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TÍTULO: Raw materials and usages of Biochar: A state of art.

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Dedicatoria

Esta Tesis va dedicada a todas las personas que han formado parte de mi vida los años que duró esta carrera universitaria, quienes fervientemente han forjado en mí, una profesional hábil, capaz, inteligente, íntegra y noble; principios que me acompañarán el resto de mis días.

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RESUMEN

El Biocarbón o *Biochar* es una alternativa tecnológica para resolver problemas de contaminación ambiental, tanto en países desarrollados como en países en vías de desarrollo. Uno de los problemas ambientales que enfrenta el mundo actualmente es la enorme cantidad de residuos orgánicos e inorgánicos que se producen cada año. Las grandes industrias demandan una cantidad importante de materia primas de origen natural, de ahí una de las mayores fuentes de residuos orgánicos, también conocida como biomasa. Sin embargo, gracias a los avances tecnológicos y la extensa investigación en varios campos, se han descubierto nuevas formas de reutilizar las materias primas desechadas. Los beneficios del Biocarbón lo convierten en una de las tecnologías más innovadoras para reducir la contaminación. Además, se propone una aplicación en la remediación ambiental, dando un nuevo uso a la inmensa cantidad de residuos que se producen anualmente. La biomasa obtenida a partir de residuos orgánicos se somete a calor, en procesos de pirólisis, para obtener Biocarbón. Este material tiene una amplia gama de aplicaciones. Ecuador, un país que produce una gran diversidad de productos agrícolas, genera una gran cantidad de residuos orgánicos cada año. Esta disertación tiene como objetivo revisar, analizar y resumir todos los tipos de residuos orgánicos y agrícolas que se generan en el país, creando un abanico de opciones a partir de las cuales se puede obtener Biocarbón, y elaborar un completo estado del arte de las materias primas disponibles en el Ecuador, para la posterior producción de Biocarbón.

Palabras claves: residuos agrícolas; bioadsorbente; Biocarbón; biomasa, Ecuador, materias primas.

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ABSTRACT

Biochar is a new technology proposed to solve one of the biggest pollution problems in developed and developing countries. One of the environmental problems that the world faces with the greatest boom at present is the enormous amount of waste that is produced each year, be it organic or inorganic waste. Large industries demand a significant amount of raw material to produce essential products, hence one of the largest sources of organic waste, also known as biomass. However, new ways of reusing discarded raw materials have been discovered due to technology and extensive research in various fields. One of the most studied alternatives in recent years is the creation of biochar from biomass (organic, agricultural, timber residues). Biochar is mainly composed of carbon from various organic and farming residues such as plant or animal biomass. The benefits of biochar make it one of the most innovative technologies for reducing pollution. In addition, it proposes an application in environmental remediation, giving new use to the immense amount of waste produced annually. This material has a wide range of applications. Ecuador, a country that produces a great diversity of agricultural products, generates a large amount of organic waste each year. This dissertation aims to review, analyze and summarize all types of organic and agricultural waste generated in the country, creating a range of options from which biochar can be obtained, and elaborate a complete state-of-the-art of raw materials available in Ecuador for the subsequent biochar production.

Keywords: agricultural waste; bio adsorbent; biochar; biomass, Ecuador, raw materials.

Contenido

CHAPTER I

INTRODUCTION

The excessive production of raw materials generates organic waste in large quantities in developed and developing countries, generating excessive environmental pollution. Biochar has broad application prospects in environmental remediation, and the mechanism of biochar in the ecological application should be further investigated.

The Republic of Ecuador is considered one of the sources with the world's greatest animal and plant diversity. Due to several factors, such as the rise of the Andes, the influence of ocean currents, its geographical location, variety of climatic regions, ecosystems, and life zones, has positioned Ecuador as one of the countries with the most remarkable biological diversity. (INABIO, 2016) One of the country's main activities is the export of products produced in the region and the export of various raw materials. Due to the export of raw materials, much agro-industrial waste is generated in Ecuador. This country, being a productive country of diverse raw materials, generates a large amount of agro-industrial waste annually, the sector agro-industrial leave considerable amounts of shells after industrialization Amon the most outstanding companies are: Toni S.A.Sumesa, Reysahwal, among others; the main production are Banano, pineapple, apple et al. (Gissel., 2021) These agro-industrial wastes can be used to produce biochar in the country and thus be able to remedy environmental disasters caused by ignorance and human negligence. Due to Biochar application for improving crop productivity and soil health, along with environmental benefits.

Biochar is a new technology that has been booming in recent years due to a large amount of research focused on its production from waste such as fruit, wood, and organic waste, among others. Climate change caused by an increase in atmospheric concentrations of greenhouse gases (GHG) is expected to cause catastrophic impacts on our planet like the pollution of natural water sources due to acid rains that acidify the soil and water. This provides the impetus for action to reduce emissions and increase the removal of GHGs from the atmosphere. (Cha, (2016)).

Therefore, biochar is considered one of the new technologies under development that has a focus based on environmental remediation as well as soil remediation, wastewater treatment, CO_2 capture, among other possible environmental and ecological solutions. (El-Naggar, 2019)The process that transforms biomass into biochar is called pyrolysis and is a process in which the biomass undergoes a thermal treatment at specific temperatures.

The present dissertation compiles a series of bibliographic reviews of various raw materials that have been used to obtain biochar, investigating the availability of these products as agroindustrial wastes present in the country to select the main raw material for the production of biochar. Recycling agroindustrial products generated in the country and producing new products from them gives added value to the waste and is called a circular economy. The circular economy is the production and consumption model that involves sharing, leasing, reusing, repairing, renewing, and recycling existing materials and products for as long as possible. It aims to address global challenges such as climate change, biodiversity loss, waste management, and pollution. Biochar fits perfectly within these defining characteristics of the circular economy.

1. Problem Statement and Justification

Biochar is a new and innovative chemical compound derived mainly from agro-industrial waste from food companies. What is innovative and novel about this compound is the proposal of a new technology that can be used as a contribution to the repair of soils, and waters even more interesting is that it can be created from agricultural, forestry, cattle waste, etc. In addition, biochar is a technology under development that has an innovator to solve the damage caused to the soil and wastewater. It can reduce methane and NO_2 emissions and all environmental approaches. Biochar is a new development technology that allows the reuse of waste generated mainly in agro-industries, giving it a unique added value. Ecuador is a diverse country in flora and fauna and is also an agricultural country that generates a large amount of waste annually. Due to the great variety of agro-industrial waste generated in the country, it is considered a great source of raw materials to obtain good quality biochar, thus giving it utility and added value to the waste generated in the country. Besides, Ecuador is one of the most diverse countries in Latin America, with essential waste varieties from which good quality and low-cost biochar can be generated.

The present work allows us to collect and classify the waste from which biochar can be generated, investigate the amount of waste produced in Ecuador, and evaluate if its production is feasible. This new technology is friendly to the environment and is helpful to combat some environmental problems such as soil pollution, water pollution, and greenhouse gas emissions, among others.

The generation of waste is a global problem because it pollutes the environment. One of the new technologies proposed to combat or reduce this problem is the opening of further research to generate new compounds from waste, in this case, agricultural waste. In this way, a possible solution to a global problem is given, contributing to eliminating environmental contaminants. This new technology of using agro-industrial residues to improve the environment is one of the latest technologies under development and with a strong source of research in recent years. The waste generated does not have any added value, however, converting the waste into Biochar gives a value and a new opportunity to use the waste, specifically waste generated in food industries. Ecuador, being an exporting country of raw materials, has a diversity of resources as raw materials for research and production of Biochar. Hence the proposal to carry out an art study that compiles the identity of the raw material found in the country as an agro-industrial waste and its possible potential for producing biochar.

2. Objectives

2.1.1 General Objective.

To conduct a review, analysis, and summary of the primary residues as raw materials obtained in Ecuador and conclude on the best option for producing biochar in the country.

2.1.2 Specific Objectives.

- To investigate the type of raw material required for producing biochar based on scientific articles published in recent years.

- To limit the raw material produced in Ecuador based on the raw material required to obtain biochar
- To propose through an analysis the most suitable raw material for a subsequent production of Biochar in Ecuador.
- To summarize the utilities and positive impact of Biochar in environmental remediation.

3. Search strategy

3.1.1 Keywords

Keywords are search terms that can be entered into a search engine. It refers to terms of one or more words used to perform exhaustive searches. Keywords can be a main path or an efficient way to have a particular and narrow search. By inserting a keyword in the search box, it allows you to obtain results on different websites which have previously been worked on to position themselves based on the keyword inserted in the search engine. By inserting a keyword in the search box, it allows you to obtain results on different websites, which have previously been worked on to position themselves based on the keyword inserted in the search engine.

This dissertation is based on the collection of data on all possible agro-industrial wastes that have the potential to produce biochar for later application in Ecuador. For this study, a set of keywords is determined to make a targeted, specific search and limit the field of investigation. Due to the wide range of information accumulated by recent research contributions, there is a lot of information in the search box regarding the topic of biochar. A good selection of keywords makes it possible for searches to be filtered and articles of interest to appear at the top of the search engine results. For the selection of keywords, the following strategy is used. A specific vocabulary was established based on words that guide a particular search. A specific vocabulary was selected based on words that guide a thorough search. Considering that the first google search engines monopolize the majority of visualizations in google, words of title or subtitle of the topic to be investigated are used.

For the search, different types of keywords were used: Those with a single term, which presented complications due to the existing competition. Keywords composed of 2 or 3 terms also showed high match, but their importance was reflected in the importance of having a quality search. The following keywords used were words made up of 4 or more terms. Compound phrases were also used and are much more recommended because the competition is less and closer to the search intention.

3.1.2 Search engines used

Several search engines facilitate the search for scientific documents and academic articles that allow obtaining valid and reliable information and are used as a complement or as a basis for new research. Search engines are easy-to-use tools that work by entering a keyword allowing you to filter precise information. It is a free resource to complement a bibliography or enrich any study. It has a comprehensive search option through many sources, such as articles, theses, books, and summaries. The most used search engines in this state-of-the-art are the following:

- Google Schoolar,
- PubMed,
- Scielo,
- Recymundo.

CHAPTER II

DEFINITIONS AND FUNDAMENTALS OF BIOCHAR

1. Biochar: Definitions

Biochar (Figure 1) is a fine-grained, pore-containing substance that is generated from the decomposition of biomass that has been thermally treated under oxygen-limited conditions and at relatively low temperatures. (The biomass derived from plants or animals) in oxygen-limited environment. “The process does not involve the emission of CO_2 because the sources of carbon produced in the biomass would return to the soil, and no escape of CO_2 is generated.” (Anush, 2020). The definition of Biochar explains the purpose of an intentional application of the material to achieve agricultural and even environmental gains.

Biochar is a new technology that has a lot of development in recent times due to its applications for the benefit of the environment, such as mitigation of global warming, sustainable agriculture, and other applications (Ahmad, 2014).

Image 1. Biochar

(Source: https://www.biochar.info/biochar.biochar-overview.cfml)

“The production of biochar is varied. It can be produced from easy methods such as the implementation of holes in the ground to methods that involve the construction of sophisticated industrial ovens that carry out the pyrolysis process” (Anush, 2020).

2. Utilizing biochar as a base to create activated carbon

The creation of activated carbon involves two key processes. The two basic uses of charcoal are: (a) producing charcoal by carbonizing raw materials (such as agricultural leftovers) in an inert or low-oxygen environment, (b) activating the char through chemical or physical means (Weber, 2018). Typically, the activation temperature ranges from 600 to 1200 °C. Chemicals are not used in physical activation procedures to activate the carbon (Chen Z, 1995).

