People`s Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
University of Echahid Hamma Lakhdar - El Oued

Faculty of Technology

Department of Methods Engineering

Dissertation

ACADEMIC MASTER

Domain: Science and Technology

Division: Methods Engineering

Specialty: Chemical Engineering

Presented by:

1. Chennouf Riadh

Entitled:

Turning Waste into Wealth: A Filed Study on Boosting Soil Quality through Organic Waste Recycling

Dissertation Submitted in Partial Fulfillment of the Requirements for the Master Degree in Academic Master

Publicly defended in: 28/05/2025

Board of Examiners:

Dr. Ben Seghir Bachir	**Chairman**
Dr. Hemmami Hadia	**Supervisor**
Dr. Dia Wahida	**Examiner**
Dr. Ben amor Ilham	**Assistant Supervisor**

Academic Year: 2024/2025

Abstract:

This study aims to investigate the potential of converting organic wastes into valuable resources for improving soil quality and plant nutrition. The research focuses on improving soil fertility and facilitating the growth of pea (Pisum sativum) and chickpea (Cicer arietinum) plants by using soil biochar made from watermelon rinds, eggshells, lemon peels, and agricultural wastes with soil irrigated with a basic organic solution. Fourier transform infrared (FTIR) and ultraviolet-visible (UV-Vis) spectroscopy techniques were used to characterize these samples. The results showed that eggshell ash (EA) extract was beneficial for pea, while lemon peel extract (LG) enhanced chickpeas growth. For iron (Fe) and zinc (Zn), both LG and EG fertilizers demonstrated their role in sustained nutrient release. To improve soil quality and agricultural production, this work highlights the role of appropriate organic fertilizers for plant adaptation and the importance of recycling organic waste in an environmentally safe manner.

Keywords: Organic waste, organic fertilizers ،Soil Biochar ،Recycling.

الملخص:

تهدف هذه الدراسة إلى دراسة إمكانية تحويل النفايات الزراعية والعضوية إلى موارد قيّمة لتحسين جودة التربة وتغذية النبات. يركز البحث على تحسين خصوبة التربة وتسهيل نمو نباتات البازلاء (Pisum sativum) والحمص Cicer (arietinum) باستخدام الفحم الحيوي للتربة المصنوع من قشور البطيخ وقشور البيض وقشور الليمون والنفايات الزراعية، مع ري التربة بمحلول عضوي أساسي. استُخدمت تقنيات التحليل الطيفي بالأشعة تحت الحمراء بتقنية تحويل فورييه (FTIR) والأشعة فوق البنفسجية المرئية (UV–Vis) لتوصيف هذه العينات. أظهرت النتائج أن مستخلص رماد قشر البيض (EA) كان مفيدًا للبازلاء، بينما عزز مستخلص قشر الليمون (LG) نمو الحمص. بالنسبة للحديد (Fe) والزنك(Zn) ، أثبت كل من أسمدة (LG) و(EG) دورهما في إطلاق المغذيات بشكل مستدام. لتحسين جودة التربة والإنتاج الزراعي، يُسلط هذا العمل الضوء على دور الأسمدة العضوية المناسبة لتكيف النبات وأهمية إعادة تدوير النفايات العضوية بطريقة آمنة بيئيًا.

الكلمات المفتاحية: النفايات العضوية، الأسمدة العضوية، الفحم الحيوي للتربة، إعادة التدوير.

Dedication

In the Name of Allah

The Most Gracious, the Most Merciful Praise be to Allah, and peace and blessings be upon the one from who's light and bounty souls draw, our Master Muhammad, the Seal of the Prophets and Messengers, and upon his family and all his companions.

The last day of my academic life, and thanks be to God for completing “number of years” a year of study. I dedicate my graduation to the one who drank the cup empty so that you could give me a drop. To the one who harvested the thorns from my path so that you could pave the way for me to learn. To the one who breastfed me with love and tenderness. To the symbol of love and the balm of healing, my beloved mother. To my small family and my extended family who supported me despite my failures and setbacks... to those who thought well of me and saw the good in me with their eyes and hearts.

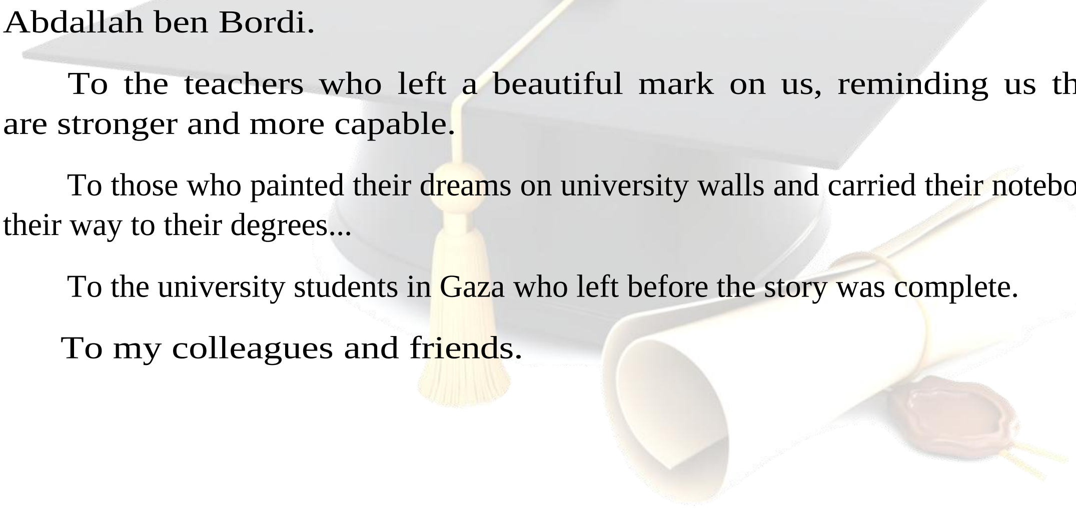
To my spiritual father and teacher, with whom I learned the love of success, development, responsibility, and media integrity... To Imam Abdallah ben Bordi.

To the teachers who left a beautiful mark on us, reminding us that we are stronger and more capable.

To those who painted their dreams on university walls and carried their notebooks on their way to their degrees...

To the university students in Gaza who left before the story was complete.

To my colleagues and friends.



Chennouf Riadh

THANKS

Be a scholar… If you cannot, then be a learner. If you cannot, then love scholars, if you cannot, then do not hate them.

After a journey of research, effort, and diligence that culminated in the completion of this research, I thank God Almighty for the blessings He has bestowed upon me. He is the Almighty. I can also express my deepest gratitude and appreciation to **Dr. Hemmami Hadia** for the effort, advice, and knowledge she provided throughout the completion of this research.

I also extend my deepest thanks and appreciation to those who have assisted me in this research and provided light to illuminate the darkness that sometimes stood in my way.

Also extend my deepest thanks and appreciation to those who have assisted me in this research and provided light to illuminate the darkness that sometimes stood in my way. I also extend my most sincere thanks and gratitude to all those who provided me with assistance, facilitation, and information: the faculty who supervised my training, the unit manager, namely: **Dr. Oucif Mohammad El-Tayeb Khaled**, **Dr. Ben amor Ilham**,

Dr. Zeghoud Soumaya, and **Mrs. channa DJihad**.

The research is my research. Without them, I would not have experienced the joy of work and the sweetness of research, and I would not have reached this point.

They deserve thanks …

Index

Theoretical Part

Chapter 01: Biomass and Biochar

Chapter 02: Cellulose

Chapter 03: Previous Studies

Practical Part

Chapter 04: Practical Part/Results and Discussion

List of Tables

List of Figures

Figure **Page**

Chapter 01

Chapter 02

Chapter 04

List of Figures

List of Symbols

Symbols	Signification
A	Absorbance
AC	Ambient Condition Extraction
ADF	Acid Detergent Fiber
AFM	Atomic Force Microscopy
AGU	Anhydroglucopyranose Unit
AmimCl	1-allyl-3-methylimidazolium chloride
ATR-FTIR	infrared absorption spectroscopy
AWC	Available Water Content
BC	Biochar
BET	Brunauer–Emmett–Teller
$[Bu_4P]^+$	Tetrabutylphosphonium
C	Carbon
c	Sample cocentration
Ca	Calcium
$Ca(OH)_2$	Calcium Hydroxide
Cd	Cadmium
CH3COOH	acetic acid
CH4	Methane
CHN	Carbon, Hydrogen, Nitrogen
$C_2H_4O_3$	Organic Peroxide
$C_6H_{10}O_5$	The basic repeating unit in carbohydrate polymers
$[C_nmim]^+$	1-alkyl-3-methylimidazolium
CO	Monoxide carbon
CO_2	Carbon Dioxide
Cu	copper
d	Distance between the two planes
EC	Ethylcellulose
ES	Eggshell
Fe	Iron
FTIR	Fourier Transform Infrared Spectroscopy
GFAAS	Graphite furance atomic absorption analytic spectroscopy
GHGs	Greenhouse gas emissions
GLC	Gas-Liquid Chromatography
HCl	Hydrochloric Acid
HGA-70	Model atomic absorption spectrophotometer
HKL	Miller's of the indicator for the respective levels
HMs	Heavy Metals
HNO_3	Nitric Acid
H_2O	Water
H_2O_2	Hydrogen Peroxide
H_3O^+	Hydronium Ion
HPC	Hydroxypropyl Cellulose
H_3PO_4	Phosphoric Acid
HS	Hestrin-Schramm
HT	High Temperature
HT	Hydrothermal Extraction
I	The intensity of light transmitted by the sample solution
I0	The intensity of the incident light

List of Symbols

I/I 0	permeability
I0/I	Absorbance
ICP	Inductively Coupled Plasma
IR	Infrared
K	Potassium
Kfs	Saturated Hydraulic Conductivity
K(h)	Unsaturated Hydraulic Conductivity
L	The length of the sample path
LC-MS	Liquid Chromatography–Mass Spectrometry
LDL	Low-Density Lipoprotein
log10	Napierian logarithm
LT	Low Temperature
MCC	Microcrystalline Cellulose
MDSC	modulated differential scanning calorimetry
Mg	Magnesium
MSW	Municipal Solid Waste
N	Nitrogen
n	Ordre of reflection
N2	Azote
Na	Sodium
$NaClO_2$	sodium chlorite
NaOH	Sodium Hydroxide
NDF	Neutral Detergent Fiber
NH_4N	Nitrogen as Ammonium
NH_4 NO_3	Ammonium Nitrate
NMR	Nuclear magnetic resonance
N_2O	Nitrous oxide
NO_3-N	Nitrate Nitrogen
NUE	Nitrogen Use Efficiency
O	Oxygen
O_2	Oxygen
O_3	Ozone
OFI	Opuntia ficus-indica
P	Phosphorus
Pb	Lead
PC	pineapple core cellulose
PCs	phenolic compounds
PDF	pineapple core dietary fiber
pH	Power of hydrogen
PTEs	Potentially Toxic Elements
RH	rice husk
S	Sulfur
SA	Standard Alkali Extraction
SEM	Scanning Electron Microscopy
SOC	Soil Organic Carbon
T	permeability
TEM	Transmission Electron Microscopy
TGA	Thermogravimetric Analysis
TS	Two-Stage Extraction
UV	Ultra violet
WD	Wetting and Drying

List of Symbols

WUE	Water Use Efficiency
XRD	X-ray Diffraction
Zn	Zinc
ε	Molar absorption coefficient

General introduction

The world today suffers from the accumulation of organic waste, especially agricultural waste, which has become an environmental problem. Despite the significant properties of lemon, watermelon, and egg peels, they are not well utilized, especially in areas with high consumption. However, once reclaimed, they can have numerous benefits, including improving and enriching the soil [1].

Biomass is defined as any organic material derived from living organisms, such as solid waste and animal dung. It is considered one of the most important biodegradable and renewable resources that can be converted into energy, cellulose, and biochar. The latter is considered one of the results of the thermal decomposition of biomass, and it is a solid material full of carbon, and it is relied upon to increase soil fertility [2].

Several studies have addressed the topic of converting fruit and egg peels into biochar, given its benefits in improving soil. Eggshells are the primary source for producing calcium oxide by burning, which is suitable for adjusting pH. Watermelon and lemon peels have proven effective in extracting cellulose, as they are rich in lignocellulosic materials [3].

