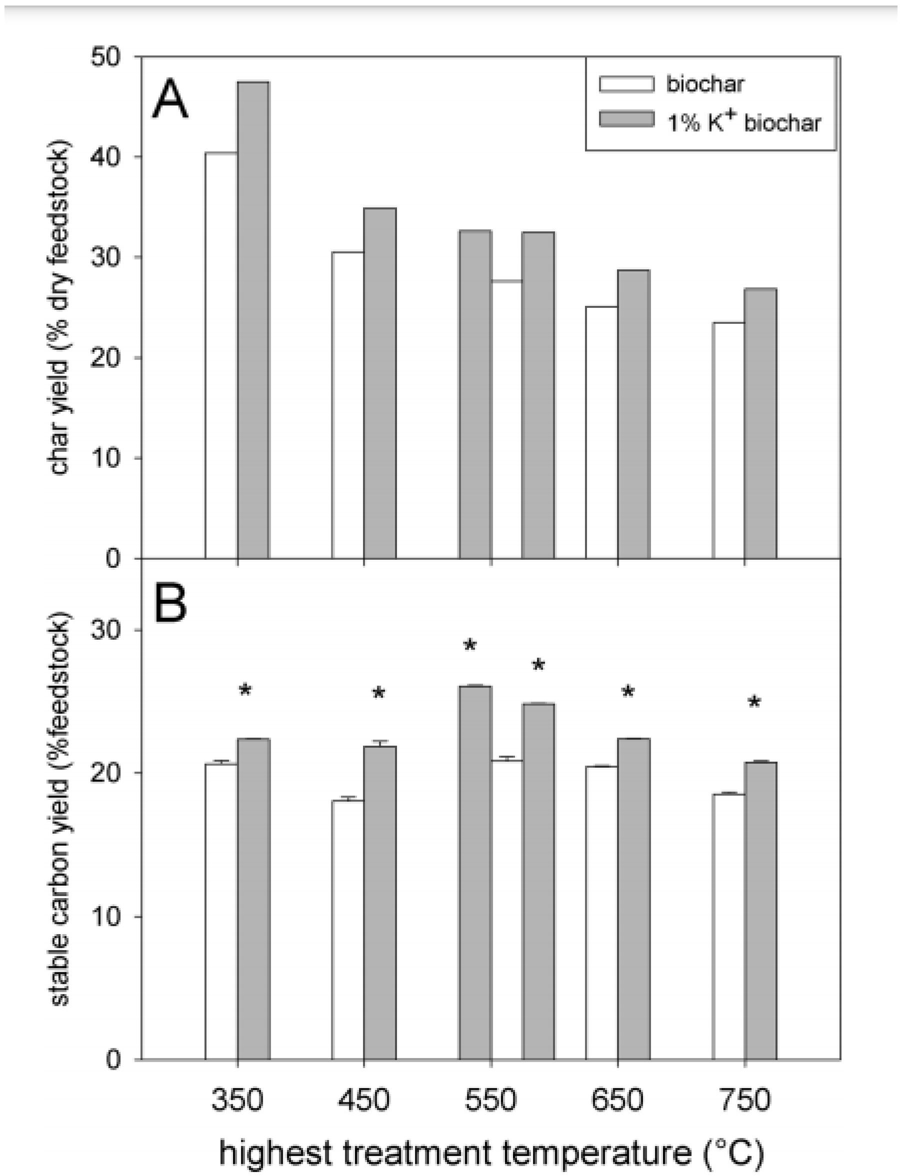

Fig 2: Comparison between untreated & potassium treated biochar [Masek et al., 2019]

3. Role of phosphoric acid

As previously studied biochar has given lots of beneficial aspects that are helpful to our environment but several of studies show that biochar has generally low specific surface area therefore scientists are working on the methods through which this specific surface area can be increased so as to get greater CO_2 sorption (Keiluweit et al., 2010). Therefore experiments performed by Zhao et al., 2017 shows that phosphoric acid can be used to pretreated biochar that would result in increased specific surface area.