The materials used to make Biochar are very numerous. However, there are several factors that determine the properties of Biochar, such as the pyrolysis process that involves a complex network of reactions associated with the decomposition of the main constituents of biomass, such as cellulose, hemicellulose and lignin. That is, its thermal degradation between 250 and 350 °C gives rise to many volatile compounds (Nanda, 2015.) . As the temperature increases, the relative proportion of aromatic carbon increases due to the loss of volatile compounds and carbon conversion takes place. development of new technology such as Biochar is a natural resource used for the production of biomaterials, energy production, soil improvement, pharmaceuticals, and carbon sequestration. However, the properties of Biochar depend on the physicochemical and electrochemical properties that Biochar has, factors such as Pyrolysis temperature, heating rate, residence time, and Biochar properties. (Novak, 2016)

Another factor that influences the properties of Biochar is the particle size that constitutes Biochar, which depends on the source and size of the raw material (Lehmann, 2009) Biochar has various particle sizes, high porosity with micro, meso and macropores, the macropores come from the spaces of the original raw material and allow the rapid transport of sorbates, for their subsequent diffusion in the volume of micropores, helping the transport of concentrated molecules (Martínez, 2006) It should be considered that biochar undergoes chemical and structural changes during “aging” processes, that is, over time which modifies its physical, chemical, and biological properties.

That is, the Biochar produced at maximum temperature is effective in the adsorption of organic contaminants due to an increase in the surface, microporosity, and hydrophobicity. On the contrary, a Biochar obtained at low temperatures has a better electrostatic attraction towards cationic nutrients in the soil. (Zhang Z. G., 2019)

3. Char and charcoal

The ending char is used to name a solid product from decomposing organic and synthetic wastes. Therefore, Biochar is a very complex organic product chemically speaking. It comes from the pyrolysis or combustion of biomass (any organic material is fine: wood, leaves, organic waste, manure, etc.) and focuses on environmental remediation and carbon sequestration. (J.O. Skjernstad, 1999)

4. Hydrochar

Biomass subjected to a respective process is used to produce biochar by processes such as carbonization, pyrolysis or gasification while hydrothermal biomass subjected to a carbonization process under low pressure is used to produce hydrocarbons. Hydrochar can be manufactured from wet animal manure, wastes, municipal solids, and organic or inorganic wastes (Masoumi, 2021). After a drying process, biomass is used to produce biochar through carbonization, gasification, or pyrolysis. In contrast, the carbonization method has hydrothermal biomass, which requires low pressure and is used to produce hydrocarbons. Organic wastes such as human wastes, such as wet animal manure, sludge, and solid wastes from municipal, aquaculture, and algae scraps can be used directly without drying to prepare hydrochars. "The hydrothermal carbonization method that provides high yields of char with more water-soluble compounds (Masoumi, 2021). Biochar and hydrochars differ in composition and chemical and physical properties. (J.O. Skjernstad, 1999)

5. Biochar production and characterization.

Biomass can be converted into biofuels and bioproducts through thermochemical processes such as pyrolysis and gasification. The net CO_2 emissions from biofuel use are considered zero or negative because the released CO_2 is captured from the atmosphere and captured during photosynthesis. Biomass also contains small amounts of sulfur and nitrogen, so burning biofuels emits fewer harmful gases such as nitrogen oxides (NO_x) and sulfur dioxide (SO_2) than most fossil fuels. These advantages of biomass make it a promising renewable energy source. The main products of thermochemical biomass processes are syngas, bio-oil, biochar, and tar, the yields of which depend on the process conditions. The International Biochar Initiative defines biochar as “a solid material obtained by thermochemical conversion of biomass in an oxygen-limited environment” (Chen Y. H., 2010). Biochar is produced in solid form by coking, pyrolysis, or gasification of biomass and sewage sludge (Figure 2).

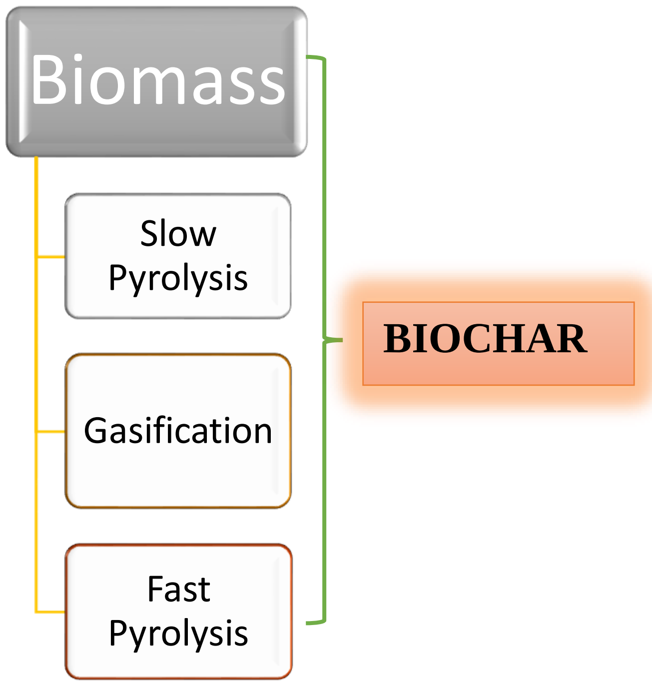

Figure 1. Biomass schematic production.

The most common method of producing biochar is pyrolysis. Based on the heating rate and residence time, pyrolysis can be divided into slow and fast pyrolysis. Slow pyrolysis, also called conventional carbonization, produces biochar by heating biomass at low heating rates for relatively long residence times (up to several days). This process has been used to extract coal for centuries. On the other hand, fast pyrolysis produces biochar with high heating rates (greater than 200 K/min) and short residence times (less than 10 seconds). (Chen Y. H., 2010). According to the literature, the most attractive feature of biochar is that it is an economical, sustainable and easy-to-manufacture process that can produce materials for a wide range of applications at lower costs than materials from petrochemical or other chemical processes. (Oni, 2020) Applications are still in their infancy, and biochar can already be used in many applications with extraordinary effects. These uses include soil improvement, catalysis, water treatment, energy, and gas storage. For most tropical agricultural soils, soil fertility is a significant restriction because of decreased soil organic matter (SOM) and nutrient imbalances. Is a considerable barrier for the majority of tropical agricultural soils. An important environmental issue is soil salinization (20% irrigated soil), which affects around 8.31 108 hectares of land globally.

6. Characterization of Biochar.

Chemical Characterization.

pH measurement is important giving its likely influence on soil pH and other properties and processes in soils on biochar application. While the effect of biochar on soil. (Enders, 2012)

Elemental analysis of biochar's present challenges during digestion because of biochar's chemical recalcitrance and widely varied composition. (Enders, 2012)

BET areas increased with an increase of carbon burn off, irrespective of pyrolytic temperature that indicates that the burn off of the carbon has the most significant consequence on the increase of the surface area. (Nartey, 2014)

Boehm titration determination of acidic and basic functional groups that can be performed where can be equilibrated in presences of consecutively strong bases or strong acids. The Bohem titration operates well for hydrophobic substances. (Nartey, 2014)

FTIR/FTIS can be used to identify the chemical functional groups present on waste raw material (Nartey, 2014)

CEC analysis is Cationic exchange capacity as widely known in agronomical sector is the measure of the surface charge in soil (Nartey, 2014)

Gas chromatography Utilization of these modern techniques provides the quantitative as well as qualitative information, determining the sizes, shapes and physicochemical characteristics of biochar, which is reliable to track changes in the carbon arrangement over reaction time and temperature, and will be useful for efficient production of biochar and application (Amin, 2016)

7. Physical Characterization

SEM is Scanning electron microscopy is a microscopic technique in determining the image microporosity and physical morphology of solid substances. It can also be detected that the surfaces of low temperatures that can be hydrophobic. (Nartey, 2014)

Particle size distribution was estimated from the TEM images, particle size are all factors that affect the mass yield of Biochar. (Ennis, 2012)

Moisture content is a very important factor when it comes to the growth of bacteria and if the environment condition were dry then most bacteria would die. (P., 2021)

Ash content composition on the properties of biochar derived from sewage sludge with high ash content and sorption capacity of biochar. (Fan, 2020)

Bulk density which generally implies increased pore volume. Is the measure of relative soil compaction, as expressed in total mass per total volume that helps to determine the porosity of the soil and the porosity decreases. (Omondi, 2016)

Pore volume of carbonaceous materials, which are commonly determined by N2 and/or CO2 gas-physisorption, are important parameters when describing environmental processes such as adsorption. Their measurement requires prior degassing of samples, which can change the nature of the material. (Sigmund, 2017)

8. Methods for Producing Biochar.

8.1.1 Pyrolysis

Pyrolysis is defined as the thermal treatment that is carried out on the decomposition of biomass in a temperature range (Figure 2). The pyrolysis process is used to generate charcoal, activated carbon, methanol, and other chemicals derived from wood (Birk, 2012)

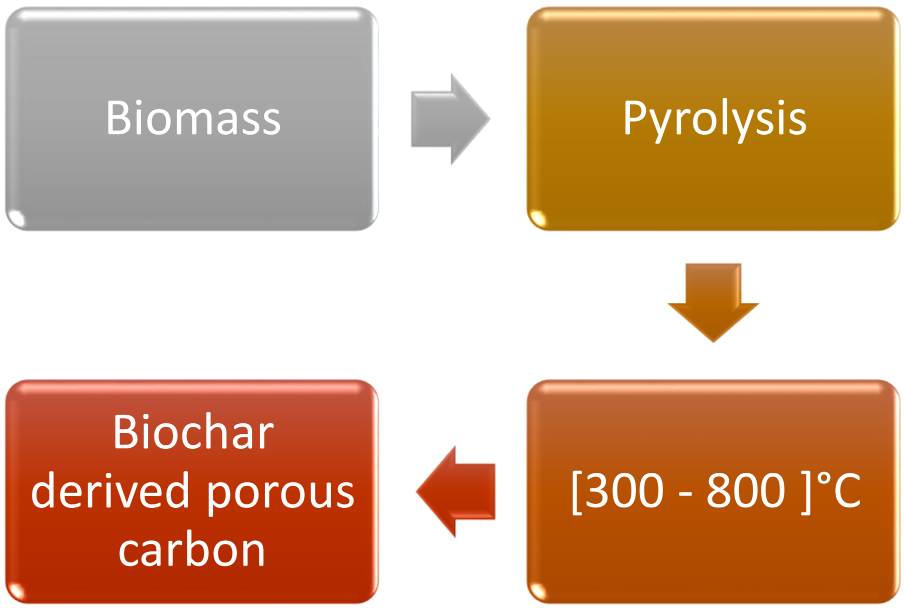

Figure 3. Pyrolysis process schematic.

Pyrolysis conditions and feedstock properties significantly control the physicochemical properties (composition, particle size, pore size distribution, etc.) The pyrolysis process touches the biochar quality, affecting its suitability for specific applications, environmental behavior, transport, and deciding fate. The reported biochar properties are highly heterogeneous, both within individual biochar particles and between biochar's mainly derived from different feedstocks. Properties of biochar with cation exchange capacities (CEC) from negligible to about 40 cmolc g-1 (Clough, 2010) Pyrolysis "has the potential to develop biochar with properties best suited for specific application opportunities (soil type, hydrology, climate, land use, soil contamination, etc.) (Clough, 2010) In addition, the pyrolysis process is one of the developing technologies for the fuel processing of carbonaceous materials by reallocation of carbons into three pyrogenic products (i.e., synthesis gas, pyrolytic oil, and coal) under oxygen-free conditions. The pyrolysis process (Figure 3) is classified into slow, fast, flash. The resulting products, such as gasification, depend on the pyrolysis conditions. Among these pyrolysis platforms, slow pyrolysis of biomass mainly produces solid biochar. “The heating temperature, heating rate, and retention time for slow pyrolysis are 300-800 °C, (B, 2007).