Cellulose is the most widely used organic polymer and represents the formal structure of plant cell walls. It has several properties, including biodegradability and the ability to be chemically modified. Lemon and watermelon peels are among the best raw materials for the sustainable and economical production of cellulose for industrial and environmental use. Eggshells, while not plant-based, may not contain cellulose. However, their protein-rich membranes possess biological functional properties that enable them to form complexes with cellulose [4, 5].

After heat treatment, organic residues may undergo structural changes that improve their surface activity and adsorption capacity. Biochar and ash are also produced, which can stabilize heavy metals, improve soil aeration, and provide nutrients. The calcium oxide in eggshell ash can help remove metals such as iron and copper, while biochar can preserve functional surface groups to enhance heavy metal adsorption and improve soil structure [3, 6].

Despite the properties of these materials, there is little knowledge about their quality in soil and plants, whether they are heat-treated or not. It is necessary to study the effect of heat treatment on their physicochemical properties, as well as their role and effectiveness as a source of nutrition and soil improvement.

The study includes four chapters:

Chapter One: This chapter provides general information about biomass valuation and the importance of biochar and agricultural waste used in this study.

Chapter Two: This chapter covers general information about Cellulose sources, its importance, extraction and most important uses.

Chapter Three: This chapter reviews previous studies.

Chapter Four: We first discuss the practical aspects, then move on to the results and discussion.

Lastly, we offer the study's overall conclusion, which shows how well the goals of the investigation were met by the outcomes.

Reference:

[1] S. Kaza, L. Yao, P. Bhada-Tata, and F. Van Woerden, What a waste 2.0: a global snapshot of solid waste management to 2050: World Bank Publications, 2018.

[2] A. Demirbaş, "Biomass resource facilities and biomass conversion processing for fuels and chemicals," Energy conversion and Management, vol. 42, pp. 1357-1378, 2001.

[3] J. Lehmann and S. Joseph, Biochar for environmental management: science, technology and implementation: Taylor & Francis, 2024.

[4] D. Klemm, B. Heublein, H. P. Fink, and A. Bohn, "Cellulose: fascinating biopolymer and sustainable raw material," Angewandte chemie international edition, vol. 44, pp. 3358-3393, 2005.

[5] M. T. Hincke, Y. Nys, J. Gautron, K. Mann, A. B. Rodriguez-Navarro, and M. D. McKee, "The eggshell: structure, composition and mineralization," Front Biosci, vol. 17, pp. 1266-1280, 2012.

[6] H. J. Park, S. W. Jeong, J. K. Yang, B. G. Kim, and S. M. Lee, "Removal of heavy metals using waste eggshell," Journal of environmental sciences, vol. 19, pp. 1436-1441, 2007.

Chapter One: Biomass and Biochar

Preface

If we are to make the necessary changes to address the effects of global warming, the usage of renewable energy sources is becoming more and more important. The most popular renewable energy source is biomass, which is utilized extensively in the third world but less so in the West until recently. Finding appropriate biomass species that can produce high energy outputs to replace traditional fossil fuel energy sources has received a lot of attention lately[1].

I.1.Biomass

I.1.1. Definition

A contemporaneous (non-fossil) and complex biogenic organic–inorganic solid product, biomass is produced by both natural and man-made (technogenic) processes. It is composed of natural components that are produced by photosynthesis in growing land- and water-based vegetation or by the digestion of food in animals and humans, as well as technogenic products that are produced by processing the aforementioned natural components[2].

Furthermore, this biomass is one of the key components of renewable energy sources and can be used for energy purposes.

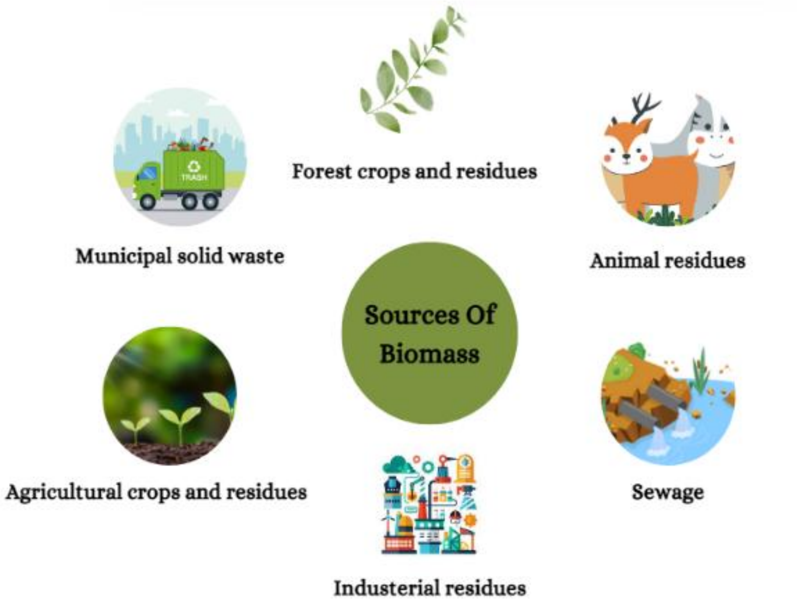
Forest harvesting, land cultivation, and the organic fermentable component are all related to the production of biomass energy. These include household, urban, industrial, and animal waste[3].

I.1.2. Sources of Biomass

The European Commission defines biomass as a variety of resources, including non-fossil, biodegradable components of industry and municipal solid waste (MSW), as well as products, by-products, and residues from forestry, agriculture, and related industries. The classifications of biomass resources that now exist are mostly determined by their intended use[4]. Addressing the variability issues needs a thorough understanding of the chemical makeup of biomass and the behavior of each component in the chosen conversion processes. Cellulose, hemicellulose, lignin, extractives/volatiles, and ash are the five main constituents that govern the chemical characteristics of lignocellulosic materials, also known as biomass [5] as shown in **Figure (I.1)**.

So, we can summery the sources of biomass:

- Industrial Residues.
- Forestry Crops and Residues.
- Agricultural Crops and Residues.
- Animal Residues.
- Municipal Solid Waste.
- Sewage.



Fig(I.1): Sources of Biomass.

I.1.3. Biomass Valuation

- **Biomass Gasification Process**

Gasification is a partial thermal oxidation process that produces a large amount of ash, condensable compounds (tars and oils), and gaseous products (carbon dioxide, water, carbon monoxide, hydrogen, and gaseous hydrocarbons). The addition of steam, air, or oxygen to the reaction serves as an oxidizing agent. The resulting gas is easier to utilize and more adaptable than the original biomass (for example, it can power gas engines) and its quality can be standardized [6].

Biomass gasification is the process of converting a solid/liquid organic compound into a gas/vapor phase and a solid phase as shown in **Figure (I.2)**. The solid phase, known as "char," contains the organic unconverted fraction and the inert material present in the treated biomass. The gas phase, typically referred to as "syngas," has a high heating power and can be used for power generation or the production of biofuel. This conversion represents a partial oxidation of the carbon in the feeding material and is typically carried [7] .

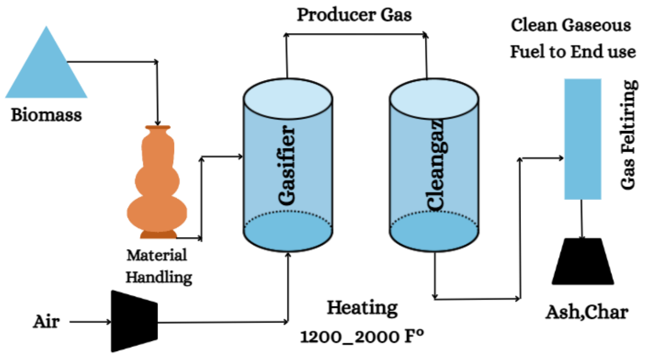


Fig (I.2): Biomass Gasification Process.

- **Conversion of biomass under combustion conditions**

A residual char is created when a solid fuel particle is placed in a high combustion environment and dries and devolatilizes. O_2, CO_2, and H_2O oxidize the remaining char, leaving behind an ash residue. Many studies have looked into the steps of thermal conversion, including drying, volatile release, and char conversion. When comparing biomass to coal, the emission of volatiles and, in particular, the oxidation of char happens significantly differently. The output of volatiles is very high, usually between 80 and 90 percent [8] .

The cost of using fossil fuels to generate energy has surpassed that of using biomass fuels. Generally speaking, energy derived from fossil fuels will be more expensive than the same amount of energy produced by biomass conversion. Increased usage of renewable energy sources, such as biomass fuels, is of great interest globally due to concerns about global warming[9]. **Figure (I.3)** below explains what was written previously.

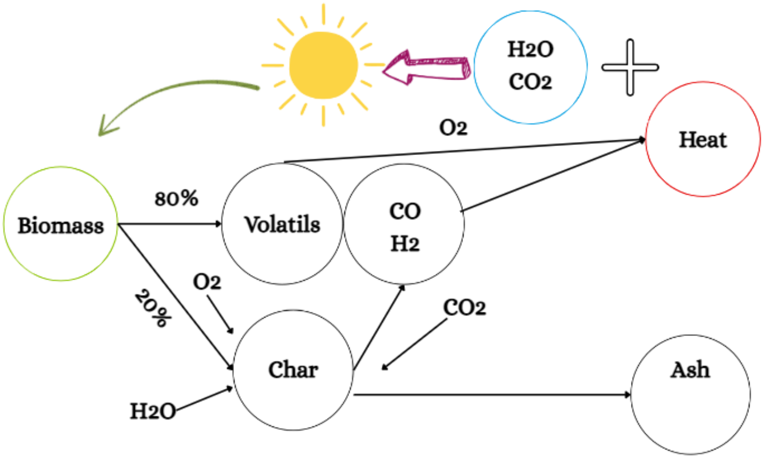


Fig (I.3): Combustion of Biomass.

- **Biomass Pyrolysis**

The main components of biomass are complex biopolymers called cellulose, hemicellulose, and lignin, which change in different ways when the reaction temperature rises. This can be seen in the thermogravimetric analysis (TGA) results for the different biomass constituents. The mass of the biomass decreases during the initial heating stages when the temperature is increased to roughly 100 °C due to water evaporation. As the temperature increases [10] .

Biomass pyrolysis is challenging because different biomass components decompose differently and have varying reaction mechanisms and rates, which are also influenced in part by reactor designs and thermal processing settings. Previous research has established interactions between the main components of woody biomass, including cellulose, hemicelluloses, and lignin, during pyrolysis , therefore predicting the pyrolysis characteristics of biomass based solely on the thermal [11] as shown in **Figure (I.4)** .

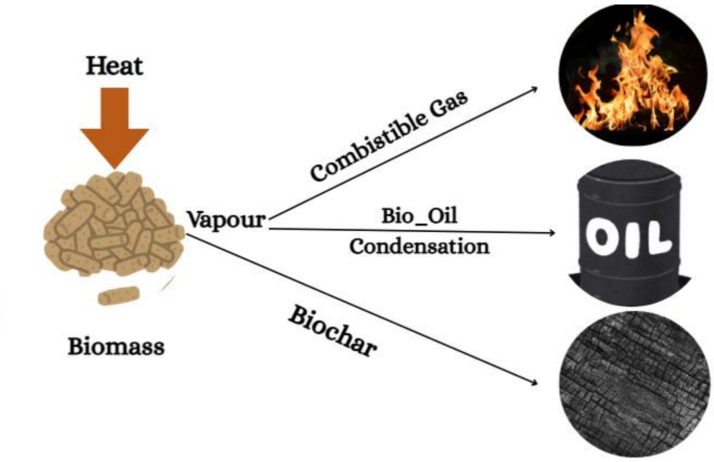


Fig (I.4): Biomass Pyrolysis.

- **Biomass Methanation**

Methanation research has been around for more than a century, but it is currently receiving greater attention due to factors including climate change, the depletion of fossil fuels, and a shifting energy system that uses a lot of renewable energy. There is discussion of two distinct methanation processes: CO_2 methanation for the chemical storage of electric energy and CO methanation for the manufacture of natural gas alternatives in conjunction with coal or biomass gasification [12] as shown in **Figure (I.5)** below .