This experiment was performed to get the results of various questions that were:

- To examine the pyrolysis temperature and inducing ratio of phosphoric acid on biochar so as to get appropriate pore structure.
- To check Carbon structure during co pyrolysis with phosphoric acid.
- To check sorption ability of phosphoric acid (Hungal et al., 2014).

3.1. Biochar production with Phosphoric acid

- Pine tree saw dust were collected
- Dried at 60 degree Celsius till particle size become greater than 1mm
- Then this sawdust was treated with diluted phosphoric acid
- 85% of phosphoric acid was diluted to 8.5 and then mixed with 50g of sawdust
- Thus inducing ratio were 0.359:1 and 0.718:1

Therefore the values were decreased as compared to those that were used to produce activated carbon (Le Blance et al., 2016).

3.2. Results of Biochar yield and CO_2 retention

Biochar yield can be calculated by weight of biochar subtracted by phosphoric acid upon weight of biomass. Thus Zhao et al 2016 found that there was a change in the weight of phosphoric acid thus actual yield came out to be much higher. CO_2 retention can be calculated by total carbon contents of biochar. Therefore it was concluded that the yield of biochar treated with phosphoric acid was quit high and the retention or absorption of CO_2 was also increased as compared to the untreated one.

3.3. Changes in pore formation by adding phosphoric acid

The surface area and pore volume show that they were much higher in biochar inducing with phosphoric acid. The experiment was performed at three different level and results show that the untreated biochar was having lesser specific surface area. There observation finally concluded that phosphoric acid induced biochar has shown better results than that of untreated one where there was increase in the surface area and increase in the pore size and its pore volume (Wang et al., 2017).

3.4 Enhancement of $C0_2$ Retention by adding phosphoric acid

The biochar that was pretreated with phosphoric acid results in better CO_2 retention and greater carbon yield that has increased from 46.5% to 78.5%. In addition it also increases the aroma that is due to decrease in hydrogen. The carbon retention was observed at three different temperatures that are 300,500,600 degree Celsius and the results that were observed were positive they concluded the biochar treated with phosphoric acid shows better carbon retention capacity than that of untreated biochar (Xu et al., 2014).

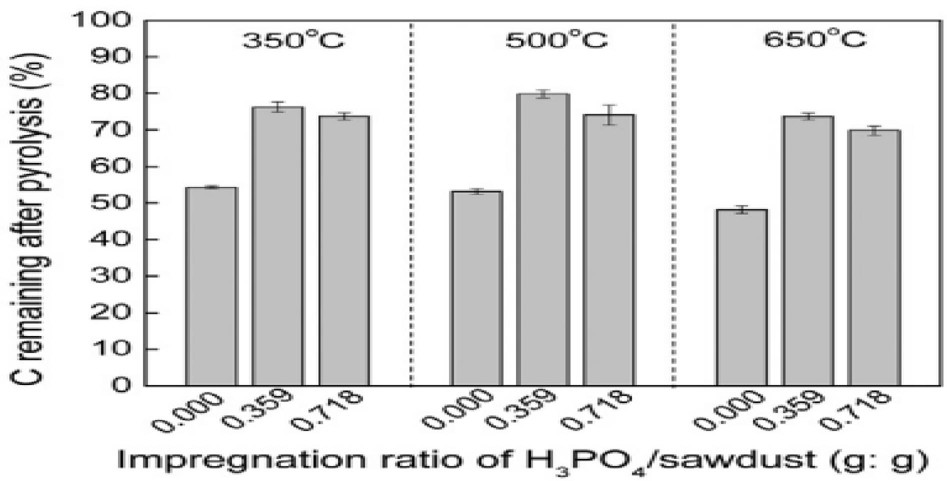

Fig 3: CO_2 remaining in biochars after pyrolysis under different production temperatures and impregnation ratios (Ling et al., 2017).