Both physical and chemical activations have two steps: biomass carbonization by pyrolysis at high temperatures (300-900 °C), and biochar activation with oxidants at high temperatures (500-900 °C) (Birk, 2012). Generally, the biochar yield obtained in the slow pyrolysis process is 35-50 wt% of the original biomass weight, and the biochar yield decreases with increasing heating (Abit, 2012). In general, lignin-rich biomass offers higher biochar yields, and such observations are probably attributed to the high thermal stability of lignin regarding cellulose and hemicellulose. (Manyà, 2012)

Pyrolysis is one of the most effective and efficient processes to obtain energy from coal from biomass, contributing to environmental remediation. Apart from coal, pyrolysis also produces different bio-oils and other value-added products.

Pyrolysis is a process that involves the thermal degradation of a substance in the absence of oxygen, so these substances are decomposed by heat, without combustion reactions taking place. The basic characteristics of this process are the following:

Gas, whose basic components are CO, CO2, H2, CH4, and more volatile compounds from the cracking of organic molecules.

Liquid residue, basically composed of long-chain hydrocarbons such as tars, oils, phenols, and waxes formed when condensing at room temperature. Solid waste can be used as fuel in industrial facilities, such as cement plants. Liquid and gaseous waste can be used by combustion through a steam cycle for the production of electrical energy. Fig (3)

Human society has extensive experience with pyrolysis in charcoal production, primarily as a clean-burning fuel. It is now produced in rural areas for urban markets and industrial smelting. In the iron ore industry (where carbon credits can be purchased to offset coke emissions), traditional charcoal production methods dominate and are now the most common form of pyrolysis.

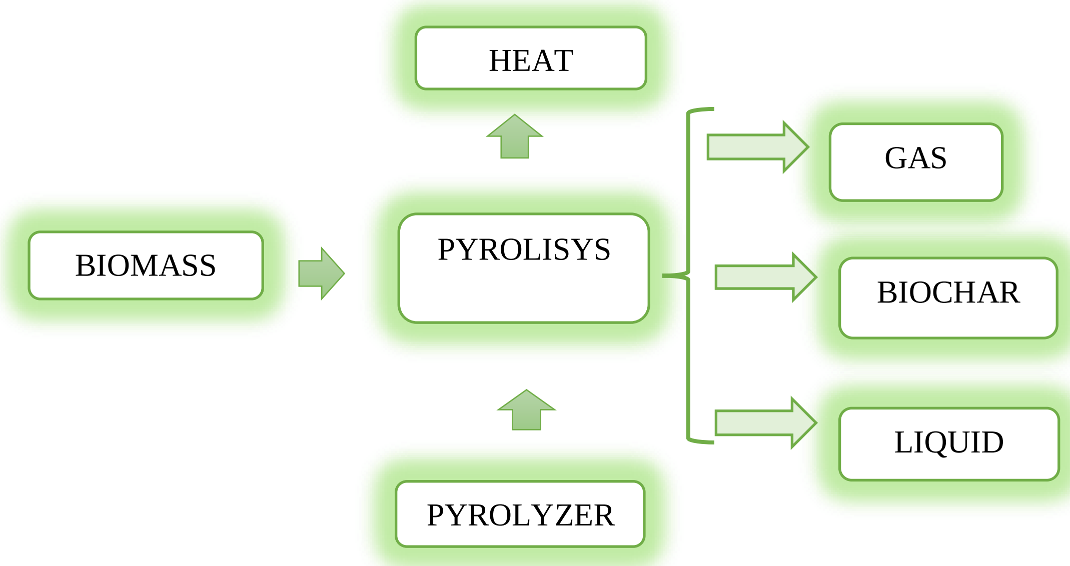

Figure 3. Pyrolysis process feed and production

8.1.2 Process to obtain Biochar.

A wide variety of organic wastes, including municipal solid waste and agricultural waste, can be utilized as raw material to obtain biochar.

The simplest way to characterize biochar, an organic compound produced by the pyrolysis of feedstock or biomass, is as a "soil improver," among other qualities. Wood, crop waste, and manure are just a few of the materials that have been suggested as biomass feedstocks for biochar; however, the feasibility of any feedstock for this application depends on a variety of chemical, physical, environmental, economic, and logistical factors. There is proof that soil's biochar carbon content is quite resistant. (Lehmann, 2009)

In the Pyrolysis process, the temperature is one of the most important factors since it directly affects the characteristics of the Biochar. One of the most important characteristics in the composition of Biochar is the porosity and aromatic character as well as the fixed carbon as a maximum temperature is used, which increases the capacity of Biochar to retain nutrients from soil improved and modified with Biochar. Stability and nutrient retention capacity are determinants to classify Biochar. (Lehmann, 2009)

The development of innovative processes, such as flash carbonization is a new technology that is under investigation that could improve the productivity and quality of fixed carbon yield from Biochar. (Manyà, 2012)

New research proposes improvements in the performance of Biochar through an activation process through a gasification method using an oxidizing agent in a temperature range of (300 to 850 °C) or another method such as a carbonization step. (Manyà, 2012)

The Activation methods propose to improve the porosity of the Biochar, which would increase the potential of Biochar to improve water retention in the soil and the carbon sequestration capacity.

9. Biochar production techniques

Biomass is mainly converted to biochar; a small amount can be condensed into a liquid (bio-oil) and non-condensable gas (syngas). Pyrolysis plants or reactors have been developed for this process. The reactor operates similarly in terms of Carbon dioxide availability, but the heating rate, pressure. The heating rate, pressure, and residence time can be varied, which can alter the product ratio. The yield of biochar, bio-oil, and syngas depends on the type of pyrolysis used and pyrolysis conditions. Biomass pyrolysis has previously generated much interest in biofuels due to, Yields of up to 80% on a dry biomass basis. Recently, research aimed to obtain high-quality biochar from green waste for biofuels. This product, improves soil fertility and soil moisture conservation during the sequestration of C.

10. Biochar Properties

Biochar consists of stable or fixed carbon, labile carbon and other volatile compounds, moisture and ash. Biochar changes when heated, creating an aroma. The structure is highly resistant to microbial degradation. For instance, the C compounds in biochar are stable for a long time. They are therefore considered to be effective in sequestering considered effective for long-term C sequestration (Hale, 2012). The skeletal structure of biochar consists mainly of carbon and minerals with different pore sizes. Important for aeration, hydrology, root movement, and bulk soil structure. The size and pattern of pores in biochar depend on the composition of raw materials and the temperature used during biochar formation. It is important, the pore size morphology and distribution. Biochar can be scanned from different feedstocks by electron Microscopy (SEM). The porous structure varies depending on various aromatic and other functional compounds. The group is produced from lignin-based biomass. This porous structure is used as a channel for the flow of nutrient-rich soil resolution; they also serve as a shelter for soil microbes (Hale, 2012). During pyrolysis, Hydrocarbons, tar vapors, H_2, CO, and CO_2 are formed. Nitrogen biomass volatilizes, while K and Cl volatilize at relatively low temperatures. Ca, Si and Mg are released at higher temperatures. However, most of the P, S, Fe, and Mn remained in the biochar. During pyrolysis, inorganic compounds are evaporated, but mainly the parts remain as part of the biochar structure. When The pyrolysis temperature rises above 400 °C, cross-section biochar is shown as graphene sheets (hexagonal structure of C residues). Graphene has a planar polyaromatic monolayer carbon structure. Atoms with high stability indices are formed at a temperature of 250-550 °C, Breaking strength and conductivity. Predominantly aromatic biochar C formed above 350 °C. Groups that adsorb heavy metals or hazardous molecules very efficiently. H, N, O, P and S are connected to aromatic rings. On the other hand, determining the biochar product's electronegativity affects the cation exchange capacity (CEC). CEC is a parameter. The surface charge of the biochar or soil increases as the biochar ages. (Hilber, 2012).

Pyrolysis above 900 °C causes deformation leading to expansion due to the destruction of the micro pore walls between the adjacent ones and increased porosity at the surface. In addition, the maximum temperature reduces the volatile substances and the size of biochar particles, leading to higher orders of the graphene layers, and increasing solid density. As a result, the higher mechanical strength of biochar in the soil is achieved. It breaks down when applied to the soil. As a result, the particles tend to increase their surface area and promote the growth of biochar. Biochar particles are moved in the soil by wind and water erosion, allowing them to penetrate and help dissolve organic carbon (Whalen, 2015) as mentioned above, the properties of biochar are as follows.

It depends on the type of feedstock and processing parameters such as temperature, heating rate, furnace residence time, and types of pyrolysis reactors (Gul S. W., 2015). Biochar from plant waste Compared with biochar from plant residues, it contains more N. Although the pore structure of plant-derived biochar is more orderly, it presents higher fertilizer quality and the adsorption capacity of heavy metals is higher. The adsorption with time is reduced as well as the adsorption capacity of the Biochar and the pores are blocked therefore biochar is deactivated.

11. Factors affecting Biochar quality.

12.1.1 Temperature.

Temperature has a direct relationship with the surface area, ash content and pH of the biochar (Ameloot, 2013). Biochar produced at low pyrolysis aliphatic and cellulose-type structures give a more diversified organic character to the biochar (Birk, 2012). These can be good substrates for mineralization by bacteria and fungi that are important in the renewal and in nutrient renewal processes and aggregate formation. (Zhang H. V., 2015)

As the pyrolysis temperature increase, rings are formed, which improved the surface area and pore development of the biochar. The feedstock composition and pyrolysis are also reported temperature affects the surface charge of biochar. The micropores of biochar are directly related to the surface area which imparts a high adsorption capacity to biochar produced at high temperatures" (Gul S. W., 2015). To high temperatures, higher yields of biochar, strong bonds between carbon and oxygen as well as carbon and hydrogen the functional groups were better obtained at lower temperatures (250 - 400 °C), and these serve as nutrient exchange sites after oxidation (Abit, 2012)

Developed at high temperature. Contains high volatility characters Substances (MV) release aldehydes and other aliphatic compounds with oxygen compounds other than aromatic hydrocarbons (toluene, phenol, benzene, etc.) and carbohydrate degradation products at lower temperatures. (Abit, 2012). Biochar, which contains a lot of C is produced at temperatures range (400 -700 °C).

Biochar (lignin-rich) results from a similar but different number of transformations during slow pyrolysis at 100-700 °C." (Abit, 2012) There are four temperature-dependent structural transitions: transformational carbonization, where precursor material is retained, amorphous carbon which is random mixture of thermally altered molecules and original aromatic compounds. Condensation polymer, weakly ordered graphene composite carbon. "The amorphous phase is dominated by fixed poles and by the turbulent layer of carbon dioxide through disordered graphite crystallites. Sudden changes in crystallinity and Porosity and losses of O2 and H2 that occur at 300-500 °C," (. Dunst, 2013)

A decrease in volatiles (increase in solid carbon) is most pronounced at 400-600 °C. Development of biocul porosity, and growth and polymerization of aromatic structures occurs. Therefore, it can be concluded that the pyrolysis temperature is one of the main factors determining its performance and quality.

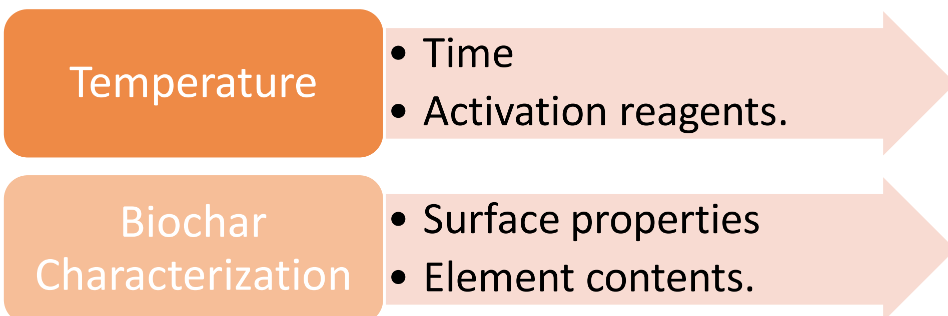

Figure 4. Schematic of Biochar quality.