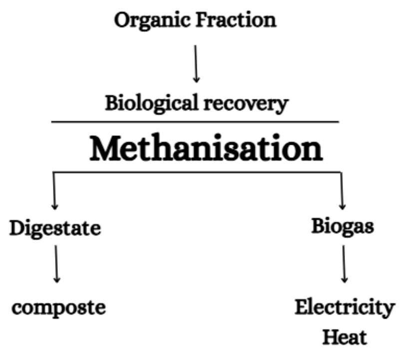


Fig (I.5): Biomass methanation.

I.2.Biochar

I.2.1. Definition

A solid substance called charcoal is produced when biomass is thermochemically converted in an oxygen-limited environment. In areas with an abundance of wood, wood charcoal has historically been produced since very early times. One of the main reasons for deforestation in Europe is the extensive use of it as smelting fuel for metallurgical processes. The conventional fuel for a blacksmith's forge and other devices requiring high temperatures is charcoal. It was only lately that the term "biochar" was used to refer to the same substance. The primary distinction between biochar and charcoal is its intended use: biochar is meant to be added to soils to improve soil fertility while also guaranteeing long-term carbon storage[13].

Biomass pyrolysis, a low-oxygen thermal process that breaks down organic materials at temperatures between 350°C and 1000°C, produces biochar. However, the final products of other carbonization processes including torrefaction, hydrothermal carbonization, and coke formation cannot be referred to as biochar in the sense described above. Thus, biochars are distinct pyrolysis chars distinguished by their extra ecologically friendly manufacturing, quality, and use characteristics [14] as shown in **Figure (I.6)** below .

Fig (I.6): Biochar.

I.2.2. Sources of Biochar

One of the cheapest and most efficient ways to enhance the quality of paddy soil and significantly lessen the effects of global warming is to use biochar. Biochar is a solid byproduct that is created by pyrolyzing biological organic materials, such as agricultural crop waste, forest waste, and algae waste, in an anaerobic or hypoxic environment [15] as shown in **Figure (I.7)** .

- Agricultural crop waste.
- Forest Waste.
- Algea Waste.
- Biogas.

Fig (I.7): Sources of Biochar.

I.2.3. Applications and Importance of Biochar

Because of its unique properties, including as its high adsorption capacity, high specific surface area, microporosity, and ion exchange capacity, biochar offers a wider range of environmental uses as shown in **Figure (I.8)**. The physicochemical characteristics of the biochar, which are ascribed to the types of feedstock and pyrolysis conditions employed during its creation, regulate the variability and predominance of a particular reaction. These two variables significantly alter the biochar's overall surface attributes, including surface area, polarity, atomic ratio, pH, and element content. The acceptability and effectiveness of biochar in remediating specific contaminants are significantly impacted by these differences in its properties. Applying biochar to soil not only removes contaminants but also enhances the soil's qualities. Biochar enhances physical properties (such as water retention capacity, oxygen content)[16].

Biochar has the potential to generate income and improve environmental and agricultural sustainability. Until biochar's exact impacts on soil characteristics and crop productivity are demonstrated, the bioenergy and agricultural sectors will be unwilling to pay for it. Finalization of biochar's commercial development[17].

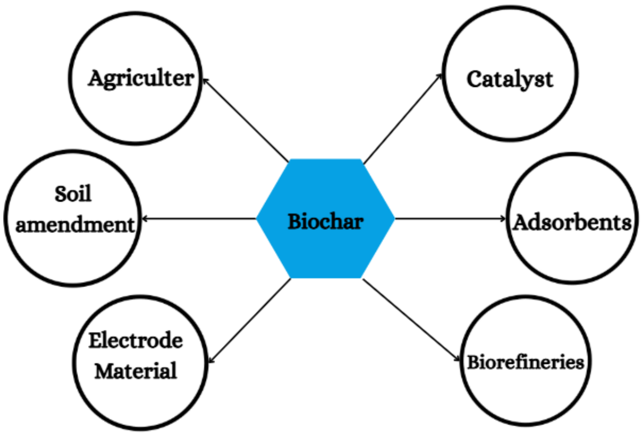


Fig (I.8): Biochar's application.

I.2.4. Characterization of biochar

Surface area, pH, and the concentration of different elements and nutrients (such as carbon (C), oxygen (O), nitrogen (N), phosphorous (P), potassium (K), and calcium (Ca)) are among the unique physico-chemical characteristics of each type of biochar. These characteristics of biochar depend on the temperature at which it is produced and the feedstock[18].

By altering the bulk surface area, pore-size distribution, particle-size distribution, density, and packing, biochar can have a substantial impact on the physical characteristics of the system, including depth, texture, structure, porosity, and consistency. Because the physical composition of soil strata greatly influences the penetration depth and availability of air and water inside the root zone, the effects of biochar on soil physical qualities may then directly affect plant growth[19].

I.2.5. Future prospects of biochar

As of right now, BC has shown to be a useful resource for soil amendments. Because it can immobilize heavy metals (HMs), reduce greenhouse gas emissions (GHGs) (CO_2, N_2O, and CH_4), and act as fertilizer when given to soil that isn't fertile. However, a lot more work needs to be done before the technology and its uses are widely adopted[20].

Since BC can help reduce greenhouse gas emissions by immobilizing carbon in soil structures, it has been a popular material for soil amendments in recent years. A brief discussion is given of the current obstacles to a broader use of BC for large-scale applications in order to meet sustainability requirements[21].

Finding the best methods for applying biochar is crucial for minimizing any potential negative effects and lowering the expense of applying biochar to low-fertility soils[22].

I.3. Wastes

It includes all residues from manufacturing, transformation, or usage processes, as well as all materials and moveable objects that their owner discards, plans to discard, or needs to be removed in order to protect the environment or public health. It can also refer to items associated with several facets of human activity that need to be disposed of or materials that are unfit for use [23].

I.3.1. Agricultural waste

trash generated as a result of several agricultural activities. It comprises fertilizer runoff from fields, pesticides that get into water, air, or soils, salt and silt drained from fields, manure and other waste from farms, poultry houses, and slaughterhouses, and harvest waste[24].

Crop residues, livestock waste, agro-industrial waste, and aquaculture waste are all considered plant residues[25].

I.4. Watermelon

The Cucurbitaceae family includes the watermelon (Citrullus lanatus). Commercial production of the crop occurs in regions with extended warm seasons free from frost. Its lengthy, trailing tendrils require that plants be spaced widely apart. In the warmest regions of the world, watermelons, or Citrullus Schrad., are one of the most popular vegetable crops. Asia produces three-fourths of the world's output, with China being the top producer[26, 27] as shown in **Figure (I.9).**

Fig (I.9): Watermelon fruit.

I.4.1. Common names [28]

- Scientific name: Citrullus Lanatus
- Name in French: Pastèque
- Name in Spanish: sandía
- Name in Italian: anguria

I.4.2. Classification of watermelon [28, 29]

- ✓ Kingdom: Plants
- ✓ Phylum- Embryophyta
- ✓ Class- Dicotyledoneae
- ✓ Order: Cucurbitales
- ✓ Family: Cucurbitaceae
- ✓ Genus: Citrullus
- ✓ Species: Citrullus lanatus

I.4.3. Chemical compounds and components of watermelon

Lycopene, a precursor of β-carotene and a carotenoid of great interest due to its antioxidant ability in scavenging reactive oxygen species, which cause oxidative damage and loss of appropriate cell function, is one of the many phytonutrients found in watermelon[30]. According to **Table (I.1)** nutritional profile, the fruit is incredibly nutrient-dense, thirst-quenching, and recognized to be low in calories.

Table (I.1) : Chemical compounds and components of watermelon[31].

Watermelon	**Watermelon seed**	**Watermelon rind**
Quantity (Per 152 g)	**Quantity (Per 100 g)**	**Quantity**
Calories	45.60 kcal	557 kcal
Energy	NR	2,330 kJ
Moisture	NR	5.05 g
Lipids	0.23 g	47.37 g
Protein	0.93 g	28.33 g
Ash	0.38 g	3.94 g
Dietary fiber	0.61 g	Not reported
Carbohydrates	11.48 g	15.31 g
Total sugars	9.42 g	Not reported
Lycopene	6,888.64 µg	Not reported
β-Carotene	Not reported	Not reported

I.4.4. Medical uses of watermelon[29, 32]

According to reports, wild melons, or Citrullus lanatus var. citroide, are frequently employed in traditional herbal therapy. When completely ripe or even nearly rotting, Citrullus lanatus fruits are consumed as a febrifuge. The root has purgative properties and can also have emetic effects when taken in large quantities. The seed has pectoral, tonic, and demulcent properties. It can occasionally be used to treat bedwetting and urinary tract infections. The fruit works well to cure kidney stones and dropsy because it is also a diuretic. The seed also has a hypotensive effect and works well as a vermifuge. Antioxidant, antibacterial, hypoglycemic, antiviral, hypotensive, anticancer, neuroprotective, immune system boosting, heart disease risk reduction, blood pressure improvement, LDL oxidation reduction, and cardioprotective effects are just a few of the health benefits of the bioactive compounds found in watermelon rind.

I.4.5. Benefits of watermelon[26, 33]

Numerous goods, including sauces, juice, smoothies, jams, and candies, have been made with it. The antioxidant capacity of watermelon is higher than that of common fruits like guavas, strawberries, and tomatoes. It is regarded as a component of a nutritious diet that is low in sodium and cholesterol. In some desert areas, watermelon is a valuable supply of water. Among other cancers, lycopene may help reduce the incidence of prostate, pancreatic, and stomach cancers.

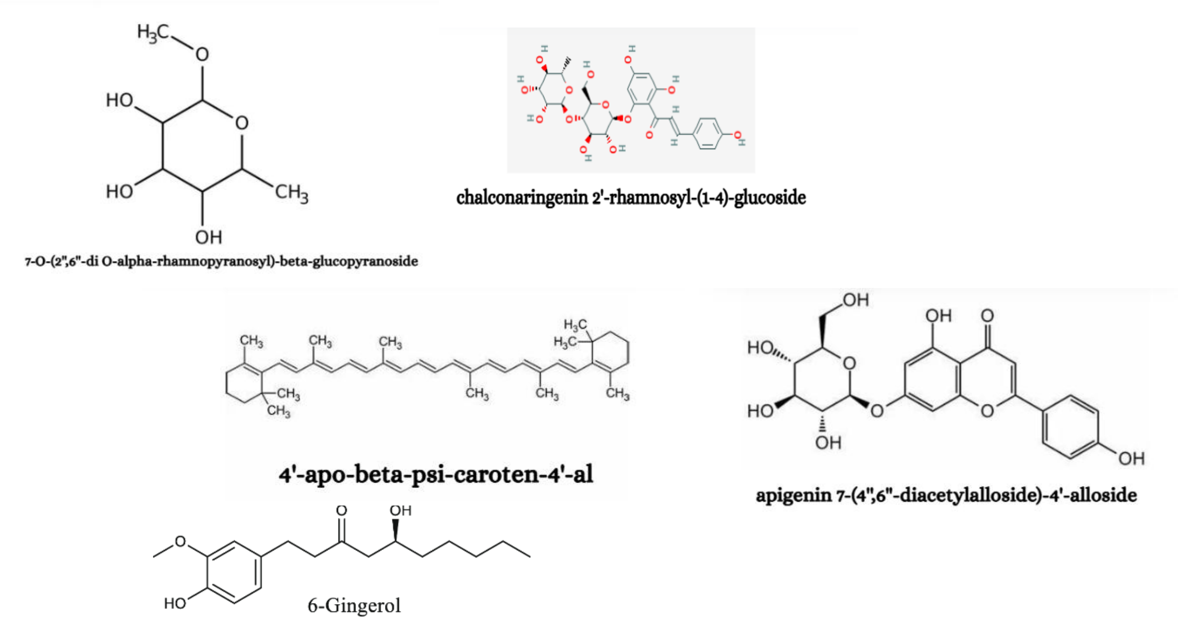
I.4.6. Watermelon peels

Summer-harvested dried watermelon rinds are used to make it. After being dried at 50°C, the fresh rinds are ground into a fine powder. The rind of watermelons makes up 15–30% of the fruit's weight, depending on how the peel is removed. However, watermelon peel is frequently seen as agricultural trash that has limited use in the food processing industry, which pollutes the environment and wastes resources [34-36] as shown in **Figure (I.10).**

Fig (I.10): Watermelon peel.