4. Adsorbents for CO_2 capture on biochar

Biochar has been proven to be environmental friendly and has proven its benefits in various aspect but one of the important is use of biochar as carbon dioxide adsorbent it is because biochar is 10 times more cheaper than other adsorbents thus it becomes economically feasible (Chatterjee et al., 2018). Studies show that raw biochar has low adsorption capacity but if this raw biochar is modified we can get enhanced biochar for great CO_2 adsorption.

4.1. Properties of biochar that influences CO_2 adsorption

4.1.1. Physical properties

Vander Waals forces are involved in $C0_2$ adsorption between biochar and gas molecules that are mainly related with specific surface area and pore size (Sun et al., 2014).

(a) Specific Surface area

Specific surface area of biochar is determined as the ratio between total surface area and total mass of biochar (You et al., 2017). The effect of Specific surface area of biochar has a greater impact on CO_2 adsorption (Xu et al., 2016). Greater the surface area greater the active site for CO_2 adsorption (Creamer et al., 2016). According to some studies high mineral content leads to reduction of specific surface area and blocking its pores on biochar surface. Furthermore if we increase the temperature during pyrolysis the surface area has also increased that may be due to increase in volatile matter that increases the volume of pore (Ahmad et al., 2014).

(b) Pore size and pore volume

Micro pores having diameter less than 1mm plays a vital role because CO_2 capture capacity is dependent on them (Zhang et al., 2013). An experiment as resulted that effect of pyrolysis temperature on pore volume leads to increase in micro pore volume (Angin et al., 2013).

4.1.2. Chemical properties

Alkalinity, mineral composition, functional groups are certain chemical properties that adversely affect the biochar (Huang et al., 2015).

(a) Basic functional groups

The adsorption of CO_2 on the surface of biochar is very essential thus surface basicity has a greater contribution on it because ultimately it enhances the affinity of biochar for CO_2 (Shafeeyan et al., 2010). Functional groups containing nitrogen (amide, imides, pyridium) and oxygen (ketones, pyrones, chromens) have a major role in surface basicity (Chiang et al., 2017).

(b) Alkaline and alkaline earth metals

The presence of alkaline metals such as Sodium, potassium, Calcium and magnesium has proven to increase the adsorption capacity of carbon dioxide on the biochar surface that may be due to formation of basic sites (Xu et al., 2016).

(c) Hydrophobicity, polarity, aromaticity

Biochar having characteristics of Hydrophobicity, non polarity mainly contributes to greater CO_2 adsorption capacity, low hydrogen and carbon ratio has found to have higher degree of aromaticity (You et al., 2017).

4.2 Modification of Biochar for greater CO_2 adsorption

4.2.1 Alkali based modification

Various studies have shown the use of KOH or NaOH as the activating agent for biochar that helps to increase the O content that initially increase the surface basicity of biochar. They also help to create greater surface area (Li et al., 2014) there were different experiments performed where KOH was induced in biochar and it has shown positive results that includes high surface area and greater micro pores thus exhibiting higher capacity for carbon dioxide adsorption.

4.2.2. Amino based modification

Introduction of ammonia or nitrogen containing functional groups has proven to increase surface area and enhance carbon dioxide adsorption (Palansooriya et al., 2019).

4.2.3. CO_2 activation of biochar

Biochar can be treated with certain activated CO_2 that leads to enhancement of micro pores that helps increasing CO_2 adsorption (Rashidi et al., 2016).

5. Use of metals for biochar modification:

Modification of biochar in order to increase CO_2 adsorption has become a necessary aspect. There are various techniques that are being discovered but with various shortcomings and those is not much environment friendly. Thus it is the necessity to develop such technologies that are environmental friendly too. In this situation use of solid adsorbents are being preferred (Madzaki et al., 2016).