12.1.2 Biochar properties as function of feedstock and production temperature

Physical-chemical characteristics of each biochar vary, including surface, pH, and the concentration of different elements and nutrients.

For instance, calcium (Ca), phosphorus (P), oxygen (O), nitrogen (N), carbon (C), and phosphorus (O). These characteristics of biochar depend on the input material and the temperature at which the biochar is produced, as illustrated in it (Manyà, 2012).

In contrast to lignocellulose-rich beginning materials like lignocellulose, manure and crop leftovers are nutritious, have a high pH, and are sources of more labile carbon. Seaweed is typically used to make biochar. Compared to lignocellulose-rich beginning materials like wood. Generally speaking, surface area, pH, carbon: nitrogen (C : N) and carbon (C):oxygen (O) biochar ratios, as well as nutrients like P, K, and Ca (Manyà, 2012) As DOC and dissolved organic matter concentrations rise, so does the temperature at which biochar is produced. Biochar's C: O ratio is usually unaffected by rapid pyrolysis. The surface area of biochar, however, rises as compared to slow pyrolysis.

12.1.3 Heating rate

The rate of heating also has a significant effect on the structure. Biochar and bio-oil and syngas production increase with high temperature (Chen Z, 1995) Optimal feedstock processing rates and temperatures increase biooil yields, but at lower rates and shorter processing times. Temperature promotes biochar formation.

It is clear that lower pyrolysis temperature and lower heating rate lead to the formation of carbon products, whereas higher pyrolysis end temperatures, lower heating rates, and longer residence times are favorable converting biomass to gaseous products. Medium Pyrolysis temperature (500-550 °C), high heating rate, and short time with steam residence time generally increase the yield of liquid products. Pyrolysis "always produces three types of products (biochar, liquid, and gas), but the ratio can be different), the ratio can be varied and controlled over a wide range by adjusting the pyrolysis parameters (Zhang H. V., 2015).

The feedstock composition and pyrolysis conditions can affect Biochar. The pore structure, surface area, pH, CEC, EC, OC-related adsorption, and chemical properties. Biochar content is the result of increased temperature" (Hilber, 2012).

For example, during pyrolysis, the sugar forms a liquid phase, the resulting carbon visually changes its original physical form. The sugar structure, high porosity and N concentration in charcoal produced from vegetable raw materials increase its properties after a pyrolysis process.

Concentrations drop when the raw materials are rich in minerals. Concentrates are lost due to volatiles during the pyrolysis process. Volatile nutrients such as N are almost completely removed. (Pokas, 2011)

Reduction of manure (bovine, human, poultry, sludge, and lakes) has high N content after pyrolysis" (Gul S. W., 2015). Most of the plant biomass contains very little S and P and, therefore, very little N content. Information on the S and P content of biochar is available. The P content in manure is usually higher than in other feedstocks. This level increased during the formation of the corresponding biochar. Biochar of plant origin also showed similar results Biochar for fertilizer production, A suitable temperature should be selected to retain most of the nutrients in the biochar. Nutrients in biochar act as a source of N and P in the soil. The elements are not retained during pyrolysis, there is no nutrient availability. Unfortunately, there is very little information on the bioavailability and nutrients found in biochar and nutrients found in biochar (Dunst, 2013).

12.1.4 Particle size

Biomass particle size is also an important parameter affecting biomass changing pore space between particles distribution of pyrolysis products affects heat and mass transfer rate and extent of secondary reactions in a particle. This particle size of feedstock varies according to the type of feedstock. Generally, "a small particle size is preferred for fast pyrolysis as smaller particles are heated uniformly, more as a consequence of the release of volatile substances, the production of bio-oil and natural gas yield increases" (Manyà, 2012). The cabin has a higher temperature gradient, resulting in a lower core temperature.

The particle size range for biochar yield with determined parameters was 0.224- 0.425 mm at 500 °C with a heating rate of 223.15 °C per min Static atmosphere, but no significant effect of particle size was found. On conversion and product yield during pyrolysis. (Birk, 2012)

At higher temperatures, the heat flux in the process is greater. The size of the particles affects the rate of heating. The heat flux and the rate of heating are greater for small particles than for large particles. The higher heating speed favors a decrease in the charring yield. (Demirbas, 2004)

CHAPTER III

BIOCHAR: ENVIRONMENTAL APPICATIONS

12. Perspectives on biochar applications.

Biochar has been successfully used in a variety of applications, including soil enhancement and fuel cells, and other similar things (Figure 5). As a soil conditioner, biochar has some benefits but is not without drawbacks like organic substances that are toxic, such as polycyclic aromatic compounds. Depending on the procedure and feedstock, biochar may contain various levels of hydrocarbons, chlorinated hydrocarbons, and dioxins. Biochar's ingrained heavy metals may make them more readily available in the soil. Additionally, biochar can lessen the impacts of ecotoxicology on soil organisms (Hale, 2012). To reduce the negative effects of biochar while gaining the benefits of soil amendment, it is essential to understand its qualities. Biochar is mainly used as a soil amendment and for carbon sequestration; while other applications such as environmental remediation may be equally important. Recently, different engineering methods have been developed and used to expand the applications of biochar. Therefore, a systematic review of the literature on the links between production methods and applications of engineered biochar is critically needed. (Weber, 2018)

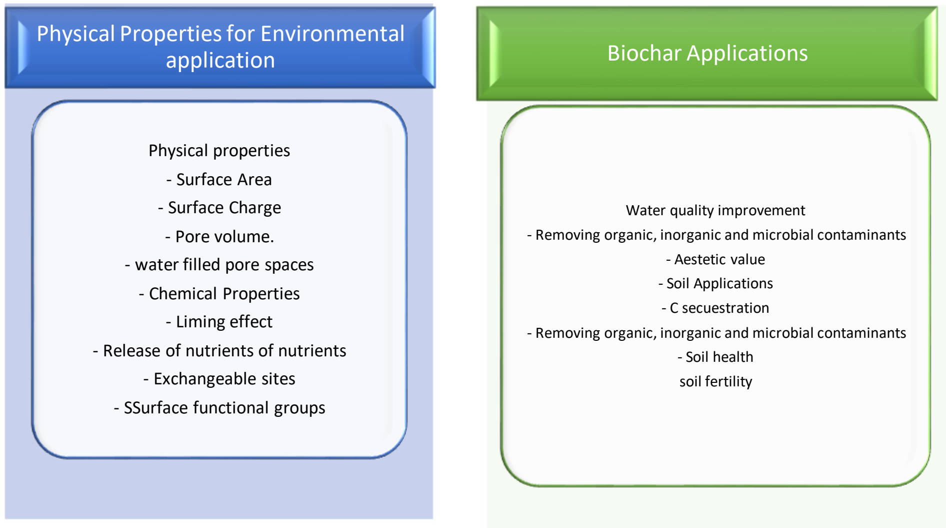

Figure 5. Summarize of biochar applications.

13. Biochar research for environmental sustainability

Different studies have been carried out in recent years on biochar with applications for soil and water remediation applying the potential of this new technology. According to recent publications, the application of biochar has had a positive impact on the environment through soil remediation that allows an increase in crop production and significant plant growth. Biochar is an innovative technology and an economical substitute for activated carbon developed for the removal of contaminants from water as well as from soil. The economic feasibility of biochar depends on the biomass used and the benefits that the client wants, for example, biomass from agro-industrial waste allow the producer obtains a higher production and lower fertilizer requirements. Biochar with application directed to electricity production due to electrical properties and waste management are economically viable in addition, biochar systems contribute to the economic development of communities. Eventually, this combination of environmental, economic, and social outcomes leads to a sustainable development of the world. (Manyà, 2012)

14. Soil and water remediation and CO_2 capture

15.1.1 Improvement of water quality through biochar

Ecuador is a mega diverse country in natural resources including water resources such as lakes, rivers, waterfalls, river sources. This natural resource is important because it serves as food for the entire population. In general, the world's demand for safe drinking water is becoming increasingly important. The growing population of the country as well as the increase of the world population and anthropogenic activities are the main cause of the rapid contamination of water sources. The World Health Organization (WHO) reported that 2.1 billion people (equivalent to 29% of the world's population) do not have access to safely managed drinking water (contamination-free water), and one in three people do not use such water in rural areas.

Currently, the most challenging problem associated with surface water is the presence of organic, inorganic, and microbial contaminants due to industries near water resources, while exposure to these toxic substances can cause various health problems (Lehmann, 2009). Nowadays, new water treatment techniques based on biochar have caused interest due to their unique performance in the elimination of pollutants in water. It is worth noting the cost-effectiveness and environmental friendliness of using a waste-generated and environmentally friendly technology.

The raw material from which biochar is made plays an important role in drinking water treatment processes. Depending on the type of biochar and the techniques used, biochar can be used in water purification processes to remove various contaminants in drinking water. To identify the efficiency of biochar-based processes, understanding the possible removal mechanisms is crucial. In addition to the usual application of biochar for water treatment, innovative techniques have been reported in recent decades (Juanli, 2019)

Biochar modification is an important tool in water treatment operations due to the superior capacity of this modification compared to pristine biochar. The treatment given to the feedstock or the resulting biochar improves the surface area, surface functionality, pore volume and pore distribution (Juanli, 2019) (Fig 5)

There are some chemical modifications of biochar have a major impact on product efficiency and consists of treatments with acids, bases, oxidants, organic compounds and mineral oxides, while physical modifications include steam activation and purge gas (Masoumi, 2021). The development of new research allows the creation of new techniques such as hybrid techniques consisting of a biochar-based modification combined with permeable reactive barriers and biofilters augmented with biochar which have recently been developed for water purification systems. (Anush, 2020)

Organic pollutants in general such as agrochemicals including pesticides, herbicides, fertilizers, liming and acidifying agents, and pharmaceuticals are the most common organic pollutants found in water sources. In general, the performance of biochar for the removal of organic pollutants has been reported in recent years to have maximum Adsorption capacities respectively.

Chemical and physical interactions between biochar and adsorbate are the factors governing the removal of contaminants from water. "The presence of oxygen-containing surface functional groups, such as carboxyl and hydroxyl groups (-OH, -COOH), in biochar is one of the main factors favoring the adsorption of organic pollutants" (Qambrani, 2017). The formation of H-bonds between the polar functional groups of biochar and organic contaminants allows for increased resistance to adsorbate retention in biochar (Ahmad, 2014).