I.4.6. Phytochemical compounds of watermelon peel

Rich in antioxidants In addition to the simple sugars, amino acids, fatty acids, and organic acids found in C. lanatus extracts, LC-MS was helpful in identifying secondary metabolites with potent antioxidant properties, such as curcuminol, 6-gingerol, 4'-apo-beta-psi-caroten-4'-al, apigenin 7-(4",6"-diacetylalloside)-4'-alloside, chalconaringenin 2'-rhamnosyl-(1-4)-glucoside, and narenginin 7-O-(2",6"-di O-alpha-rhamnopyranosyl)-beta-glucopyranoside, among others[37]. The peel and rind of watermelon have high moisture content (80.58% and 93.57%), high fat content (1.5% and 3.92%), high protein (6.12%), high fiber (22% and 16%), low dietary fiber (NDF and ADF), high hemicellulose (0.72% and 0.58%), and high total carbohydrate content (43.97% and 54.8%)[38] .



7-O-(2",6"-di O-alpha-rhamnopyranosyl)-beta-glucopyranoside

chalconaringenin 2'-rhamnosyl-(1-4)-glucoside

4'-apo-beta-psi-caroten-4'-al

apigenin 7-(4",6"-diacetylalloside)-4'-alloside

6-Gingerol

Fig (I.11): The most important chemical families and active compounds in watermelon peel.

I.5. Eggs

Eggs have been a human food since ancient times. They are one of nature’s nearly perfect protein foods and have other high-quality nutrients. Eggs are readily digested and can provide a significant portion of the nutrients required daily for growth and maintenance of body tissues[39] as shown in **Figure (I.12).**

Fig (I.12): Eggs.

I.5.1. Chemical compounds and components of eggs

Depending on the hens' species, diet, age, and other factors, the weight and makeup of each structural component of their eggs vary somewhat. Hen eggs are primarily composed of 12% lipids and 12% proteins, with water and trace amounts of minerals and carbohydrates making up the remaining chemical composition[40] as shown in **Figure (I.13)** below.

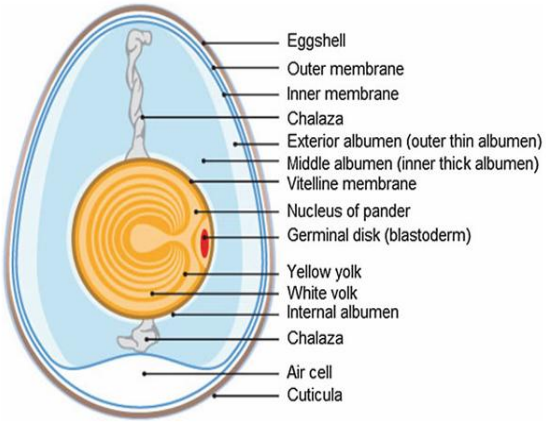


Fig (I.13): components of eggs[41].

I.5.2. Health benefits of eggs[42, 43]

Protein is one of the many nutrients and bioactive substances found in eggs that may help avoid chronic disease. From a nutritional perspective, eggs are particularly interesting because they include important fats, proteins, vitamins, minerals, and trace elements. They are also a moderate source of calories (about 140 kcal/100 g), have a lot of culinary possibilities, and are reasonably priced. In fact, eggs are the second-cheapest animal source of zinc and calcium and the lowest-cost source of proteins, vitamin A, iron, vitamin B12, riboflavin, and choline. Eggs include a variety of biologically active substances in addition to offering adults and babies well-balanced nutrition.

I.5.3 Eggshell

About 10% of hen eggs, a staple food widely used in both domestic and commercial settings globally, are eggshells. Then, the egg processing companies produce a lot of eggshells, and a lot of this solid residue is still dumped as garbage in landfills without any pretreatment, which contributes to organic pollution[44].

Typically, hen eggshells are made of ceramic materials with three layers: an inner lamellar (or mammillary) layer, a spongy (calcareous) layer, and the cuticle on the outside[45] as shown in **Figure (I.14).**

Fig (I.14): Eggshell.

I.5.4. Chemical composition of eggshell[46, 47]

Chicken eggshell powder, compared to recommended daily intake for individuals aged 51-70, provides high calcium and sodium levels, with low concentrations of hazardous elements. In order to develop lucrative uses for chicken eggshell and keep it from becoming an environmental nuisance, its chemical composition was determined. The eggshell's proximate value includes moisture, ash, protein, fat, fiber, carbohydrates, and calorific value.

I.5.5. Benefits and usage of eggshell

Eggshell use in concrete: The results demonstrated that the concrete's flexural and compressive strengths were greatly increased by using eggshells. Because the eggshell powder filled the holes and increased the concrete's porosity, there was less water absorption[48].

According to the literature, industrial eggshell applications can be divided into two groups: operating supplies and raw materials. Purified calcium carbonate, food additives, soil amendments, cosmetics, and biomaterial composites are the alternatives in the first scenario. The creation of Ca-rich compost by composting appears to be a particularly intriguing strategy toward the "circular economy," given the characteristics of ES and the soil in wide areas (low topsoil organic carbon content and acid pH)[49].

I.6. Lemon

For citrus lemon, the most common term is lemon and it is an edible fruit. After orange, lemon is the third most significant specie of citrus fruits which is farmed more than 4.4 million ton in each year[50] as shown in **Figure (I.15)**

Fig (I.15): Lemon fruit.

I.6.1. Common names[51]

- Brazil: Capim-cidrao, Capim-santo
- Egypt: Lemon grass
- English: Lemongrass, Citronella, Squinant
- Ethiopia: Tej-sar
- Hindi: Sera, Verveine
- Indonesian: Sereh
- Italian: Cimbopogone
- Malaysia: Sakumau
- Mexico: Zacate limon
- Swedish: Citrongräss
- Thailand: Ta-khrai
- Turkish: Limon out
- USA: Citronella

I.6.2. Classification of lemon[52]

- Kingdom: Plantae
- Division: Magnoliophyta
- Class: Liliopsida
- Order: Poales
- Family: Poaceae
- Genus: Cymbopogon
- Species: citrates

I.6.3. Chemical compounds and components of lemon

Vitamin C (ascorbic acid) is abundant in lemons, which are also a good source of Na, K, Ca, Cu, Fe, Mg, Zn, and P. Mineral-based products. Lemons contain a variety of phytochemicals, including terpenes and polyphenols. They contain a high concentration of citric acid (around 47g/L of juice), just as other citrus fruits. Among the many phytochemical compounds found in lemons are terpenes and polyphenols. Complexly structured essential oil that contains calcium oxalates, limonene, flavonoids, vitamin C, carotenoids, mucilages, citric, citrain, terpineol, camhenium, and fellander. There is a lot of pectin, sugar, citric acid, malic acid, and flavonoids[53, 54].

I.6.4. Medical uses of lemon

limon associated with its anti-oxidative, antiulcer, antihelmintic, insecticidal, anticancer, cytotoxic, and estrogenic activities. In addition, C. limon extracts possess hepatoprotective, anti-hyperglycemic, and antimicrobial properties[55] .

One significant medicinal plant in the Rutaceae family is the lemon. Lemon is grown primarily for its alkaloids, which have been shown to have anticancer properties. Crude extracts of the plant's leaves, stem, root, and flower have also been shown to have antibacterial properties against clinically important bacterial strains. Numerous biological actions, such as antiviral, antifungal, antidiabetic, and anticancer properties, are exhibited by citrus flavonoids[53].

I.6.5. Benefits of lemon

Rich in nutrients, lemon fruit is essential to a balanced diet and offers several health advantages. Flavonoids, vitamins, minerals, dietary fibers, essential oils, organic acids, and carotenoids are all found in interesting amounts in lemons[56].

In order to get the characteristic lemon note, lemongrass oil is utilized extensively in cosmetics, soaps, and fragrances. In addition, it is a significant source of citral, which is utilized in beverages, confections, fragrance, and as a primary source for the manufacture of vitamin A and β-ionone, among other compounds[57].

I.6.6. Lemon peel

The peel, a by-product of processing lemon juice, has a lot of possible applications. What is commonly referred to as lemon peel contains two distinct tissues: albedo and flavedo. The outer layer of the peel, known as flavedo, ranges in color from green to yellow. It is a rich source of essential oils, which the flavor and fragrance industry has been using since antiquity. The primary component of lemon peel is albedo, a spongy, cellulose layer that lies beneath flavedo[58] as shown in **Figure (I.16)** below

Fig (I.16): Lemon peel.

I.6.7. Phytochemical compounds of lemon peel

Essential oils (0.6–1%), fibers (6.30–42.13 g/100 g db), phenols (0.67–19.62 g/100 g db), and vitamin C (0.109–1.150 g/100 g db) are among the many useful components found in citrus peel. The primary phenolic compounds (PCs) found in citrus peel are flavanones (hesperidin: 0.002–80.90 mg/g db, neohesperidin: 0.05–11.70 mg/g db, narirutin: 0.03–26.90 mg/g db, naringin: 0.08–14.40 mg/g db), and polymethoxylated flavones (sinensetin: 0.08–0.29 mg/g db, nobiletin: 0.20–14.05 mg/g db, tangeretin: 0.16–7.99 mg/g db). Because of their antioxidant properties[59].

I.6.8. Benefits and uses of lemon peel

Weight loss, skin care, constipation relief, healthy nutrition, eye care, and the treatment of scurvy, hemorrhoids, stomach ulcers, respiratory disorders, gout, gingivitis, urinary tract disorders, and more are among the health advantages of lemon peels. Lemon peels are likely the first thing that spring to mind when considering their potential medical applications. This sour citrus fruit can do what many specialty drugs cannot[60, 61] .

Conclusion

By turning trash into valuable goods like biochar, biomass valorization is an essential field that helps achieve sustainable development. Eggshells, watermelon peels, and lemon peels are examples of natural waste that are rich in healthy components and have a variety of medical applications. This chapter emphasizes how crucial it is to use these natural resources, creating numerous opportunities for future economic and environmental exploitation.

References

[1] P. McKendry, "Energy production from biomass (part 1): overview of biomass," Bioresource technology, vol. 83, pp. 37-46, 2002.

[2] S. V. Vassilev, D. Baxter, L. K. Andersen, and C. G. Vassileva, "An overview of the chemical composition of biomass," Fuel, vol. 89, pp. 913-933, 2010.

[3] N. ALLEMAND, "La biomasse, le bois et les déchets de bois–définitions Biomass, wood and wood wastes–definitions," Pollution atmosphérique, vol. 19, 2009.

[4] H. Long, X. Li, H. Wang, and J. Jia, "Biomass resources and their bioenergy potential estimation: A review," Renewable and Sustainable Energy Reviews, vol. 26, pp. 344-352, 2013.

[5] C. L. Williams, T. L. Westover, R. M. Emerson, J. S. Tumuluru, and C. Li, "Sources of biomass feedstock variability and the potential impact on biofuels production," BioEnergy Research, vol. 9, pp. 1-14, 2016.

[6] M. Puig-Arnavat, J. C. Bruno, and A. Coronas, "Review and analysis of biomass gasification models," Renewable and sustainable energy reviews, vol. 14, pp. 2841-2851, 2010.

[7] A. Molino, S. Chianese, and D. Musmarra, "Biomass gasification technology: The state of the art overview," Journal of Energy Chemistry, vol. 25, pp. 10-25, 2016.

[8] M. Hupa, O. Karlström, and E. Vainio, "Biomass combustion technology development–It is all about chemical details," Proceedings of the Combustion institute, vol. 36, pp. 113-134, 2017.

[9] A. Demirbas, "Potential applications of renewable energy sources, biomass combustion problems in boiler power systems and combustion related environmental issues," Progress in energy and combustion science, vol. 31, pp. 171-192, 2005.

[10] R. W. Nachenius, F. Ronsse, R. Venderbosch, and W. Prins, "Biomass pyrolysis," in Advances in chemical engineering. vol. 42, ed: Elsevier, 2013, pp. 75-139.

[11] T. Kan, V. Strezov, and T. J. Evans, "Lignocellulosic biomass pyrolysis: A review of product properties and effects of pyrolysis parameters," Renewable and sustainable energy reviews, vol. 57, pp. 1126-1140, 2016.

[12] S. Rönsch, J. Schneider, S. Matthischke, M. Schlüter, M. Götz, J. Lefebvre, et al., "Review on methanation–From fundamentals to current projects," Fuel, vol. 166, pp. 276-296, 2016.