The experiment performed by Guo et al that notices that use of MgO is beneficial because of various characteristics that are non toxicity and basic nature (Guo et al., 2020). In their studies they concluded that presence of MgO has basic sites of biochar surface leads to adsorption of acidic CO_2 with basic O^{2-} in the O^{2-}—Mg^{2+} bonds to form carbonate (Lahijani et al., 2018).

Secondly in the presence of MgO the adsorption of CO_2 is more even at low temperature that can be done by the process called carbonation (Elvira et al., 2017).

5.1 Experiment performed by Guo et al was

- Rambutan peel (Naphelium lappaceum) was used for making biochar.
- Rambutan peel were washed, cut and dried in oven at 105 degree Celsius for 24 hrs
- Rambutan peel biomass was heated in tube furnace under N_2 for pyrolysis temperature ranging from 500-900 degree Celsius
- Samples were allowed to cool down for 90 minutes
- The biochar yield obtained were: 27.18% at 500 degree Celsius
  21.47% at 700 degree Celsius
  13.25% at 900 degree Celsius
- Samples were set for grinding and then stored

5.2 Preparation of metalized biochar

- To obtain metal oxide biochar different magnesium salts were introduced through wet impregnation method. The Mg salts used were:
  - Magnesium nitrate hexahydrate
  - Magnesium sulphate heptahydrate
  - Magnesium chloride hexahydrate
  - Magnesium acetate tetra hydrate
- 5% Mg solution has to be achieved
- Thus, metal precursor was dissolved in 60ml of deionized water.
- 0.5g biochar was added in the solutions
- Mixture was kept for stirring for 6hrs
- Then was kept in oven at 105 degree Celsius for 24hrs

- Afterwards dry metalized biochar was obtained and heated under Nitrogen flow at 500 degree Celsius for 15 minutes.
- Then obtained metalized biochar were stored in sealed container

5.3 Results of metal loading on biochar

- The biochar pyrolyzed at 900 degree Celsius shows highest CO_2 adsorption
- The biochar loaded with magnesium nitrate shows the highest CO_2 adsorption that is 76.78 mg g^{-1} that has been increased by 11.7% then the untreated one.
- The biochar loaded with magnesium acetate shows the lowest adsorption capacity that was 68.15 mg g^{-1}

Thus, scientists study shows that loading of metal ion on the surface of biochar leads to increase in surface basicity that leads to higher adsorption of CO_2 (Xu et al., 2016).

6. 1. Chemical Methods used to increase CO_2 adsorption

Membranes are used as a method of CO_2 capture in various fields because of its advantage that is low price and easy availability. Membranes act as a filter various gas molecules get filtered through it and thus the desired molecules of gas are achieved.

Advantages of membranes:

- Cost effective
- Low capital & operational cost
- Simplicity & Reliability
- Adaptability
- Design efficiency

Table 1: Classification of membrane based on pore size

Pore Classification	Pore size (nm)
Micro pore	<2
Meso pore	2-50
Macro pore	>50

6.1 Membrane separation mechanism

- Size sieving: The gas molecules can be filtered based on their size. The size of membrane is based on the size of desired gas.
- Surface diffusion: It is generally based on the affinity of desired gas molecule that diffuses the desired gas. Diffusion rate of Carbon dioxide is 0.33nm
- Ion transport: Ions of desired gas is used in the membrane filtration process

6.1.1 Membranes used for CO2 adsorption

Table 2: CO_2 selectivity of different membranes at different temperature

Membrane	Permeability (mol/s/m Pa)	CO_2 selectivity (%)	Temperature (degree Celsius)	References
Palladium	$9x10^{-9}$	27	227	Khatib et al., 2011
Silica (Si400)	$2.01x10^{-6}$	7	200	Tong et al., 2004
Poly vinyl chloride	$5.36x10^{-12}$	11	35	Choi et al., 2008
Zeolites-A	$9.45x10^{-10a}$	10	35	Gu et al., 2008
MOF-5	$2.80x10^{-6}$	4.3	25	Cao et al., 2012
Cellulose acetate	$2.48x10^{-7a}$	40.17	37	Ahmad et al., 2014