For water treatment there are conventional processes such as coagulation-flocculation, sedimentation, filtration and disinfection. These physicochemical processes can remove some of the inorganic contaminants, turbidity, organic matter, and pathogens in the water. Conventional low-cost treatment methods are generally considered as treatments that have low removal efficiency, especially for heavy metals pesticides and herbicides. Currently, research focuses less on unit performance but more on a modified or combined conventional treatment process for energy savings, cost reduction, and enabling different application purposes (Yong, 2022)

Conventional treatment techniques exist for purifying water. However, these methods have drawbacks such as the formation of disinfection by-products due to these by-products, it is desirable to develop a safer purification technique. Biochar is an effective candidate to solve the drawbacks in the treatment of common contaminants that occur in the purification of drinking water with common treatments such as inorganic contaminants, microbials, heavy metals, volatile organic compounds, etc. (Palansooriya, 2019)

Biochar has attractive pollutant retention properties as well as environmentally friendly sorption properties. One of the Biochar-based water treatment methods consists of gravel layers of different sizes, filtered through fine sand, Biochar is applied which retains contaminants and clean water is obtained (Fig 6). Biochar-based water treatment techniques are gaining attention due to their performance in removing contaminants from water and soil. Some of the chemical modifications of Biochar include treatments with acids, bases, oxidants, organic compounds, and mineral oxides, while steam activation and purge gas have been identified as physical modifications. (Palansooriya, 2019)

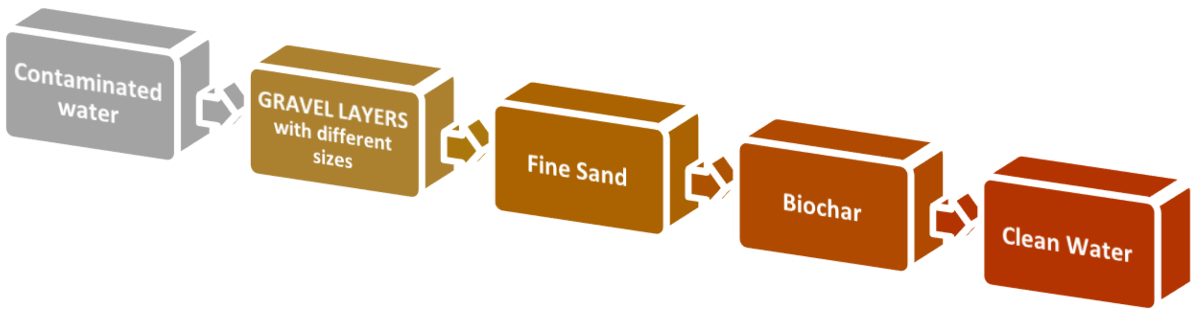

Figure 6. Biochar based water treatment system for purify contaminated water.

15.1.2 Impact on soil

Biochar can potentially increase agricultural productivity, increase agriculture's resilience to climate change's effects, reduce greenhouse gas emissions and ensure sustainable energy production. When added to soil, biochar increases soil productivity, increasing soil ecosystems' resilience to increased weathering and stress. However, not every biochar is made equally. The variety of biochar feedstocks, manufacturing methods, and end users create a complicated web of factors. Although some regions of the world have long added charcoal to their soil, biochar as a product is still relatively new to academics and the formal industry, which is working to encourage its acceptance as a common practice. Its interactions and synergies are still being researched as the fertility control of the soil. (Hossain, 2020)

Biochar properties (chemical composition, surface chemistry, particle and pore size distribution, etc.), as well as the biochar's physical and chemical stabilization mechanisms in soil, determine the impact of biochar on soil performance (Downie, 2010). The relative impacts of each of these factors, especially under the influence of different soil and climatic conditions, as well as soil management and land use, have not been adequately evaluated.

The reported loss of soil biochar can be partially explained by abiotic and biotic factors decomposition and migration of soil profiles and water systems. However, quantification and understanding of these mechanisms remain limited, in part due to a limited number of long-term studies and in part due to the lack of standardized methods for bioburden modeling and long-term environmental monitoring. is. A deeper understanding of biochar as a means of improving soil properties, processes, and performance, or at least as a means of preventing adverse effects, will greatly contribute to understanding the full extent and implications of biochar and biochar interactions. Scientists and policymakers increasingly recognize biochar's potential role in carbon sequestration, reduction of greenhouse gas emissions, renewable energy, waste reduction, and soil remediation. To date, published reviews of biochar application to soil have focused on agronomic benefits with little attention to potential unintended consequences. This chapter aims to provide a balanced view of the agronomic and environmental impacts of biochar soil amendments.

To try to bridge the gap between small-scale controlled experiments and large-scale implementation of biochar application to a variety of soil types in a variety of different climates (although mainly tropical), a state of art is performed. A thorough search of the scientific literature led to a compilation of studies used for the compilation of the effects of biochar application on soils. The research results found in the literature show a positive effect of biochar application to soils on plant productivity in most cases. The greatest positive effects were observed in free-draining acidic soils with other soil types, specifically calcarosols showing no significant effect (either positive or negative). There is also a general tendency for simultaneous increases in crop productivity with increases in pH up to in addition of biochar to soils. This suggests that one of the main mechanisms behind the reported positive effects of biochar application to soils on productivity may have positive effects. However, more research is needed to confirm this hypothesis (Hale, 2012)

Sludge, a solid waste product created during wastewater treatment, needs to be treated and disposed of. However, due to its high amount of nutrients like carbon and ammonia Biochar has a high carbon content, a high cation exchange capacity, a high specific surface area, and a stable structure. (Mukherjee, 2013)

The literature shows that the effectiveness of biochar in mitigating pollution impacts depends on several factors in this field, including the period of use, site-specific factors (e.g., weather, biochar application rate, and depth of mixing) and the type of biochar feedstock and biochar properties. The results of this review show that the use of biochar can reduce the bioavailability of contaminants in the field; for example, a significant reduction in Cd enrichment was observed in rice cultures. Studies have found that the use of biochar can help increase yields on polluted soils and thus reduce the use of mineral fertilizers in fields. (Mukherjee, 2013)

Adding biochar to soil with a similar carbon content results in stabilizing soil carbon levels due to its stability in the soil. (Zhang H. V., 2015) Biochar as a carbon sequestrant that remains in the soil for a long time, high level of resistance to chemical and biological degradation, which in turn increases terrestrial carbon stocks. Although soil contains more than 80% terrestrial organic carbon reservoirs (Weber, 2018), soils have low potential carbon storage and forest growth.

15.1.3 Biochar influence on changing the soil habitat.

The properties of the Biochar are very different from those of the carbonized organic soil material and it is known that these properties change over time as a result of meteoric processes, interactions with the organic and mineral soil, and microbial oxidation of the soil (Valentine N, 2022) . However, little is known about the connections between the chemical and physical characteristics of biocarbon and its effects on the soil's biota as well as potential simultaneous effects on soil processes. The processes of the soil are not well understood.

The main component is made up of minerals that are found in biochar as ash inclusions. These minerals are key resources in the soil food web because they contain a number of macro- and micronutrients that are crucial for biological absorption. Additionally, due to their incorporation into the aromatic or organo-metal structure, these components' presence during pyrolysis influences the chemical composition of biochar. “At high temperatures, the reactions are thermodynamically advantageous. For instance, in aromatic compounds, N might take the place of one or two C atoms Compounds" (Valentine N, 2022) with implications on how biochar behaves in soil that are mostly unknown.

Soil health refers to the capacity of soil to perform a number of agronomic and environmental functions. Important among these functions are agronomic/biomass productivity, response to management and inputs, and resistance to biotic and abiotic stresses (Doran, 2000.).

Any soil management system must maintain enough quantities of soil organic matter and biological nutrient cycling to be successful. A number of soil degradation processes, such as erosion, compaction, salinization, and nutrient depletion (Ahmad, 2014). Therefore, a thorough analysis of the usage of biochar and its impact on the functional quality of soil it is necessary. Through their impacts on soil stability, soil strength, and soil quality, tillage techniques and topsoil management have an impact on the sustainable use of soil resources. The ability of soil to change in response to anthropogenic or natural disturbances is referred to as soil stability. In contrast, soil resilience is the capacity of the soil to recover its quality in the wake of anthropogenic or natural disruptions.

15.1.4 CO_2 Adsorption by biochar

Global warming due to greenhouse gases is one of today's major environmental problems. There has been a dramatic increase in CO_2 emissions to meet global carbon demand for chemicals, goods and fuels. CO_2 is considered a major contributor to global warming. For this reason, CO_2 capture and sequestration has been considered as one of the strategic objective principles to nullify the release of CO_2 from anthropogenic activities in line with the use of fossil fuels. Therefore, it is required to develop materials with the capacity to absorb CO_2 whose characteristics are efficient and economically viable. Among CO_2 absorbing materials, biochar (i.e., porous carbon-based materials) has been considered as an efficient and viable new technology. At present, a great deal of research, development and application has been made to biochar generated from biomass (Chen Z, 1995).

Biochar for carbon sequestration. Carbon sequestration is a process in which carbon is captured and stored to avoid its emission into the atmosphere. It is essential that carbon is transferred to a passive carbon pool that is stable or inert, to decrease the emission of C to the atmosphere. Transferring even a small amount of the carbon that circulates between the atmosphere and plants, at a much slower rate than biochar cycling, would have a large impact on atmospheric CO2 concentrations because the annual uptake of CO_2 by plants from the atmosphere through photosynthesis is eight times greater than anthropogenic Greenhouse effect gases (GHG) emissions. Biochar is biologically and chemically more stable than the original carbon form, due to its molecular structure, and its origins. It is difficult for the sequestered carbon to be released as CO_2, making it a good method for carbon sequestration. Diverting even 1% of the annual net carbon uptake by plants to biochar would mitigate almost 10% of current anthropogenic carbon emissions. (Mukherjee, 2013)

The highest adsorption capacity of pure CO_2 gas on biochar or activated hydrocarbon was 22 wt% of CO_2 adsorption on CO_2 adsorbents. In addition, the significant decrease of CO_2 adsorption capacity through physisorption at elevated temperatures requires further treatment to have a stronger interaction between CO_2 and the activated biochars surface.

Porous CO_2 adsorbents, produced from the pyrolysis of biomass lignocellulosics with activation and surface treatment, has remarkable adsorption capacity with recyclability and stable regeneration (Jung, 2019) The preparation of activated biochar from biomass is a promising way to produce desired CO_2 adsorbents. Using biomass is a cost-effective, environmentally benign and sustainable way to produce biochar, but the general steps of pyrolysis, activation and surface treatment require high temperature, additional chemicals and longer reaction time (Anush, 2020)

15.1.5 Use in agriculture

Biochar, a product of thermochemical conversion of biomass, has received increasing attention in recent years due to its use in a variety of applications, most common. Biochar application is a soil conditioner that reduces greenhouse gas emissions and improves soil health. This is most of the organic matter in the soil. Therefore, the addition of biochar to the soil will increase C. However, it is important to note that there is little data on biochar made from raw materials other than wood and its uses. (Birk, 2012). With the current focus on mitigating climate change in soil, effective methods to assess the environmental stability of biochar and its impact on soil processes and performance are of great importance.

The potential of biochar to be a source of soil contamination should be evaluated on a case-by-case basis, taking into account not only the biochar itself, but also the soil type and environmental conditions. (Jung, 2019)

Biochar generally contains primarily organic carbon in stable, aromatic forms that are less likely to return to the atmosphere as CO_2 than carbon in pyrolysis feedstocks, even under favorable ecological and biological conditions with properties similar to charcoal. (Chen Z, 1995)

15.1.6 Microbial responses in biochar amended soils.

The physicochemical properties the physicochemical properties of biochar determine application of this biomaterial as an additive to improve soil quality Biochar's surface and holes, offer microorganisms a home. As a result, the bulk density, pH, and movement of water, air, and nutrients within the soil matrix are all improved. (Tomczyk, 2020)

Microorganisms can live on the biochar's surface and in its pores. The bulk density, pH, and movement of air, water, and nutrients within the soil matrix are all improved by this modification. (Lü, 2016) These alterations to the soil's physicochemical composition promote microbial activity. Expanded niche in an environment with lots of room and diverse objects. Directly advantageous effects of this biochar. This may occur as a result of soil and microbial characteristics. (Ambambi, 2020).

15. Modern technology

As mentioned earlier, research on the different methods and parameters of biochar production, such as heating temperature and rate, and residence time, has found that the properties of biochar can change depending on the production technology. The production process begins by burning fuels, by electrical or microwave heating. At present, cheap, simple and traditional charcoal making technologies and brick and metal kilns are being changed to modern biochar production technologies which are being changed to modern biochar production technologies resulting in higher yield of biochar (Masoumi, 2021).