[13] L. Montanarella and E. Lugato, "The application of biochar in the EU: challenges and opportunities," Agronomy, vol. 3, pp. 462-473, 2013.

[14] H. P. Schmidt, T. Bucheli, C. Kammann, B. Glaser, S. Abiven, and J. Leifeld, "European biochar certificate-guidelines for a sustainable production of biochar," 2016.

[15] X. He, Y. Yang, B. Huang, Z. Wang, and M. Wang, "An overview of characteristic factors of biochar as a soil improvement tool in rice growth-A review," Environmental Research, vol. 242, p. 117794, 2024.

[16] F. R. Oliveira, A. K. Patel, D. P. Jaisi, S. Adhikari, H. Lu, and S. K. Khanal, "Environmental application of biochar: Current status and perspectives," Bioresource technology, vol. 246, pp. 110-122, 2017.

[17] H. S. Jatav, S. K. Singh, S. S. Jatav, V. D. Rajput, M. Parihar, S. K. Mahawer, et al., "Importance of biochar in agriculture and its consequence," Applications of Biochar for Environmental Safety, vol. 109, 2020.

[18] S. Gul, J. K. Whalen, B. W. Thomas, V. Sachdeva, and H. Deng, "Physico-chemical properties and microbial responses in biochar-amended soils: mechanisms and future directions," Agriculture, ecosystems & environment, vol. 206, pp. 46-59, 2015.

[19] A. Downie, A. Crosky, and P. Munroe, "Physical properties of biochar," in Biochar for environmental management, ed: Routledge, 2012, pp. 45-64.

[20] F. Amalina, A. S. Abd Razak, A. Zularisam, M. Aziz, S. Krishnan, and M. Nasrullah, "Comprehensive assessment of biochar integration in agricultural soil conditioning: Advantages, drawbacks, and future prospects," Physics and Chemistry of the Earth, Parts A/B/C, vol. 132, p. 103508, 2023.

[21] M. Kamali, N. Sweygers, S. Al-Salem, L. Appels, T. M. Aminabhavi, and R. Dewil, "Biochar for soil applications-sustainability aspects, challenges and future prospects," Chemical Engineering Journal, vol. 428, p. 131189, 2022.

[22] A. El-Naggar, S. S. Lee, J. Rinklebe, M. Farooq, H. Song, A. K. Sarmah, et al., "Biochar application to low fertility soils: A review of current status, and future prospects," Geoderma, vol. 337, pp. 536-554, 2019.

[23] L. Lombardi and E. A. Carnevale, "Evaluation of the environmental sustainability of different waste-to-energy plant configurations," Waste Management, vol. 73, pp. 232-246, 2018.

[24] R. Nagendran, "Agricultural waste and pollution," in Waste, 2011, pp. 341-355.

[25] B. Koul, M. Yakoob, and M. P. Shah, "Agricultural waste management strategies for environmental sustainability," Environmental Research, vol. 206, p. 112285, 2022.

[26] T. C. Wehner, "Watermelon," in Vegetables I: asteraceae, brassicaceae, chenopodicaceae, and cucurbitaceae, ed: Springer, 2008, pp. 381-418.

[27] H. S. Paris, "Origin and emergence of the sweet dessert watermelon, Citrullus lanatus," Annals of botany, vol. 116, pp. 133-148, 2015.

[28] E. Erhirhie and N. Ekene, "Medicinal values on Citrullus lanatus (watermelon): pharmacological review," International Journal of Research in Pharmaceutical and Biomedical Sciences, vol. 4, pp. 1305-1312, 2013.

[29] J. K. BROWN and M. R. NELSON, "Characterisation of watermelon curly mottle virus, a geminivirus distinct from squash leaf curl virus," Annals of applied biology, vol. 115, pp. 243-252, 1989.

[30] M. P. Tarazona-Díaz, J. Viegas, M. Moldao-Martins, and E. Aguayo, "Bioactive compounds from flesh and by-product of fresh-cut watermelon cultivars," Journal of the Science of Food and Agriculture, vol. 91, pp. 805-812, 2011.

[31] M. Nadeem, M. Navida, K. Ameer, A. Iqbal, F. Malik, M. A. Nadeem, et al., "A comprehensive review on the watermelon phytochemical profile and their bioactive and therapeutic effects," Food Science and Preservation, vol. 29, pp. 546-576, 2022.

[32] A. Ahmad, S. Sartini, Y. Leman, H. Karim, and M. T. Duppa, "Potential of Watermelon waste in several Pharmaceutical preparations in Global Medicine: A Review," Research Journal of Pharmacy and Technology, vol. 17, pp. 5113-5118, 2024.

[33] M. M. Maoto, D. Beswa, and A. I. Jideani, "Watermelon as a potential fruit snack," International Journal of food properties, vol. 22, pp. 355-370, 2019.

[34] Z. Liu, S. Wu, H. Zuo, J. Lin, H. Zheng, H. Lei, et al., "Freeze-drying pretreatment of watermelon peel to improve the efficiency of pectin extraction: RSM optimization, extraction mechanism, and characterization," International Journal of Biological Macromolecules, vol. 249, p. 125944, 2023.

[35] M. S. Hasanin and A. H. Hashem, "Eco-friendly, economic fungal universal medium from watermelon peel waste," Journal of Microbiological Methods, vol. 168, p. 105802, 2020.

[36] F. D. Romelle, A. Rani, and R. S. Manohar, "Chemical composition of some selected fruit peels," European Journal of Food Science and Technology, vol. 4, pp. 12-21, 2016.

[37] M. M. Jibril, A. Abdul-Hamid, H. M. Ghazali, M. S. P. Dek, N. S. Ramli, A. H. Jaafar, et al., "Antidiabetic antioxidant and phytochemical profile of yellow-fleshed seeded watermelon (Citrullus Lanatus) extracts," J. Food Nutr. Res, vol. 7, pp. 82-95, 2019.

[38] N. Saiharini and A. Padmaja, "Studies on nutrient and phytochemical composition and assessment of in vitro antioxidant and enzyme inhibitory properties of watermelon fruit by-products," Annals of Phytomedicine, vol. 11, pp. 419-425, 2022.

[39] H.-D. Belitz, W. Grosch, and P. Schieberle, "Eggs," Food chemistry, pp. 546-562, 2009.

[40] H. Sugino, T. Nitoda, and L. Juneja, "General chemical composition of hen eggs," in Hen eggs, ed: CRC press, 2018, pp. 13-24.

[41] H. H. Sunwoo and N. Gujral, "Chemical composition of eggs and egg products," in Handbook of food chemistry, ed: Springer, Berlin, Heidelberg, 2015, pp. 331-363.

[42] M. J. Puglisi and M. L. Fernandez, "The health benefits of egg protein," Nutrients, vol. 14, p. 2904, 2022.

[43] S. Réhault-Godbert, N. Guyot, and Y. Nys, "The golden egg: nutritional value, bioactivities, and emerging benefits for human health," Nutrients, vol. 11, p. 684, 2019.

[44] A. Laca, A. Laca, and M. Díaz, "Eggshell waste as catalyst: A review," Journal of environmental management, vol. 197, pp. 351-359, 2017.

[45] W. Tsai, J. Yang, C. Lai, Y. Cheng, C. Lin, and C. Yeh, "Characterization and adsorption properties of eggshells and eggshell membrane," Bioresource technology, vol. 97, pp. 488-493, 2006.

[46] E. Ajala, O. Eletta, M. Ajala, and S. Oyeniyi, "Characterization and evaluation of chicken eggshell for use as a bio-resource," Arid Zone Journal of Engineering, Technology and Environment, vol. 14, pp. 26-40, 2018.

[47] A. Schaafsma, I. Pakan, G. Hofstede, F. Muskiet, E. Van Der Veer, and P. De Vries, "Mineral, amino acid, and hormonal composition of chicken eggshell powder and the evaluation of its use in human nutrition," Poultry science, vol. 79, pp. 1833-1838, 2000.

[48] G. Vasudevan and S. C. Wei, "Utilisation of eggshell powder (ESP) as partial replacement of cement incorporating superplasticizer," in IOP Conference Series: Materials Science and Engineering, 2020, p. 012016.

[49] M. J. Quina, M. A. Soares, and R. Quinta-Ferreira, "Applications of industrial eggshell as a valuable anthropogenic resource," Resources, Conservation and Recycling, vol. 123, pp. 176-186, 2017.

[50] S. Rafique, S. M. Hassan, S. S. Mughal, S. K. Hassan, N. Shabbir, S. Perveiz, et al., "Biological attributes of lemon: A review," J Addict Med Ther Sci, vol. 6, pp. 030-034, 2020.

[51] G. Shah, R. Shri, V. Panchal, N. Sharma, B. Singh, and A. Mann, "Scientific basis for the therapeutic use of Cymbopogon citratus, stapf (Lemon grass)," Journal of advanced pharmaceutical technology & research, vol. 2, pp. 3-8, 2011.

[52] S. S. Ranade and P. Thiagarajan, "Lemon grass," Int. J. Pharm. Sci. Rev. Res, vol. 35, pp. 162-167, 2015.

[53] T. S. Al-Qudah, U. Zahra, R. Rehman, M. I. Majeed, S. Sadique, S. Nisar, et al., "Lemon as a source of functional and medicinal ingredient: A review," Int. J. Chem. Biochem. Sci, vol. 14, pp. 55-61, 2018.

[54] A. Carnat, A. Carnat, D. Fraisse, and J. Lamaison, "The aromatic and polyphenolic composition of lemon verbena tea," Fitoterapia, vol. 70, pp. 44-49, 1999.

[55] N. Singh, N. S. Yarla, N. J. Siddiqi, M. de Lourdes Pereira, and B. Sharma, "Features, pharmacological chemistry, molecular mechanism and health benefits of lemon," Medicinal Chemistry, vol. 17, pp. 187-202, 2021.

[56] A. M. G. N. Mamede, C. C. de Souza Coelho, O. Freitas-Silva, H. T. G. Barboza, and A. G. Soares, "Lemon," in Nutritional Composition and Antioxidant Properties of Fruits and Vegetables, ed: Elsevier, 2020, pp. 377-392.

[57] R. Lal, "Stability for oil yield and variety recommendations' using AMMI (additive main effects and multiplicative interactions) model in Lemongrass (Cymbopogon species)," Industrial Crops and Products, vol. 40, pp. 296-301, 2012.

[58] J. García-Pérez, J. Cárcel, G. Clemente, and A. Mulet, "Water sorption isotherms for lemon peel at different temperatures and isosteric heats," LWT-Food Science and Technology, vol. 41, pp. 18-25, 2008.

[59] N. M'hiri, I. Ioannou, M. Ghoul, and N. Mihoubi Boudhrioua, "Phytochemical characteristics of citrus peel and effect of conventional and nonconventional processing on phenolic compounds: A review," Food Reviews International, vol. 33, pp. 587-619, 2017.

[60] P. Jana, P. A. Sureshrao, and R. S. Sahu, "Medicinal and health benefits of lemon," Journal of Science and Technology, vol. 6, pp. 16-20, 2020.

[61] M. Mohanapriya, L. Ramaswamy, and R. Rajendran, "Health and medicinal properties of lemon (Citrus limonum)," International Journal of Ayurvedic and Herbal Medicine, vol. 3, pp. 1095-1100, 2013.

Chapter Two: Cellulose

Preface

The globe is moving toward recycling plant waste, which includes cellulose and many other components. Cellulose is the most prevalent natural polymer on Earth, as its name implies. Since it can be utilized as an environmentally benign material, a lot of research has concentrated on its potential application in creating molecules with unique features that could provide workable answers to a lot of scientific issues.

II.1. Historical Overview

In 1838, Anselme Payen, a French scientist, identified and separated cellulose. Payen figured out the chemical formula as well. Using cellulose, the Hyatt Manufacturing Company created celluloid, the first thermoplastic polymer, in 1870. Cellulose was then utilized to make cellophane in 1912 and rayon in the 1890s. In 1920, Hermann Staudinger discovered the chemical makeup of cellulose. Without the use of biological enzymes, Kobayashi and Shoda manufactured cellulose in 1992. In the late 1970s, Schneider, Torback, and Sandberg of Whippany Rayonier Laboratories in New Jersey, USA, used the name "nanocellulose" to refer to a product that was transformed into a gelatinous substance by putting wood pulp through a particular chemical solution at high pressure and high temperature[1].