6.1.2. Modified biochar used for CO_2 capture:

Table 3: CO_2 adsorption capacity of modified biochar

Modified biochar	CO_2 adsorption (%)	Temperature (degree Celsius)	References
Potassium based biochar	31.8	300-600	Masek et al., 2019
Phosphoric acid based biochar	73.9-78.5	350-500	Zaho et al., 2017
Magnesium nitrate based biochar	76.75	400-700	Guo et al., 2020

7. Role of Biochar enriched with nutrients for increasing soil fertility

As we know that India is counted amongst the highest agriculture cultivating countries in the world and is found that the traditional agricultural system are the major contributor for environmental pollution. According to various studies and survey it is found that agricultural waste is always left untreated thus contributing to the pollution. Hence this waste can be converted into Bioenergy or biofertilizer that can help to enhance the fertility of soil (Geissdoerfer et al., 2017).

Anaerobic digestion has been considered as a greater technology that can produce Bioenergy from the agricultural waste from past few decades (Angelidaki et al., 2018). The anaerobic digestate generally includes various nutrients such as Ca, Mg, K, Zn, Cu, Fe, Mn in added to organic matter thus it concludes to be greater source of agricultural nutrients (Risberg et al., 2017).

But the present scenario is facing certain challenges which are as follow:

- Increase in the number of industrialized livestock and biogas plant the production of anaerobic digestate is higher than the agricultural potential (Torrijos et al., 2016).
- Due to guidelines of agricultural councils only small amount of anaerobic digestate can be used in the land and use of anaerobic digestate is totally restricted in non cropping season (Chen et al., 2013).
- It requires large storage area and transportation to the distance parts are also difficult (Chadwick et al., 2015).

Therefore, for dealing with such difficulties one alternative that could be considered is anaerobic digestion treatment integrated with pyrolysis. Thus resultant biochar can help in adsorption of nutrients and helps to increase the soil fertility. Various studies show that biochar adsorbs Nitrogen, Phosphorus, Potassium and various organic matters from different areas (Takaya et al., 2016).Thus this biochar will help to improve soil texture and nutrients (Novak et al., 2018).

7.1 Experimentation

Experiment by Simon Kizito et al., 2019 was as follow

BIOCHAR

↓

Corn cobs (CB) | Pruning of fig trees (WB)

↓

Biochar was produced by slow pyrolysis at 600 degree Celsius for 10hrs

↓

Biochar surface area was determined by N2 adsorption and structural composition was determined by XRD technology

7.2. Procedure to concentrate anaerobic digestate nutrients on biochar

- Raw biochar (CB & WB) were dried at 85 degree Celsius overnight to stabilize moisture content
- Biochar was added to digestate with the ratio of 1:5 (wt/wt)
- Mixture was stirred for 48 hrs
- pH was adjusted at 6
- Thus, amount of nutrients adsorbed on biochar were calculated based on initial or final concentration.
- At the end liquid and solid phase were separated by manual sieving (0.25)
-

7.3 Results

Table 4: Recovery of nutrients from the experiment

Nutrients	Corn cobs (CB) (mg/g)	Pruning of fig trees (mg/g)
NH_4^+--N	15.3	23.6
PO_4^{3-}--P	23	19
K^+	27.2	21

8. Effects of biochar on sustainable agriculture

Various greenhouse gases are released through agriculture that leads to their contribution in global warming (Burney et al., 2010 ; Robertson, 2000; Smith et al., 2008). Contribution of agriculture for the release of greenhouse gases is approximately 24% (Smith et al., 2007) and contribution for release of methane and nitrous oxide is 54% and 84% (Smith et al., 2008). Therefore use of biochar has come on a positive note that would lower the greenhouse gas emission (Spokas and Reicosky, 2009; Zhang et al., 2012b; Zimmerman et al., 2008). The release of CO_2 is mainly observed by burning of the agricultural waste (Smith et al., 2008). CO_2 released through agricultural process is naturally sequestrated through photosynthesis but in a long term for greater CO_2 entrapment it is not an effective way therefore biochar can be added that would increase the efficiency for CO_2 sequestration (Lee et al., 2010). In addition to increase CO_2 sequestration through biochar it has also decrease the release of methane and nitrous oxide (Liu et al., 2011).