16.1.1 New science and technology of Biochar obtaining.

These include the use of biochar as a precursor for the manufacture of catalysts and pollutant sorbents. These new high-value applications are still evolving technologies and require further research and development to achieve commercialization. Currently, biochar is only used as a sustainable feedstock for applications such as catalyst precursors and adsorbents for pollutants and soil conditioners. However, some applications are being considered. It depends on its properties. For example, biochar, with its high electrical conductivity, porosity, and low-temperature stability, is an electrode material for microbial fuel cells.

Biochar is a new technology rich in carbon which can be obtained from different biomasses that are products or raw materials that originate from organic matter and in turn renewable from biological formation, but the most abundant are in fact agricultural residues. and sewage sludge. Due to its large amount of carbon and cationic composition, biochar has been growing as a research topic to provide composting alternatives. (Sanchez, 2020)

The physicochemical properties of biochar vary according to the biomass used as feedstock and pyrolysis, gasification and hydrothermal carbonization procedures are the common methods for biochar preparation. The selection of modification methods takes into account the application that is given to the biochar. (Fig. 7).

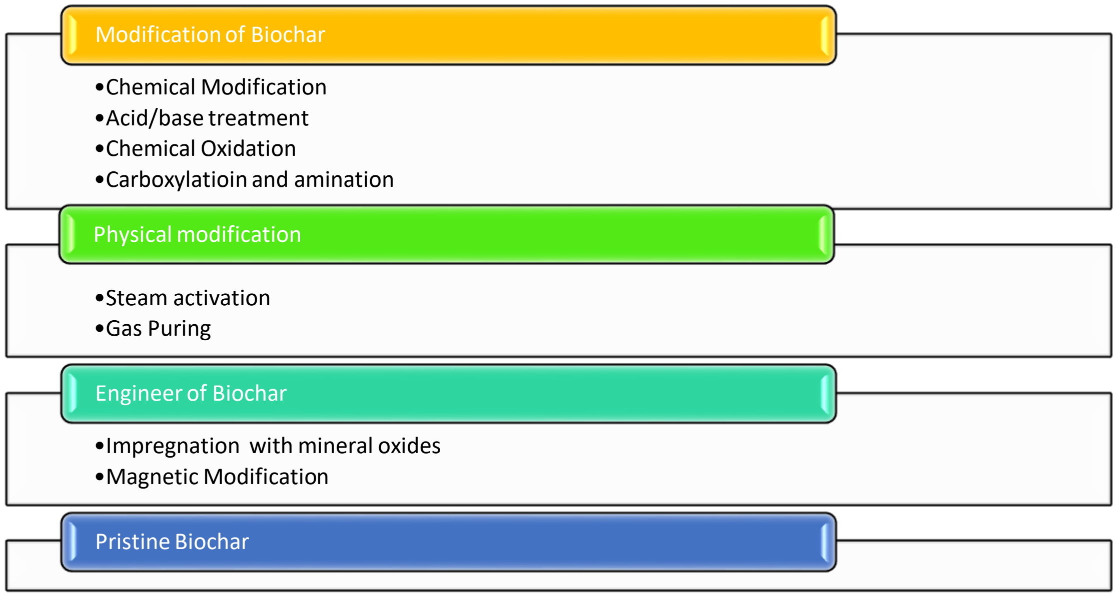

Figure 7. New technology in biochar.

16.1.2 Biochar as a starting material for the production of catalysts

Catalyst for use in cleaning syngas. Because of the significant amount of tar it contains, syngas generated from biomass gasification is bad for the processes that come after. Thermal cracking is energy-intensive, incapable of dissolving refractory tars, and may encourage the development of polyaromatic hydrocarbons that are carcinogenic. Dolomite and catalysts made of metals have traditionally been used to purify syngas. Recent studies also show promise for the use of biochar " (Clough, 2010)

In order to purify syngas, biochar can be employed either as an active metal support or as a catalyst on its own. Pore size, surface area, and mineral content are all related to the catalytic activity of biochar. (Chen Z, 1995) A model catalyst for the catalytic breakdown of tar is pine bark biochar utilizing unprocessed pine bark charcoal produced through delayed pyrolysis (950 °C) to break down toluene in the presence of steam between 600 ° C and 900 ° C. Using tar compounds, pine bark biochar was compared to synthetic catalysts such dolomite, olivine, nickel, catalysts, and fly ash and produced better results (Whalen, 2015)

By requiring less material and processing, the use of biochar-based catalysts for uses like syngas cleaning will boost the overall sustainability of the bioenergy refinery system. Biochar offers both financial and environmental advantages for usage in fuel cells and supercapacitors. However, the leftover biomass precursors have a significant impact on the characteristics of biochar-based functional materials. Additionally, the performance of biochar-based fuel cells or supercapacitors is still poor. For instance, a nanotube-based supercapacitor's, whereas a biochar-based supercapacitor's claimed maximum capacitance is only 250 F/g (Hilber, 2012). Improved structure and performance have been seen when biochar has been treated with HNO_3 or KOH. The type of biomass and the technique used to produce the biochar also have an impact on its quality.

To improve surface area, electrical conductivity, recalcitrance, and tensile strength, high carbonization temperatures are also recommended. It is imperative to do research on carbonization technique optimization, biomass selection, and post-treatment to create biochar with the qualities required for particular applications. (Weber, 2018). Enhancing the material Anode structure can increase the DCFC's power output and robustness. By lowering the demand for materials and processing, the use of biochar-based catalysts in applications like syngas purification would increase the overall sustainability of bioenergy processing systems.

Additionally, there are financial and environmental advantages to using biochar in fuel cells and supercapacitors. However, the residual biomass precursors have a significant impact on the characteristics of biochar-based functional materials. Biochar-based fuel cells or supercapacitors continue to function poorly (Zhang H. V., 2015). The growth of the supercapacitor sector depends on the manufacture of appealing, high-quality carbon materials at competitive prices. Recently, several researchers have employed biochar made from different biomasses, including paper, cardboard, and woody biomass, as feedstock to make supercapacitors (Ameloot, 2013) (Weber, 2018). The findings indicate that biochar is a viable electrode because of its affordable price and good performance. Biochar electrodes for supercapacitors (produced from woody biomass) are quick and have a potential window of roughly.

Biochar has been successfully used in a variety of applications, including soil enhancement and fuel cells, as was previously mentioned. As a soil conditioner, biochar has some benefits but is not without drawbacks organic substances that are toxic, such polycyclic aromatic compounds. Depending on the procedure and feedstock, biochar may contain various levels of hydrocarbons, chlorinated hydrocarbons, and dioxins. Biochar contains heavy metals that can increase its availability in the soil. The effects of ecotoxicological effects on soil organisms can also be lessened by biocarbon. Knowing the properties of biocarbon is crucial for minimizing its unfavorable effects while yet reaping the benefits of soil enlargement (Masoumi, 2021).

Recent developments in biochar production, use, characteristics, and characterization methods are presented. As a soil amendment to enhance soil quality and carbon sequestration, as adsorbents to remove toxins from soil and water, as a CO_2 and H_2 storage material, and as battery fuel, biochar has a variety of potential uses (Manyà, 2012). Overall, the future of using Biochar as a high-value sustainable commodity looks quite bright. However, the characteristics of biochar need to be improved and catered to the right applications in order to be used successfully for a variety of uses. To be effective as soil amendments, catalysts, and adsorbents, biochar's criteria and methods for assessing its structure and properties must be further refined.

After being treated with nitric acid or potassium hydroxide, biochar has displayed better structure and functionality. The type of biomass used and the process used to produce the biochar also have an impact on how well it functions. Herbaceous biomass is inferior to woody biomass with a high lignin content and porosity. Woody biomass can boost porosity and conductivity for the formation of high-quality biochar. Increasing the surface area also favors a high carbonization temperature.

All biochar applications must also undergo a life cycle study to determine the possible advantages and difficulties of each one. However, because "the ideal circumstances for producing biochar and biofuel are not always the same, the parameters should be tailored to the desired end result for each use. (Valentine N, 2022) is the preferred method.

Carbonization temperatures between 400 and 600 °C are preferred for producing bio-oil with excellent bio-oil yields in CBM applications. "The life cycle analysis of the production of bioproducts (biooil and syngas) and byproducts (biochar) will therefore aid in the selection of biomass to minimize costs and environmental impact." (J.O. Skjernstad, 1999)

CHAPTER IV

BIOMASS RESOURCES IN ECUADOR

16. Production of biochar

Biochar is a solid product of the pyrolysis of biomass, resulting in waste raw material at elevated temperatures and without the addition of external oxygen. The process begins with the drying of the biomass. (Chen Y. H., 2010)

In biochar production, the main focus is on solid carbon-containing products evaporation of moisture and release of volatile substances. The composition leads to an increase in the relative fixed carbon content. The heating rate is low and the residence time is long. In the traditional coal production process, the typical temperature is slow pyrolysis around 500°C, but ultimately depends on preference. (Dunst, 2013)

A process temperature of close to 1000 °C is required, which can be achieved not only for wood raw materials, but also for agricultural residues and other low ash melting point materials. Therefore, they are normally not treated at temperatures above 700 °C. Pyrolysis in the temperature range temperatures between 200 °C and 300 °C are referred to as roasting store and concentrate most of the energy in solids, and significantly improve the mechanical properties of the biomass (e.g., grinding power) that might otherwise limit certain applications. (Downie, 2010)

In addition to process conditions, feedstock properties also affect the conversion process and product properties. Biochar is it is mainly composed of three organic compounds: cellulose, hemicellulose and lignin. They behave differently during heat treatment. Therefore, the composition of the biomass directly affects the product performance and characteristics. Hemicellulose describes a group of polysaccharides with a branched structure. it is the most attractive three main components. (Birk, 2012)

How the most common organic compound on earth, cellulose, has been studied for decades. However, the thermal decomposition is not yet complete. Lignin is a complex three-dimensional macromolecule with different chemical bonds. Therefore, decomposition does not occur like hemicellulose, it does not occur within a limited temperature range and cellulose. By contrast, lignin degrades over a wide range of temperatures. Due to the large number of different functional groups. (Sanchez, 2020)

Thermal degradation starts at 200 °C and may require up to 900 °C to complete (depending on residence time)". (Birk, 2012) "Biomass residues such as manure and sewage sludge do not contain significant amounts of lignin. Due to their different origins, it is necessary to characterize them differently in comparison to other raw material (Birk, 2012).

17. Raw materials to elaborate biochar

In Ecuador, large amounts of fruit peels are disposed of by the food industry also organic and inorganic waste coming from municipalities (Fig 8). Due to its composition, rich in fermentable soluble sugars such as cellulose, hemicellulose, and glucose, the chemical structure of the fruit peel can be transformed into biochar-based adsorbents (Yi, 2019). In this context, several studies have been developed involving fruits peels, such as mandarin (Yi, 2019), mango (Zhang R. Y., 2020) , white dragon fruit (Sial, 2018), banana (Sial, 2018), in addition to tomato peel .

For example, mango peels as a precursor to the preparation of activated carbon, which reached removal rates of 98% and 93% for rhodamine B dye and Mn^{2+} ions from aqueous solutions (Zhang R. Y., 2020). A natural mineral and banana peel, forming an efficient adsorbent compound for removal of crude oil from water used (Sial, 2018), compared raw and modified tomato skin for Cd (II) removal, concluded that the addition of activated carbon to the parent adsorbents accelerates the adsorption rate. Flower petals are also waste generated in large quantities to meet the commercial requirements of rose oil and water, many rose flowers and petals are required due to low Weight to Yield Ratio. (Dunst, 2013).

Figure 8. Biomass to develop biochar and applications.