When several Rayonier articles and patents were released in the early 1980s, the term made its public debut. The company offered a free license to anyone who want to continue and explore this new application for cellulose. Herrick of Rayonier also published work on a dry powder of cellulose[2].

II.2. Definition of cellulose

The percentage of this complex carbohydrate in plant organs rises with age and makes for 15–60% of plant wastes. Consequently, it is thought that the most significant source of carbon and energy for microbes is plant leftovers. It helps plants stay sturdy and solid and is one among the primary components of plant cell walls. Carbon, hydrogen, and oxygen make up its composition[3].

It is made up of glucose units joined in long, straight chains by a "β 1_4glycosidic" bond, which is formed between the carbon atoms number one of the first glucose and number four of the second glucose. It is thought to be the most prevalent organic compound found in nature. Depending on the type of plant, cellulose molecules can contain anywhere from 1400 to 10,000 sugar molecules. Cellular walls contain the majority of cellulose, which has a molecular weight of 200000–2000000, instead of being found in simple chains, it is partially found in joined chains, with its groups structured in a certain manner. Cellulose is an undesirable polymer in water and a highly stable chemical. It is hydrophilic, helical in the majority of organic solvents, and undesirable for alcohol dimethicone. It is extremely crystalline, difficult to dissolve in organic solvents, and molecularly degradable. As seen in **Figure(II.1)**,this characteristic makes it an engineering material[4].

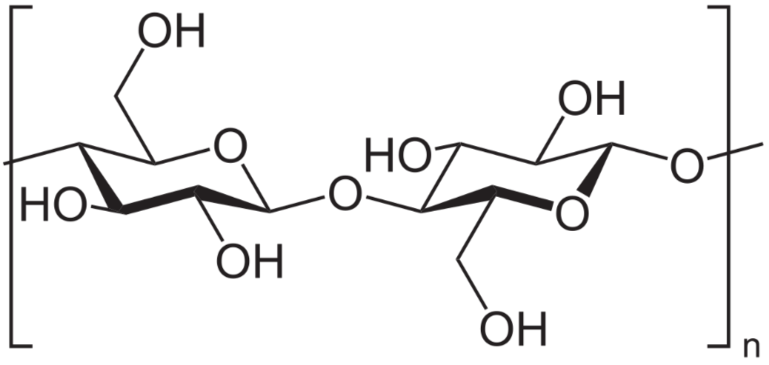
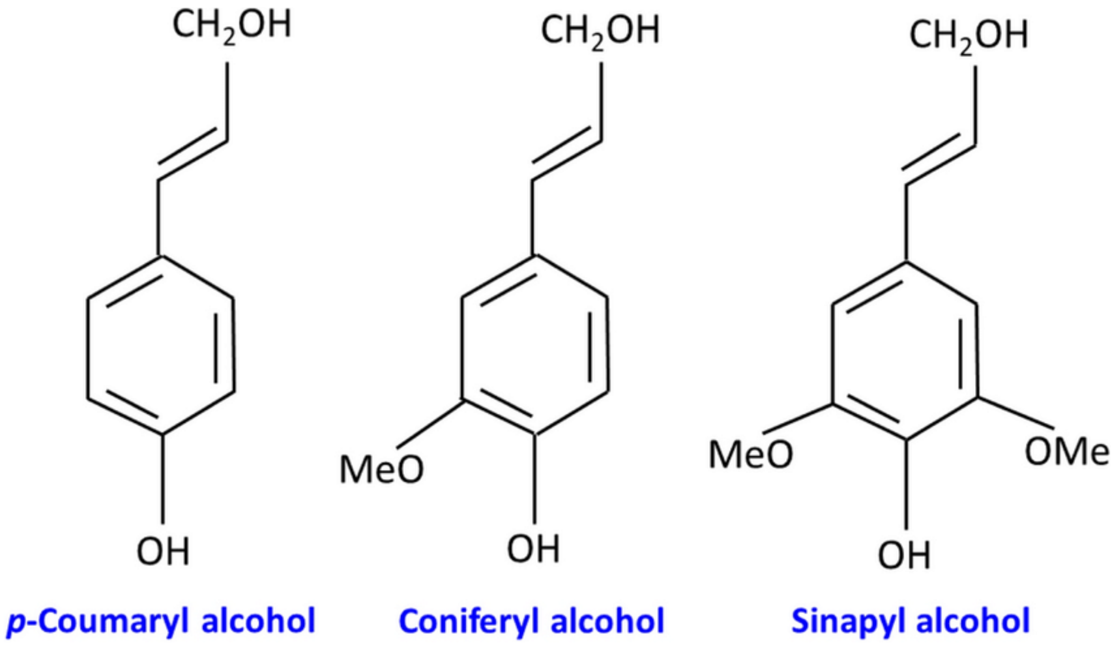


Fig (II.1): Cellulose Composition.

II.3. Definition of lignin

It is a fibrous substance that gives plants mechanical defense. Thirteen valence bonds physically bind it to hemicellulose. As seen in **Figure (II.2)**, it is composed of three fundamental units: trans-coniferyl, trans-sinapyl, and trans-p-coumaryl alcohols. **Figure (II.3)** illustrates the highly complicated, amorphous structure of lignin that results from the enzymatic polymerization of these components[5].



***p*-Coumaryl alcohol** **Coniferyl alcohol** **Sinapyl alcohol**

Fig (II.2): Building blocks of Lignin.

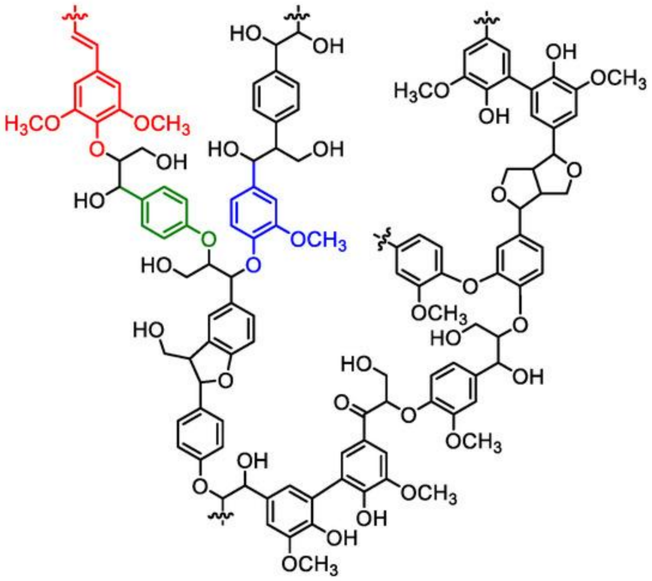


Fig (II.3): Example of the chemical structure of Lignin.

The lignin building block's general formula is (phenylpropane unit), and the carbon atoms are represented as follows (see **Figure II.4**):

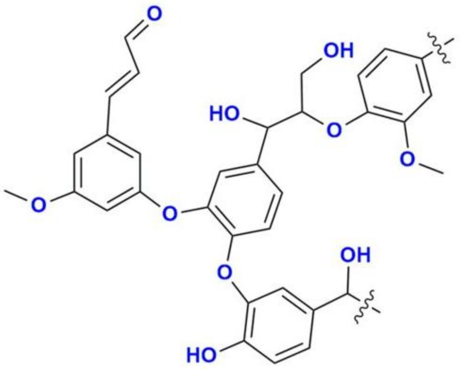


Fig (II.4): The lignin building block's general formula.

II.4. Definition of hemicellulose

All plants contain hemicellulose, a polymer that differs from cellulose in that it has a significantly lower molar mass and has branching and distinct units in its chains. The most effective fiber for easing constipation is hemicellulose because it is more bonded to water than other fibers. In contrast to cellulose, which is a distinct component that varies solely in the degree of polymerization and crystallization, hemicellulose is distinguished by its solubility in diluted alkaline solutions and makes up between 25% and 33% of the majority of plant materials, when wood is viewed as a composite material, with cellulose serving as the reinforcing fiber and lignin as the matrix, hemicellulose acts as a coordinator in the relationship between these two elements. It contains five carbon atoms, such as fructose arabinose, and other sugars with six carbon atoms, such as glucose and mannose. Unlike cellulose, hemicellulose's function is typically supportive in the cell wall and can be extracted from it by alkaline compounds. Most hemicelluloses have a degree of polymerization of only 200, and their amounts in the trunk, branches, roots, and leaves vary greatly [6]. **Figure (II.5)** illustrates the chemical structure of hemicellulose.

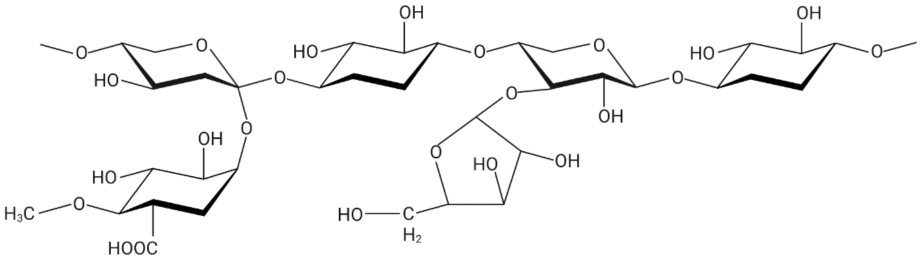


Fig (II.5): the chemical structure of hemicellulose.

II.5. Numerous Cellulose Sources

The sources of cellulose have expanded in variety as scientific research has progressed over time, particularly in recent years. Numerous types of plants, animals, and microbes can provide cellulose. Because it influences the size and characteristics of the extracted cellulose, the cellulose's source is crucial. The primary sources of cellulose fibers will be covered in this section:

- **Plant fibers**

Potato peels, orange peels, cotton fibers, corn, bamboo, water hyacinth, colocynth seeds, soybeans, algae, areca nuts, cucumber peels, garlic peels, oolong tea, sugarcane bagasse, rice straw, and sugar beet pulp[7] are just a few of the plant fibers that have been investigated for cellulose extraction.

- **Algae**

Following a number of investigations, different kinds of algae were taken into Consideration as cellulose sources. For instance, cellulose was taken out of:

- ✓ Boerogesenia
- ✓ Valonia
- ✓ Microterraterras
- ✓ Coldophora

It was discovered that the type of algae affected the characteristics and size of the separated cellulose fibers. The fibers that were isolated from Valonia have an Iα crystallization type and are square portions (20 x 20 nm). (M.denticulate) have an Iβ crystallization type and are rectangular in cross-section (20-30 x 50 nm) [8] .

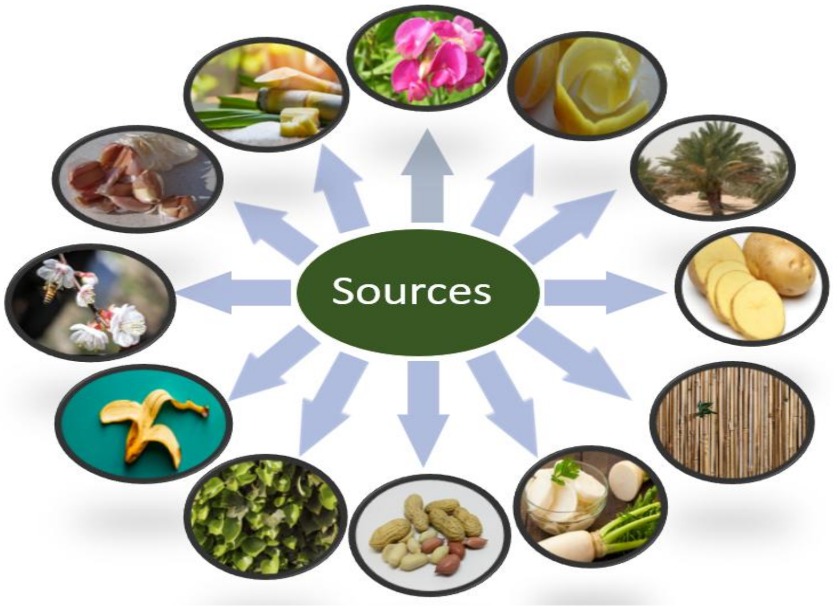


Fig (II.6): Sources of cellulose.