8.1 Effect of biochar for soil amendment

Different scientists conclude that addition of biochar into the soil has come up with not only increase CO_2 sequestration but also it has helped in amendment of soil that includes increased soil quality and soil fertility and additionally improved the nutrient cycle in the soil. The properties of biochar are depended on the type of waste material that is being used and different temperature at which pyrolysis takes place (Lehmann et al., 2011; Barrow 2012; Alburquerque et al., 2014). Various properties of biochar affect the soil quality and in addition there chemical and physical characteristics can be affected in a same way (Downie et al., 2009). When biochar is added into the soil it directly affects on the different properties of soil that includes its surface area, porous activity, water holding capacity, penetration power and many more (De la Rosa et al., 2018; Downie et al., 2009; Mukherjee and Lal, 2013).

8.1.1. Physical effects

Soil consists of different characteristics that are important role not only in the growth of plants but also in the reduced release of harmful gases because of its functions that includes water and nutrient holding capacity (Batool et al., 2015; Downie et al., 2009; Waters et al., 2011) but soil generally does not possess greater water and nutrient holding capacity that may be due to presence of clay in greater amount or smaller surface area (Troeh et al., 2005). Therefore here biochar is added as biochar posses greater surface area that would generally retain more amount of water and minerals (Downie et al., 2009). Studies have shown that addition of biochar into the soil has given 4.8 times better results as compared as compared to the untreated one (Liang et al., 2006). Many scientists have concluded that combine use of soil and clay with addition of biochar has increased number of pore as well as its size (Brodowski et al., 2006; Cheng et al., 2006).

Table 5: Results observed after addition of biochar in a field of different crops

Culture System	Crop used	Biochar added	Results	References
Open fields	Rice	Teak wood residues	➢ High grain yield ➢ Improved response to Nitrogen treatment	(Asai et al., 2009)
Open fields	Maize	Wheat straw	➢ Maize yield increased by 15.8% ➢ GHG emission was also reduced	(Zhang et al., 2012b)
Open fields	Grape	varied hardwood and	➢ No effects on plant growth	(Schmidt et al., 2014)

		varied coniferous wood chips	➢ No specific difference was observed in the quality	
Open fields	Apple	Acacia whole tree green waste	➢ Positive impacts were observed including greater water retention	(Eyles et al., 2015)
Open fields	Cotton	Cotton stalk	➢ Water content in leaf increases	(Kannan et al., 2017)
Open fields	Maize	Pine wood	➢ Addition of biochar have significant effect in biomass	(Pressler et al., 2017)

8.1.2. Chemical effects

As we know that biochar has larger surface area and greater permeability due to presence of porous, these characteristics may offer a chance to hold and adsorb plant nutrients and thus improve soil fertility (Lehmann, 2007b). Numerous new studies have recorded various advantages with biochar addition to soil, including Cation exchange capacity (CEC), decreased N leaching, upgraded microbial addition, liming, and different benefits (Cornelissen et al., 2013; Kloss et al., 2014; Lehmann et al., 2011b; Mia et al., 2014; Ventura et al., 2012). Soil cation exchange capacity (CEC) is a proportion of its capacity to hold positively charged particles (i.e., Ca^{2+}, K^{+}), while anion exchange capacity (AEC) holds negatively charged particles (i.e., NO_3^-) (Joseph et al., 2010). Nonetheless, this capacity of cations and anions of biochars are likely subject to their cation exchange capacity and anion exchange capacity (Lehmann and Joseph, 2015).