Ecuador is one of the countries that is positioned internationally as an agricultural heritage, becoming an international and versatile producer of sustainable and top-quality fresh fruits and vegetables (Table1).

Ecuador exports the fruits of its agriculture to 135 countries worldwide and has a constant demand from importing companies interested in acquiring diverse and high-quality fresh products. Between 2014 and 2018, Ecuador exported more than 3.5 billion US dollars in fresh products, mainly to Russia (18%), United States (6%), Italy (7%), Germany (7%), Turkey (5%) and China (4%). The export volume has increased by 15%, from 6 million tons in 2014 to 7 million tons in 2018. (MAGAP)

During the same period, Ecuador's exports included bananas (6 million tons), plantains (212 tons), baby bananas (139 tons), pineapples (81 tons), broccoli (74 tons), and mangoes (60 tons). (MAGAP). Ecuador plans to carry out a diversified production exhibition through the exhibition of products to reach export potential in tree tomatoes, soursop, pineapple, grapes, papayas, avocados, pitahayas and other products. In the field of fresh fruits, without a doubt, the star product is bananas, whose exports represent more than 85% (conventional and organic).

Table 1. Data base of raw material

	Fruit				Nuts/ Grain	Wood	Garbage	Animal waste
	Pulp	Seed	peel	Palm				
Banana			x		corn	thimoty paste	garbage grate	chicken litter
orange			x		Hazelnut	wheat straw	tire rubber	swine solids
watermelon			x		Chestnut	pine wood	municipal sludge	grass & waste mix
grenade			x		cocoa beans	sawdust	sewage sludge	feed lot
lemon			x		coffee	switch grass	municipal biosolids	paper slsudge
citric			x		mangosteen	pine wood		poultry
strawberry	x				beans	willow stems		poultry manure
Pineapple			x		cocoa beans	cottonseed		wastewater
bananas			x		rice	wheat straw		turkey litter
Chirimoya			x		walnut shells	soybean stubble		crab shell
avocado		x	x		miscanthus	pine cone shell		
cashew apple	x				peanut shells	oak wood		
tamarind		x	x		pipes	pine bark		
mango	x	x			apricot	switchgrass		
coconut			x	x	canola	corn stalk		
grenade			x		rapeseed	straw		
peach			x		macadamia	shaved pine		
Nut			x		mushroom	poplar wood		
peanut			x			spruce wood		
dates			x			durian wood		
cherry	x		x			camellia branches		
olive	x	x	x			bamboo		
almond	x	x	x	x		poplar branch		
pomegranate	x	x	x			corn straw		
litchi	x	x	x			water hyacinth		
grape	x		x			bamboo		
						cane bagasse		
						eucalyptus tree		
						guadua		
						pine forest		
						sugar cane bagasse		

18. Applications, biomass characteristics

Due to the large amount of export, a large amount of waste is generated that is discarded without any favorable use for the environment. Ecuador makes annual exports by tons, this is how a product with export potential is not one that has an increase in production and profitability, but rather a product that has competitive advantages and the possibility of adapting to the market. It is important that the product to be exported complies with the standards, characteristics and regulations required in the Market.

A neglect in any of the attributes that are part of the product can lead to the closure of the Market as well as a bad image of the company. That is why products that do not pass quality control are considered agro-industrial waste (Table 2), fruits that meet the standard required for export are exported, the other part of the harvest is generated for sale in the country and finally the surplus is generated waste.

Table 2. Classification of Biochar´s raw material and its application.

Fruit	Aplication	Utillity	Characteristic	Environmental S.
Banana	wastewater	Red dye removal	biochar on Hg transport reduction	Soil
orange	wastewater	Red dye removal	biochar to soils on productivity	soil
watermelon	leaching of LIBs wastes	recovery of Co(OH)2	biochar in temperate soils	soil
pomegranate	removal of metals in effluents	chromium (Cr+6) and lead (Pb)	biochar to low fertility soils	soil
lemon	potential applications	FP as a substrate for bioactives	biochar to soil	soil
citrus	removal of heavy metals	trivalent arsenic removal	biochar for land remediation	soil
strawberry	renewable energy source	biochar or Asp with carbon is potentially viable and economically beneficial for increasing HHV.	soil and water	Water
tree	fuel blends and residual energy.	Good biomass	biochar on soil physical properties	soil
pineapple	Valorization of bioenergy, biofuels.	zero waste	biochar-based water treatment	water
pineapple	Wastewater bc.	adsorbents for removal of Cu(II)	magnetic biochar	Water
bananas	cheap and environmentally friendly adsorbents	oxamyl removal from aqueous solution		Water
pineapple/custard apple	higher gross calorific value (7250 kcal/kg)	water from bio-oil decreased		production
green macro algae	Adsorption	adsorption on Cd (Ⅱ)		production
avocado peelstone	Adsorption	adsorption on Cd (Ⅱ)		production
tamarind	aquatic environment.	Cr(VI) removal		production
pineapple		Biochar production and applications		Production
coconut shell		Recent developments on algal biochar production and characterization		Production
coffee		biochar production and biochar yield		Production
mangosteen		fruit peel		Production

19. Limitation of raw material and its classification

In the literature there is a wide variety of research about Biochar, in recent years various products have been investigated as a source to produce high quality Biochar, performance and with various applications. Several investigations have been investigated to create a range of options of raw materials to make Biochar in this section the investigation is based on fruits (Table 3), wood among other waste (Table 2) which has been divided into four groups for a better interpretation. (Lü F., 2016)

Table 3. *Classification according to nature of fruit.*

Fruit Classification			
Acidic Fruits	**Semi-Acid Fruits**	**Neutral Fruits**	**Sweet Fruits**
Lemon Orange Pineapple	Strawberry Tamarind Jackfruit Mango Peach Mangosteen	Avocado coconut Nut Peanut hazelnut olive corn chestnut cocoa almond coffee	Banana Watermelon Pomegranate cherry

20. Raw material in Ecuador.

Ecuador is a country that produces: cacao, bananas, coffee, prickly pear, flowers, shrimp, and others obtained directly from nature and its commercialization has increased in recent years. Production increases to satisfy national demand and gain market at the international level. Agricultural activities in Ecuador contribute to generating capital, allowing the industry to mobilize the country. Second, the agricultural structures in Ecuador have not yet reached a level that allows them to transform into agro-industrial systems that create financial and commercial synergies but they are in process. Through the supply and export of agricultural products, industrial sector policies have a negative impact on agricultural production and exports. The agricultural sector has a great influence on the resources mobilized in these sectors. Investing in agriculture is not just about allocating capital, but about managing sustainable activities institutions that promote the development of human resources, research and innovation for this purpose. (Centanaro Paulo, 2021)

The main factor of economic growth is based on the concept of agricultural production and management. Thus, economic development and the continued development of an integrated world color the development styles of countries. Countries that use their strengths and comparative advantages to compete globally. Ecuador is located in the tropics, with different geographical conditions that make that make Ecuador have a variety of crops that can be used as raw material.

The use of natural resources in the agricultural sector has the potential to address complex relationships. It is one of the pillars of the country's development. Investments in agriculture not only increase the productivity of the sector but also create jobs and generate exportations that contribute to the country.

The objective is to promote a better and greater agricultural activity; of public spending. It is not enough to meet expectations in terms of productivity and poverty reduction. In Ecuador, agrarian reform was from the beginning a means to make agriculture more attractive. (Centanaro Paulo, 2021)The farmers' point of view, at least as a basic objective to prevent the problems caused by migration, therefore, the agricultural expansion grows with limited capital requirements that affect the establishment. The industry is not only related to raw materials but also to the staple food industry, but for the continuous and long-term growth of the industry requires fixed investments, as well as the establishment of companies. Different methods of generating profitability in the agricultural sector (Centanaro Paulo, 2021). It was Latin American agricultural exports in the 1950s that successfully gained European market share but insufficient to meet industry demand.

Most of the country's output is sold or converted into goods and services, reflecting the need to renew the management of the productive matrix, go to different places, add value and enable Domestic production replaces selective imports.

21. Main production.

According to a National Institute of Statistics study, the country's agricultural area increased to 5.3 million hectares (ha) in 2018, outpacing the production of other commodities such as dry maize, rice, bananas, African palm, and sugar cane (for sugar). According to (MAGAP, 2020) Ecuador (total of 1,464,589 hectares were planted with permanent crops, including sugar cane (for sugar), bananas, African palm, and other crops. The total tonnage of sugarcane produced was 7,502,251. A whopping 87.1% of this production came from Guayas. With 38 banana crops, Los Rios stood out (6,505,635 mt in total). African palm predominated in Esmeraldas with 42.7% (2,785,756 mt). (MAGAP,2020)

Contrarily, 941,280 hectares were planted with transient crops having a crop cycle of less than a year, including rice, potatoes, hard maize, and other such crops. The largest output in this region was reported for rice, one of several products that are consumed in Ecuador: 1,350,093 mt Guayas is home to 72.7% of the population. Ecuador has several hectares with diverse crops, due to the geographical position, the country has four main regions Coast, Sierra, Oriente and Insular (Fig. 4), each region has native products from its area which allows Ecuador to be a producer raw material constant.

Table 4. *Main Ecuador´s Production by Natural Region.*

Costa	Sierra	Oriente
Cocoa	Dry corn	Sugar cane
Rice	Sugar cane	yucca
Oil palm	beans	tobacco
Banana	dad	pineapple
Banana.	soy	lemon
Coffee	passion fruit	tomato.
orange	barley	
mango	Broccoli	
Avocado	Bean	
pineapple	peanut	
	vetch	
	wheat	
	lemon	
	White onion	
	quinoa	
	tomato	

22. Estimated of waste material and Yield Ecuadorian products to be Biochar.

Ecuador, having a diverse climate in its regions, is in production every day of the year in its regions, the area of agricultural work reaches 5.3 million hectares, and the main production of Ecuador is based on sugarcane bagasse (for sugar), bananas, African palm, rice, potatoes, corn, are the crops that exceed other products according to studies by the National Institute of Statistics and Censuses (INEC).

Each province of the country concentrates and registers a specific production represented in tons and percentages. Crop production is measured in metric tons, that is, sugarcane production in metric tons was 7,502,251. Meanwhile, rice, potatoes, and corn, among others, are transitory crops with a harvest cycle of less than one year.

The production of tons of these products in turn generates a quantity of discarded organic waste like trash. However, these residues can be used as biomass to manufacture Biochar, which is why an estimate of the most cultivated products in the country is proposed below, the product is analyzed as 100%, and the components of the fruit that can be used for the manufacture of Biochar for a brief visualization of the percentage that can be used. (Table 5).