II.6. Factors Needed by Plants to Produce Cellulose

The process by which plants produce cellulose is similar to that of photosynthesis, which is typically taught in curricula and involves the following elements: carbon, oxygen, hydrogen, and energy (sunlight). The chloroplasts, which are found in the green portion of the plant, are where cellulose synthesis or production occurs. Glucose molecules are combined into long chains called cellulose using carbon, oxygen, hydrogen, and sunlight [9].

II.7. The most crucial techniques for cellulose extraction

Extraction can be done in a number of ways, such as mechanical, chemical, and biological. Every method has benefits and drawbacks. **Figure (II.7)** shows a few extraction techniques:

II.7.1. The Biological Approach

This is a conventional extraction technique that uses bacteria like Bacillus and Clostridium to dissolve extracts. It has demonstrated remarkable efficacy in eliminating non-cellulosic components from plants and liberating fibers. Despite the somewhat lengthy extraction process, high-quality fibers are produced. The two categories of biological approaches are enzyme processing and erosion. In the first, the fibers are mechanically extracted after being soaked for a long time. Enzymes, including xylanase enzymes, are used in the second[10, 11].

II.7.2. Processing of Chemicals

This kind of processing uses chemical reactions to break down the structure of lignocellulosic materials. Because certain chemical processing techniques dissolve hemicellulose while others dissolve lignin, chemical processing is selective in its ability to break down the structure of lignocellulosic materials. By improving the extracted material's qualities and increasing extraction efficiency, these techniques can be applied singly or in combination to improve the end result. They differ in terms of cost-effectiveness and efficiency [12].These techniques are as follows:

II.7.2.1. Acid Treatment

The availability of H_3O+ ions is necessary for the acid treatment of lignocellulose materials. This ion breaks down and disintegrates the structure by attacking some of the key polymers' intramolecular and intermolecular connections. H_2SO_4, HNO_3, HCl, and H_3PO_4 are examples of concentrated acids that are used in both diluted and concentrated acid treatments. These acids are specifically utilized in the dissolution of sugar units and the synthesis of nanocellulose. Nevertheless, they have a number of disadvantages, such as their toxicity, high cost, and challenging reaction conditions, particularly in industrial settings[13, 14].

II.7.2.2. Alkaline treatment

This process primarily breaks down the structure of lignin, which makes it easier to access the residual cellulose and hemicellulose (polysaccharides). When a base like NaOH or $Ca(OH)_2$ is present, the alkaline medium breaks the unstable connections that hold lignin units together or between them and hemicellulose[15].

II.7.2.3. Treatment with Oxidizing Agents

These agents, which attack and break down the ring structure of the delignification process, include oxygen, ozone (O_3), organic peroxide ($C_2H_4O_3$, H_2O_2), and a number of other substances[16]This procedure is thought to be appropriate for cellulose extraction and is carried out in an alkaline medium (pH>12)[17] .

II.7.2.4. Organosolv

By hydrolyzing lignin and hemicellulose, the lignin fragments are dissolved from the lignocellulosic structure and the cellulose is left in its comparatively pure solid state. This process is known as organosolv. Low-boiling alcohols, such as methanol, ethanol, acetone, ethylene glycol, and ethyl acetate, are the most widely used organic solvents[18].

II.7.2.5. Ionic liquid treatment

is a novel method for breaking down the structure of lignocellulos. In a neutral media, it dissolves lignin, cellulose, and hemicellulose. Ionic liquids are room-temperature liquid salts made up of an organic cation and an inorganic anion. Tetrabutylphosphonium [Bu_4P] + 1-alkyl-3-methylimidazolium [Cnmim]+ 1-alkyl-2,3-dimethylimidazolium [Ammim]+ (n): Number of carbon atoms in the alkyl chain are the most often utilized ionic liquids for treating biomass.

In conclusion, chemical processing, which relies on the selective interaction with the chemical bonds of the lignocellulose fiber structure, can break down lignin and carbohydrates (cellulose and hemicellulose) using acids, bases, solvents, and ionic liquids[19].

II.7.3. Physical Processing

The goal of physical processing is to decrease the amount of chemical waste, the degree of polymerization and crystallinity, and the particle size. Additionally, it raises the bulk density and specific surface area, which makes chemical processing easier. This method's primary flaw is its high energy consumption, which raises processing expenses. It uses a variety of techniques, such as ultrasonics and microwaves. The raw material is cut and ground during mechanical processing. Following cutting, the size is roughly 10–30 nanometers; following grinding, it drops to 0.2-2 nanometers [12] .

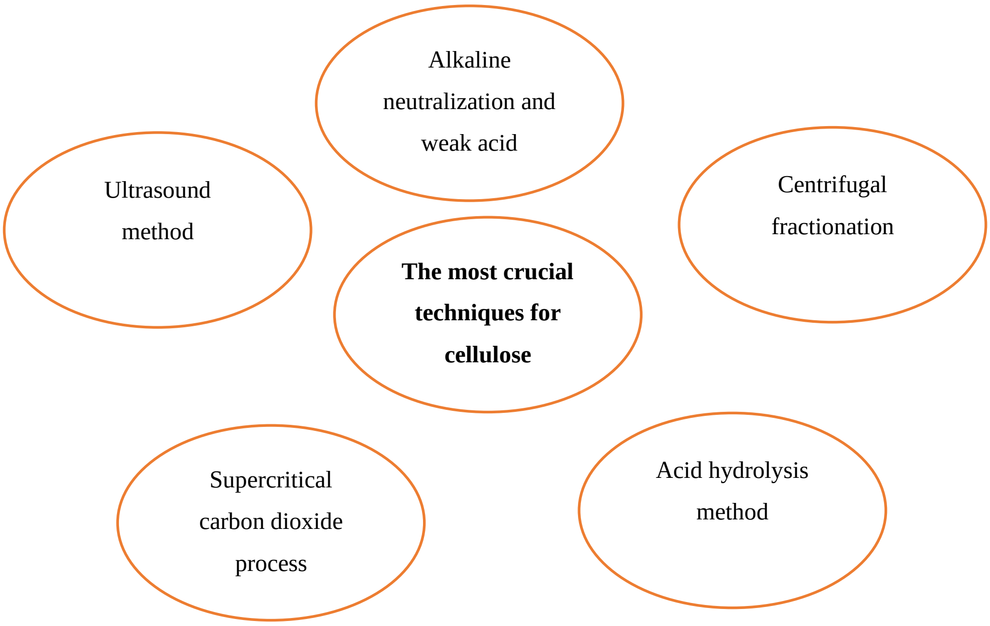


Fig (II.7): the most important methods for extracting cellulose.

II.8. Cellulose derivatives

II.8.1. Bacterial cellulose

Many bacteria, especially those of the genus Gluconacetobacter, are engaged in the creation of a very special form of cellulose with mechanical and structural qualities that can be used in a number of applications, even if plants are the primary source of cellulose. Gluconacetobacter hanseniiUCP1619 usually uses Hestrin-Schramm (HS) medium to manufacture bacterial cellulose. Bacterial cellulose does have certain drawbacks, though, including high production costs, the need for costly growth media, low productivity, downstream processing, and running expenses. Bacteria belonging to the genera Sarcina and Agrobacterium can also manufacture bacterial cellulose. In contrast to plant cellulose, bacterial cellulose, which is generated by aerobic bacteria, has distinct physicochemical characteristics[20].

II.8.2. Cellulose acetate

Depending on the processing technique, this significant cellulose ester can be utilized in a variety of materials, including films, membranes, and fibers. The creation of porous, spherical particles known as cellulose beads is one specific use for cellulose acetate[21].

II.8.3. Ethylcellulose (EC)

Also known as non-ionic ethyl ether of cellulose, is a cellulose derivative in which some of the hydroxyl groups on the repeating anhydrous glucose units have been changed to ethyl ether groups. Ethylcellulose (EC)-based microcapsule-based drug delivery systems are being researched in order to prolong drug release and shield the core material from deterioration[22] .

II.8.4. Hydroxypropyl cellulose (HPC)

It is a cellulose derivative that has lubricating properties and dissolves in both water and organic solvents. Among other things, it can be used to treat synaptitis, corneal abrasions, and keratoconjunctivitis sicca. Additionally, people who have artificial eyes utilize it as a lubricant[23].

II.9. Cellulose's Chemical and Physical Characteristics

II.9.1. Cellulose's Physical Properties

White solid cellulose can withstand temperatures of up to 200°C without breaking down. Nevertheless, it starts to fire around 27°C, demonstrating its propensity for flammable substances. Under a microscope, cellulose's structure is made up of fibers that are no longer than 20 mm. Despite lacking branches, the cellulose fibers are joined by a large number of hydrogen bonds. Because of this, cellulose has exceptional strength and flexibility[24].

II.9.2. Chemical Properties of Cellulose

As early as 1838, Payen Ansel was the first to identify the elements that make up cellulose. According to his research, cellulose is composed of 44–45% carbon, 6–6.5% hydrogen, and the rest oxygen. He concluded that the empirical formula is $C_6H_{10}O_5$ based on this data. The precise molecular makeup of cellulose is yet unknown, though.

Staudinger offered the conclusive proof of the cellulose molecule's highly polymeric character, whereas Haworth postulated a chain-like molecular structure in the late 1920s. A somewhat stiff linear polymer, cellulose is made up of anhydroglucopyranose-D (AGU units). In the solid state, the glucose moieties' C-1 and C-4 create (C → 1-) glycosidic linkages, which bind these units together, the β-linkage limitations cause the AGU units to rotate 180 degrees with respect to one another. Three (hydroxyl) (OH) groups are present in each AGU unit at locations C-2, C-3, and C-6. The cellulose molecule has terminal groups at one end that are entirely distinct from one another. The molecule's C-OH is an aldehyde group with reducing activity at one end, The aldehyde groups use an intramolecular hemiacetal conformation to produce a pyranose ring. On the other hand, the OH at the opposite end of the chain is known as the non-reducing end since it is the OH component of the alcohol. The AGU ring is known to occur in the pyranose ring form, which adopts the chair 1C-4 conformation, the lowest energy conformation of d-glucopyranose, according to nuclear magnetic resonance (NMR) studies, X-ray crystallography, and infrared (IR) spectroscopy[25].

II.10. Applications for Cellulose [20]

One of the most essential natural raw resources and one of the most extensively used natural materials is cellulose. Cotton, flax, hemp, jute, and plant fibers—nearly all of which include cellulose—are its primary sources. The following are cellulose's primary applications:

- ✓ Making Paper

Since cellulose is insoluble in water, it may be readily isolated from other plant components. Around 100 ADS, the Chinese were the first to create a highly effective and high-quality process for turning cellulose into paper. The cellulose and wood must be separated during the procedure. After that, the leftover pulp is cleaned, bleached, and put into a vibrating screen. After that, the water is drained from the pulp. Following this procedure, paper is created by drying, pressing, and smoothing the leftover fibers[26].

- ✓ The Textile Sector

Cellulose makes about 91% of raw cotton. The cotton seed's surface is covered with thousands of fibrous cells. When the cotton pod ripens and opens, these cells perish. Because cellulose makes up the majority of these cells, threads may be easily formed and woven into textiles. To manufacture rayon, various natural fibers like cotton, linen, and others are either treated or used directly[27].

- ✓ Food Sectors

In addition to being an ingredient in many culinary items, cellulose is a dietary fiber supplement. In cheeses, it also serves as a preservative and an anti-caking ingredient. Additionally, cellulose powder and microcrystalline cellulose are utilized in food as stabilizers, emulsifiers, and thickeners.

- ✓ Materials for the Home

utilized in the production of photographic film, eye drops, sponges, adhesives, coffee filters, and laxatives.

- ✓ Building Supplies

utilized as an electrical insulator, building material, and in the production of moisture-resistant coatings.

- ✓ Production of Fuel

Plant-based cellulose has been utilized as a fuel source in the past. Biobutanol fuel can also be produced by processing cellulose derived from animal manure.

- ✓ Numerous Applications.

Cellulose can be made from cotton or cellulose nitrate, which are utilized in explosives. It creates celluloid, a type of plastic, when combined with camphor. This substance was utilized in early motion pictures, but more stable and contemporary plastics have taken its place due to its extreme flammability. It is also utilized by researchers in thin-layer chromatography and liquid filtration.