8.1.3. Soil biological activity

There are varieties of complex organism present in soil, like microbes, parasites, nematodes, protozoa, and different spineless creatures. The presence of these microbes are constantly changing because of soil qualities and the various factors, especially concerning the addition of biochar (Thies et al., 2009). The studies dine till date shows that the addition of biochar to soils can establish a medium that increases soil microbial activity, and hence influencing soil microbiological properties. For example, (Lehmann et al., 2011b; Rutigliano et al., 2014; Tong et al., 2014; and Gul et al., 2015) increase in the biological activity of microbes when biochar was incorporated into soil. Additionally types of feedstock added in the soils could have a poisonous impact on soil microorganisms due to bio-oils and natural mixtures adsorbed on the surfaces of some biochar (McClellan et al., 2007). Biochar's high surface area and its capacity to absorb nutrients, give a positive effect to microorganisms like microscopic organisms, actinomycetes and arbuscular mycorrhizal parasites to colonize, develop and duplicate (Kookana et al., 2011; Thies et al., 2009).

9. Use of different solvents for CO_2 capture

9.1Chemical absorption solvents

9.1.1. Conventional amine-based solvents

This process is mainly amine based that can be used for removal of CO_2 and hydrogen sulfide. CO2 is retained normally utilizing amines to frame a dissolvable carbonate salt. The safeguard works underneath 60°C and surrounding pressure (Kohl et al., 1997). These days, amine-based concentration retention came up as a potential innovation that can be applied to capture CO_2 outflows in mechanical procedures such us non-renewable energy sources power plants, concrete creation and iron and steel fabricating. Post-burning is the closest near market and modernly created carbon catch and capacity innovation. In particular, the alkanolamines are unstable, modest and safe to deal with mixes and are usually grouped by the level of substitution on the focal nitrogen; a solitary substitution meaning an essential amine; a twofold substitution, an auxiliary amine; and a triple substitution, a tertiary amine.

9.1.2. Sterically hindered amine solvents

These are viewed as a sort of amines which can enhances CO_2 capture rates in correlation with the normal essential and second amines, typically amino alcohols. A Sterically hindered amine is framed by an essential or auxiliary amine in which the amino acids are formed to a tertiary carbon particle in the main case or an optional or tertiary carbon molecule in the second. This strong bond form high free-amine fixation in arrangement, so the vitality utilization to discharge CO2 is bring down that the basic essential and second amines decline up to 15% can be accomplished utilizing ruined amines (Hüser et al., 2017).

9.1.3 Non-amine-based solvents

These are called to those concoction solvents which don't incorporate an amine group in their structure sub-atomic. The most pertinent dissolvable proposed as an option in contrast to the traditional amine-based solvents is the sodium carbonate (Na_2CO_3). About 30% p/p sodium carbonate slurry is utilized to give a fundamental situation in which CO_2 is ingested as bicarbonate followed by sodium bicarbonate arrangement. The $NaHCO_3$ precipitation upgrades the bicarbonate development and, subsequently, the CO_2 catch limit of the dissolvable is improved (Spigarelli et al., 2013)**.**

9.1.4. Ionic liquid

Scientists have found through their studies that amine-based solvents, specifically ionic fluids (ILs) have a positive effect. These mixes are natural salts with raised heating points and in this way low fume pressure, which can specifically ingest corrosive gases, for example, CO_2 and SO_2, including moderately low recovery vitality prerequisites (Zeng et al., 2017) has a specific molecular structures specifically designed for each application, in particular for low CO_2 concentrated flue gas treatment (Luo et al., 2017).

9.2. Physical Absorption Solvents:

Physical absorption forms are energetically prescribed to isolate CO_2 in pre-combustion processes that usually work at lift CO_2 incomplete weight. Physical solvents can specifically catch CO_2 in contact with a gas stream without a synthetic response happening. As it was shown in the presentation area, the high fractional weights of CO_2 and low temperatures are alluring to acquire an improved exhibition of the physical ingestion process as far as assimilation rates and dissolvability harmony of CO_2. At that point, the rich dissolvable is recovered.