Table 5. *Yield of Ecuador product.*

Banano	Province	Yield	Production	Estimate		Exportation
	Santa Elena	16,97 t/ha	0,1 %	Fruit	100 %	
	El Oro	9,57 t/ha	0,1 %	Peel	30 %	
	Guayas	8,67 t/ha	14,02 %	Pulp	70 %	
	Morona S.	8,38 t/ha	2,93 %			
	Manabí	7,54 t/ha	40,02 %			
	Sto. Domingo		15,48 %			
	Los Ríos		7,17 %			
	Total	763,455 t				57095 t

Rice	Province	Yield	Production	Estimate		Exportation
	Chimborazo	6,48 t/ha	0,1 %	Grain	80 %	
	Guayas	4,6 t/ha	62,53 %	Peel	20 %	
	Bolivar	4,5 t/ha	0,1 %			
	Los Ríos	4,36 t/ha	30,06 %			
	El Oro	4,32 t/ha	0,1 %			
	Sucumbíos		0,46 %			
	Loja		3,22 %			
	Total	1.504,21 t				104.000 t

Sugar Cane	Province	Yield	Production	Estimate		Exportation
	Imbabura	135,55 t/ha	2,03 %	Bagasse	90 %	
	Loja	127,82 t/ha	0,1 %	Liquid	10 %	
	Guayas	88,22 t/ha	75,9 %			
	Carchi	81,9 t/ha	0,1 %			
	Cañar	78,5 t/ha	18,41 %			
	Total	11.372,51 t				1.700 t

Corn	Province	Yield	Production	Estimate		Exportation
	Santa Elena	5,99 t/ha	0 %	cob+leaf	15 %	
	Los Ríos	5,16 t/ha	46,02 %	Grain	85 %	
	Guayas	4,93 t/ha	14,97 %			
	Manabí	4,69 t/ha	29,84 %			
	St. Domingo	4,52 t/ha	0,39 %			
	Total					850 t

Cocoa	Province	Yield	Production	Estimate		Exportation
	Los Ríos	0,71 t/ha	27,7 %	pulp	25 %	
	Guayas	0,71 t/ha	23,94 %	Seeds	75 %	
	Pichincha	0,71 t/ha	0 %			
	Sta. Elena	0,64 t/ha	0 %			
	Cotopaxi	0,61 t/ha	0 %			
	Manabí		14,84			
	Zamora Ch		9,4			
	Esmeraldas		12,14			
	Sto. Domingo		4,8			
	Total		302,094			325.208 t

Soy	Province	Yield	Production	Estimate		Exportation
	Esmeraldas	1,36 t/ha	0 %	Grain	85 %	
	Los Ríos	1,16 t/ha	68,22 %	Pod	15 %	
	Sta. Elena	1,14 t/ha	0,74 %			
	Guayas	0,89 t/ha	29,43 %			
	Total					34 t

Avocado	Province	Yield	Production	Estimate		Exportation
	Carchi	7,44 t/ha	16,652 %	Pulp	70 %	
	Pichincha	4,96 t/ha	8,781 %	seed	20 %	
	Sta. Elena	15,91 t/ha	8,273 %	Peel	10 %	
	Imbabura	5,39 t/ha	4,118 %			
	Tungurahua	5,71 t/ha	2,744 %			
	Azuay	20,95 t/ha	1,329 %			
	Otras	3,55 t/ha	5,94 %			
	Total					1.000 t

Dragon F	Province	Yield	Production	Estimate		Exportation
	Morona S	4,34 t/ha	3,935 %	Pulp	80 %	
	Imbabura	9,96 t/ha	2,454 %	seed	15 %	
	Guayas	8,83 t/ha	1,123 %	Peel	5 %	
	Zamora Ch.	7 t/ha	59,2 %			
	Pastaza	8,21 t/ha	38,3 %			
	Manabí	6,62 t/ha	1,72 %			
	Otras	3,13 t/ha	14 %			
	Total					17,895 t

Mango	Province	Yield	Production	Estimate		Exportation
	Guayas	7,95 t/ha	120,621 %	Pulp	65 %	
	Los Ríos	3,49 t/ha	2,194 %	seed	10 %	
	Imbabura	3,5 t/ha	1,01 %	Peel	35 %	
	El Oro	3,9 t/ha	101 %			
	Manabí	3 t/ha	81 %			
	Loja	7,27 t/ha	70 %			
	Otras	5,6 t/ha	89 %			
	Total					55,000 t

Quinoa	Province	Yield	Production	Estimate		Exportation
	Chimborazo	0,63 t/ha	1,743 t	Grain	95 %	
	Carchi	0,9 t/ha	253 t	Straw	5 %	
	Cotopaxi	0,28 t/ha	362 t			
	Pichincha	2,07 t/ha	19 t			
	Imbabura	0,41 t/ha	10 t			
	Cañar	0,15 t/ha	0 t			
	Total					400,000 t
Pineapple	**Province**	**Yield**	**Production**	**Estimate**		**Exportation**
	Sto. Domingo	61,13 t/ha	98,83 %	Pulp	75 %	
	Los Ríos	48,56 t/ha	85,36 %	Peel	25 %	
	Guayas	17,21 t/ha	21,509 %			
	Sucumbíos	2,24 t/ha	395 %			
	Carchi	6,91 t/ha	354 %			
	Morona S.	11,55 t/ha	131 %			
	Otras	2,03 t/ha	85 %			
	Total					100,000 t
Roses	**Province**	**Yield**	**Production**	**Estimate**		**Exportation**
	Pichincha	639 (N°/ha)	2.614,94 N° Tallos	Petals	5 %	
	Cotopaxi	718 (N°/ha)	969,391 %	stems	15 %	
	Carchi	316 (N°/ha)	28,023 %			
	Imbabura	664 (N°/ha)	26,221 %			
	Cañar	926 (N°/ha)	9,26 %			
	Tungurahua	79 (N°/ha)	158 %			
	Total					272,700 t

Based on the data obtained and the estimation made to the main products grown in Ecuador, it is observed that sugarcane bagasse is a product grown in large tons in the country and due to the sugar mill and liquor production, a large ton of waste, 75% of waste is estimated (Table 5), which may have a higher yield in the production of Biochar.

CHAPTER V

SUGGESTED RAW MATERIAL TO BE BIOCHAR

23. Cane Bagasse

1.44 t/day of sugarcane bagasse are produced daily, resulting in negative impacts on the environment, due to the decomposition time and the volume that this residue occupies in the garbage dump; and from the economic point of view there is a loss of time and money in its collection.

The sugar and alcohol industry in Ecuador generates a significant number of by-products; In 2008, approximately 1,300,000 t of bagasse, 140,000 t of filter cake, 35,000 t of ash and 510,000 m^3 of stillage were generated. Of these, the bagasse is used in cogeneration; while, the filter cake, ash and vinasse can be used to apply to the cane crop in fresh or composted form. (Divband Hafshejani, 2016)

Filter cake, also called filter cake because of its spongy appearance, is the residue from the clarification of cane juice. It is characterized by having a high moisture content (around 75%) and it is chemically composed of cellulose, hemicellulose and lignans from the bagasse used to trap impurities and sugars.

Technological advances allow what can be considered waste to become a usable material for production. This is how a circular economy is promoted, in which materials can be reused for the sustainability of the planet. Such is the case of sugarcane bagasse, which is perfect to become a Biochar with applications for environmental remediation. Sugarcane bagasse is one of the main biomass residues from sugar production, from Sugarcane the waste represents 75% to 90% of waste. (Divband Hafshejani, 2016)

24. Materials and Methods.

The sugar cane bagasse was provided by the Northern Sugar Mill. The bagasse was recovered and dried at 100°C for 24 hours.

Sugarcane bagasse moisture determination.

Moisture is one of the variables considered when carrying out the thermal process, pyrolysis, since it is necessary for the biomass to be treated to have a humidity of less than 10%, which is why it was necessary to find the value of the humidity of the raw material to be used, according to the ASTM C566 standard (International., 2010), for this it was necessary to take into account the initial value of the capsule without the sugarcane bagasse to be placed in the oven at 100°C, the value end of the capsule after 24 h and the amount of bagasse put in the capsule, as shown below:

With these data, we sought to find the final weight of the bagasse entered.

Table 6. Result of drying process of Cane Bagasse

Weight	Value	Unit
W Capsule	3,56	g
W Capsule & CB	15,08	g
FW Capsule & CB	12,57	g

Source: Autor.

Regarding the close analysis of ashes and volatile material, the respective tests were carried out in a temperature range of 800°C to 850°C in a muffle, obtaining the respective values.

Table 7. Results of ashes and volatile material.

Parameter	Value
wet %	7,6
Ashes%	7,08
volatile%	80,44

Source: Author

24. Characterization of sugar cane bagasse

The elemental analysis of Compounds was taken from theoretical data extracted from the study "Characterization of sugarcane bagasse as vegetable biomass", in order to compare the elemental properties of the raw material before and after transformation, it is relevant to have the composition of organic compounds.

25. FRX Analysis.

The sugarcane bagasse is subjected to drying process and a pulverization, 10 grams of cane bagasse are placed in metal dishes to pulverize it for 170 seconds, after pulverization it is compacted in a metal tablet to proceed to place the tablet in an FRX (X-ray fluorescence).

The data obtained from the FRX analysis are presented in the following

Table 8. Analysis FRX

Si	Mg	Mn	Cu	Al	Na
0,9	0,058	0,0103	0,01	0,127	0,037
Cr	**Ca**	**Cl**	**Sr**	**P**	**Zn**
0,032	0,17	0,023	0,011	0,016	0,01
Fe	**S**	**Cu**	**Ti**		
0,1	0,024	0,001	0,052		

Source: Author

26. Results.

It has a very low nitrogen content and alkaline earth compounds, which makes it an excellent material with few carbonates, that is, the carbon content is basically organic carbon.

A percentage of 79 to 81% of volatile material indicates that the material burns easily and is more susceptible to degradation, for its part the ash content of 7.08% of the material is low, and having a humidity of 7, 6% guarantees the non-formation of deposits on the walls of the pyrolyzer, minimal equipment operating costs, a more effective pyrolysis process and a higher yield of biomass production. According to the literature the volatilization of the inherent alkaline or alkaline earth metal especies compounds is 10 to 20% during pyrolysis.

27. Utilities of a Sugarcane Bagasse Biochar.

It is important for the adsorption of anions, to talk about the superficial properties of Biochar, in the study "Removal of nitrate from the aqueous solution by Biochar of sugarcane bagasse" the cation exchange capacity (CEC) and the capacity of anion exchange (ACE) with results of 12.90 cmol/kg and 10.21 cmol/kg, respectively (Divband Hafshejani, 2016).

There is a strong adsorption potential of Biochar, made from sugarcane bagasse, in the elimination or removal of anionic contaminants such as nitrate, sulfate and phosphates in aqueous solution. The adsorption capacity of Biochar generated from Sugarcane Bagasse has optimal surface properties such as its surface area, and present surface charge, together with the presence of competitive ions with a high negative potential that allow polluting compounds to filter through through this.

Alkaline earth compounds (EAEMs) such as Na, K and Ca retained in biochars are the key catalytic species, and the catalytic effect appears to be in the order of K > Na > Ca during the steam gasification reaction of these biochars. (Kongvui Yip, 2010)

During steam gasification, almost all of the AAEM species inherent in the biochar are retained in the biochar which reacts during the course of the conversion. Steam gasification of raw and acid-treated biochar produces high-quality syngas products that contain little methane. Further analysis shows that during the course of biochar conversion, the main gasification product is most likely CO and, in general, the gas-water shift reaction is primarily responsible for the formation of CO_2. Inherent AAEM species are found to significantly catalyze biochar gasification. (Kongvui Yip, 2010)

Conclusion

Ecuador is a megadiverse country that generates tons of organic and inorganic waste per year, including various agro-industrial waste. The amount of cultivation, production and export that exists in the country generates a wide range of residues from fruits, vegetables, tubers that can be called agro-industrial residue. The raw material generated in Ecuador is a viable factor for the generation of Biochar, since there is a wide range of raw material ready to be recycled and converted into a new technology.

The biochar market is expanding due to new research, a diversified information chain, which includes applications, raw materials, manufacturing methods and innovation in the process of obtaining Biochar are present in different nations and Ecuador is no exception.

With an approximate estimate of the residues from the products that are generated in the country, the feasibility of generating Biochar from sugarcane bagasse is analyzed, concluding that it is the best option since most of the tuber is residue. The chemical composition of sugarcane bagasse is similar to the composition of sugarcane bagasse that has been previously investigated in the literature, it also contains lignin and alkaline earth metals that make it an excellent agroindustrial residue for soil remediation and waste purification. water because it traps organic and metallic contaminants (property of alkaline earth metals) without leaving any by-product as a convencional treatment does. This means that Ecuadorian sugarcane bagasse can generate high-quality biochar with a wide range of applicability.

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