Physical Absorption Solvents are as follow:

9.2.1. Selexol

Selexol is a process for acid gas removal solvent that separates acid gases and is being used from long period of time (Kohl et al., 1997). In this process flue gas is dehydrated and then send to absorption column at 30 atm and 0-5 degree Celsius and then there is selectivity of acid gas in the column. A pre treatment column is used for separation of carbon dioxide and thus at the last stage CO2 is recovered (Hammond et al., 2014).

9.2.2. Rectisol

Rectisol is another process that helps in removal of gas which includes H_2S and CO_2 from different mixtures of gases. The CO_2 obtained has various advantages that can be used in the production of certain value added products including methanol, ethanol, urea, ammonia and many more. This process is highly selective towards carbon dioxide and thus it can be easily separated from the mixture of gases. In Rectisol syngas needs to be cooled before its introduction to the column. Firstly sulphur compounds are removed and at the end CO_2 can be captured.

9.2.3. Ifpexol

Ifpexol gas is used for natural gas application. It is two steps process these firstly removal of condensable hydrocarbons and water. Secondly removes acid gas (Lecomte et al., 2010). In this process absorber works in low temperature that is at -29 degree Celsius so that methanol loss can be reduced. This process helps to capture carbon dioxide and methanol at low temperature.

9.2.4. Fluor

Among all the different process for carbon dioxide capture solvents fluor is considered one of the appropriate processes (Reddy et al., 2008). In this process moderate to high temperature is required. Similarly flue gas needs to be dehydrated first before it enters into the column. Hence carbon dioxide absorption takes place through carbon dioxide loaded solvents and thus high purity of carbon dioxide is recovered

9.2.5. Purisol

This process is mainly performed to treat at high temperature because it has high selectivity for H2S. In this process for obtaining carbon dioxide the removal of H2S is not needed. This process takes place at 50 bar and -15 degree Celsius and thus we can obtain the required gas (Yu et al., 2012).

Table 6: Different solvents used for CO_2 capture with their advantages and disadvantages

PROCESS	ADVANTAGES	DISADVATAGES
SELEXOL	Non-thermal solvent regeneration Non-corrosive solvent Dry gas leaves from the absorber	• Most efficient at elevated pressures
RECTISOL	• Non-foaming solvent	• High refrigeration costs
IPEXOL	• High chemical and thermal stability • Non-corrosive solvent	• High capital costs • Amalgams formation at low Temperature
FLUOR	High CO2 solubility • Non-thermal regeneration • Simple operation • Non-corrosive solvent	• High solvent circulation rates • Expensive solvent
PURISOL	• Non-foaming solvent • High chemical and thermal stability • Non-corrosive solvent	• High compression cost • Most efficient at high-pressure
SULFINOL	• High capacity • Low solvent circulation rate	• Foaming issues • Corrosive solvent • Thermal regeneration

Conclusion

Biochar has proven to be environmental friendly and economical for adsorption of carbon dioxide because of its characteristic properties. Major characteristics of biochar include greater specific surface area, pore size and pore volume. Therefore modified biochar by addition of chemical or physical solvents has proven more effective as it would increase surface area and pore size. Therefore further studies should focus on modification of biochar that would increase the capture of carbon dioxide that could be further used for sequestration of carbon dioxide. In the above work biochar was prepared from the waste material through the process of pyrolysis. Various metals were incorporated into biochar that would modify the biochar and enhance its characteristics for carbon dioxide adsorption. Therefore different metals show different results with respect to different temperature. Various chemicals such as potassium, phosphoric acid. Magnesium nitrate, magnesium acetate and many more other chemicals were incorporated into biochar that has shown positive results such as enlarged specific surface area, increase in pore size and volume, increase in carbon retention and many more. Therefore future studies and experiment should focus on engineering of biochar and development of new technologies for capture of carbon dioxide and its sequestration.

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