Conclusion:

In conclusion, cellulose is among the most important natural compounds of our time. It has biological value due to its multiple sources, from microbes to plants, which keeps it renewable and an essential element in several fields. Its uses are prominent in many fields, such as the food, pharmaceutical, textile, and paper industries, due to the development of its extraction techniques. Not only that, it is also considered an essential element in future technological industries and environmentally friendly materials. Thus, cellulose is one of the most important elements that nature provides to humanity in order to achieve environmental balance and sustainable development.

References :

[1] D. Trache, M. H. Hussin, C. T. H. Chuin, S. Sabar, M. N. Fazita, O. F. Taiwo, et al., "Microcrystalline cellulose: Isolation, characterization and bio-composites application—A review," International Journal of Biological Macromolecules, vol. 93, pp. 789-804, 2016.

[2] R. B. Seymour, H. F. Mark, L. Pauling, C. H. Fisher, G. A. Stahl, L. Sperling, et al., "Anselm payen pioneer in natural polymers and industrial chemistry," Pioneers in Polymer Science, pp. 47-61, 1989.

[3] P. Chauhan, N. Sharma, A. Tapwal, A. Kumar, G. S. Verma, M. Meena, et al., "Soil microbiome: Diversity, benefits and interactions with plants," Sustainability, vol. 15, p. 14643, 2023.

[4] S. Zuppolini, A. Salama, I. Cruz-Maya, V. Guarino, and A. Borriello, "Cellulose amphiphilic materials: chemistry, process and applications," Pharmaceutics, vol. 14, p. 386, 2022.

[5] R. Gupta, Alkaline pretreatment of biomass for ethanol production and understanding the factors influencing the cellulose hydrolysis: Auburn University, 2008.

[6] X. Liu, Q. Lin, Y. Yan, F. Peng, R. Sun, and J. Ren, "Hemicellulose from plant biomass in medical and pharmaceutical application: A critical review," Current Medicinal Chemistry, vol. 26, pp. 2430-2455, 2019.

[7] H. Seddiqi, E. Oliaei, H. Honarkar, J. Jin, L. C. Geonzon, R. G. Bacabac, et al., "Cellulose and its derivatives: towards biomedical applications," Cellulose, vol. 28, pp. 1893-1931, 2021.

[8] E. Abraham, B. Deepa, L. Pothen, J. Cintil, S. Thomas, M. J. John, et al., "Environmental friendly method for the extraction of coir fibre and isolation of nanofibre," Carbohydrate polymers, vol. 92, pp. 1477-1483, 2013.

[9] T. Wang, H. E. McFarlane, and S. Persson, "The impact of abiotic factors on cellulose synthesis," Journal of experimental botany, vol. 67, pp. 543-552, 2016.

[10] S. Muthu, V. Gopal, Z. K. AL-Younis, A. B. Altemimi, P. Perumal, M. Lakshmikanthan, et al., "Extraction, purification, and investigation of the antibacterial potential of lysozyme isolated from the latex of Calotropis procera," European Food Research and Technology, vol. 250, pp. 1401-1416, 2024.

[11] C. Bitwell, S. S. Indra, C. Luke, and M. K. Kakoma, "A review of modern and conventional extraction techniques and their applications for extracting phytochemicals from plants," Scientific African, vol. 19, p. e01585, 2023.

[12] H. Lee, S. B. A. Hamid, and S. Zain, "Conversion of lignocellulosic biomass to nanocellulose: structure and chemical process," The Scientific World Journal, vol. 2014, p. 631013, 2014.

[13] A. Hendriks and G. Zeeman, "Pretreatments to enhance the digestibility of lignocellulosic biomass," Bioresource technology, vol. 100, pp. 10-18, 2009.

[14] Z. Zhang, I. M. O'Hara, and W. O. Doherty, "Pretreatment of sugarcane bagasse by acid-catalysed process in aqueous ionic liquid solutions," Bioresource Technology, vol. 120, pp. 149-156, 2012.

[15] Y. Sun and J. Cheng, "Hydrolysis of lignocellulosic materials for ethanol production: a review," Bioresource technology, vol. 83, pp. 1-11, 2002.

[16] E. Abdel-Halim and S. S. Al-Deyab, "Low temperature bleaching of cotton cellulose using peracetic acid," Carbohydrate polymers, vol. 86, pp. 988-994, 2011.

[17] J. Miron and D. Ben-Ghedalia, "Effect of hydrolysing and oxidizing agents on the composition and degradation of wheat straw monosaccharides," European journal of applied microbiology and biotechnology, vol. 15, pp. 83-87, 1982.

[18] X. Zhao, K. Cheng, and D. Liu, "Organosolv pretreatment of lignocellulosic biomass for enzymatic hydrolysis," Applied microbiology and biotechnology, vol. 82, pp. 815-827, 2009.
[19] M. Zavrel, D. Bross, M. Funke, J. Büchs, and A. C. Spiess, "High-throughput screening for ionic liquids dissolving (ligno-) cellulose," Bioresource technology, vol. 100, pp. 2580-2587, 2009.
[20] P. K. Gupta, S. S. Raghunath, D. V. Prasanna, P. Venkat, V. Shree, C. Chithananthan, et al., "An Update on Overview of Cellulose, Its Structure and," Cellulose, p. 59, 2019.
[21] S. Fischer, K. Thümmler, B. Volkert, K. Hettrich, I. Schmidt, and K. Fischer, "Properties and applications of cellulose acetate," in Macromolecular symposia, 2008, pp. 89-96.
[22] G. S. Rekhi and S. S. Jambhekar, "Ethylcellulose-a polymer review," Drug development and industrial pharmacy, vol. 21, pp. 61-77, 1995.
[23] M. Godinho, D. Gray, and P. Pieranski, "Revisiting (hydroxypropyl) cellulose (HPC)/water liquid crystalline system," Liquid Crystals, vol. 44, pp. 2108-2120, 2017.
[24] J. Shokri and K. Adibkia, "Application of cellulose and cellulose derivatives in pharmaceutical industries," in Cellulose-medical, pharmaceutical and electronic applications, ed: IntechOpen, 2013.
[25] R. Sun, Cereal straw as a resource for sustainable biomaterials and biofuels: chemistry, extractives, lignins, hemicelluloses and cellulose: Elsevier, 2010.
[26] E. Małachowska, M. Dubowik, A. Lipkiewicz, K. Przybysz, and P. Przybysz, "Analysis of cellulose pulp characteristics and processing parameters for efficient paper production," Sustainability, vol. 12, p. 7219, 2020.
[27] N. C. Homem and M. T. P. Amorim, "Synthesis of cellulose acetate using as raw material textile wastes," Materials Today: Proceedings, vol. 31, pp. S315-S317, 2020.

Chapter Three: Previous Study

Since plant residues are a sustainable source of recyclable and convertible materials, managing them poses a serious environmental problem. Cellulose extraction and biochar generation are two interesting uses for this biomass. These procedures encourage a circular economy, increase soil quality, and lower greenhouse gas emissions. This paper clarifies the economic and environmental aspects of these techniques, emphasizing the processes that turn trash into useful resources that support sustainable development.

III. Summary of previous studies

III.1. First study [1]

Based on the work done by the researchers: Claudia Irene Kammann, Sebastian Linsel, Johannes W. Gößling, Hans-Werner Koyro.

Which came under the title: Influence of biochar on drought tolerance of Chenopodium quinoa Wild and on soil–plant relations.

The objective of this study is: Verification of the enhancement of plant ecophysiological response by biochar under moderate drought stress and sufficient water supply.

This study concluded as follows:

The First stage: Getting into the middle of poor sandy soil

Each of the 24 pots (inner diameter 10.2 cm, height 20 cm) was filled with 2 kg of air-dried sandy soil (=1.872±1.2 g dry soil) after 3/4 of pure washed sand (particle size <1.4 mm) was combined with 1/4 (v/v) of a sandy loam brown earth.

The second stage: Biochar processing

81.7 and 163.4 g of dry BC per pot, or 100 and 200 t BC ha−1 at 20 cm ploughing depth, respectively, were put to the sandy soil and thoroughly mixed for the BC treatments. Therefore, compared to the control pots, the soil surface in the pots treated with biochar was 2–5 cm higher. Commercial polyethylene pipes with five draining holes per cap were used to make the pots.

Results

The study on biochar's effect on quinoa growth under varying water conditions revealed that biochar application (100 and 200 t ha^{-1}) significantly enhanced plant growth, increasing biomass, leaf area, and tap root development. The biochar-treated plants exhibited better drought tolerance, particularly under reduced water availability, with improved water use efficiency (WUE) and nitrogen use efficiency (NUE). Despite larger leaf areas, plants in biochar-amended soils consumed lesswater, indicating improved drought resistance. Additionally, biochar reduced nitrogen (N_2O) emissions from the soil, especially in the later stages of the study, while initial CO_2 effluxes were higher but normalized over time. The study also showed that 200 t ha^{-1} biochar did not offer additional benefits over 100 t ha^{-1}, indicating a saturation point for its positive effects. These findings suggest that biochar can be a promising strategy to boost crop production, improve water and nutrient efficiency, and mitigate greenhouse gas emissions.

Conclusion

The application of biochar to sandy soil significantly improved quinoa growth and drought tolerance, especially under water scarcity conditions. Biochar enhanced water and nitrogen use efficiency, as well as plant biomass, while reducing greenhouse gas emissions, including nitrous oxide and carbon dioxide. The results suggest that biochar could play a key role in improving agricultural productivity in drought-prone areas, providing both environmental and agricultural benefits.

III.2. Second study[2]

Based on the work done by the researchers: J. A. Ippolito, J. M. Novak, W. J. Busscher, M. Ahmedna, D. Rehrah, and D. W. Watts.

Which came under the title: Switchgrass Biochar Affects Two Aridisols

The objective of this study is: Impact of pyrolyzed switchgrass (Panicum virgatum L.) biochar at low or high temperatures (250 or 500°C) on two aridisols.

This study concluded as follows:

Soil:

The University of Idaho Experimental Station in Aberdeen, Idaho, used Declo series soil for field crops like barley, wheat, and potatoes, while the Warden series soil from Washington State University Experimental Station in Prosser, Washington, was used for a three-year rotation of wheat, corn, and alfalfa.

Biochar:

Switchgrass biochar was produced by a gradual pyrolysis process at 250°C or 500°C with a continuous N_2 gas stream. The biochars were powdered and analyzed for physical and chemical properties. The pH of the biochar was measured after 24 hours of shaking, and surface area was calculated using a Nova 2000 Surface Area Analyzer.

Results

The biochar's surface area, pH, and ash content all increased at the 500°C pyrolysis temperature, while its total surface charge decreased. Leachate Ca and Mg were greatly reduced, leachate K was enhanced, and NO_3-N concentrations were decreased by the 250°C biochar.

Conclusion:

According to the study, switchgrass biochar produced at 250°C can improve the nutrient status of aridisol soil and lessen nutrient leaching; nevertheless, more investigation is required to fully comprehend its nutrient dynamics.

III.3.Third study [3]

Based on the work done by the researchers: Harry H. Schomberg, Julia W. Gaskin, Keith Harris, K.C. Das, Jeff M. Novak, Warren J. Busscher, Don W. Watts, Robin H. Woodroof, Isabel M. Lima, Mohamed Ahmedna, Djaafar Rehrah, and Baoshan Xing.

Which came under the title: Influence of Biochar on Nitrogen Fractions in a Coastal Plain Soil.

The objective of this study: In a Norfolk loamy sand, the impact of biochar on N dynamics was assessed both with and without NH_4 NO_3.

This study concluded as follows: In a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults), the effects of biochar on soil N fractions were assessed both with and without additional N provided as NH_4 NO_3.

Soil:

The dirt was collected from a South Carolina field with an acidic pH and low SOC content, which has been producing row crops like corn, soybeans, wheat, and cotton for over 20 years.

Biochar:

This study used five feedstocks to create biochars: switchgrass, pecan shells, peanut hulls, poultry litter, and hardwood waste products. The biochars were dried, ground, and sieved before being subjected to pyrolysis. Low-temperature and high-temperature biochars were developed to provide different properties. The biochars were made at various locations, including the USDA-ARS Southern Regional Research Center, the University of Georgia, and North Carolina Agricultural and Technical State University. The study used ASTM D 3172 and 3176 standard methods to estimate fixed carbon, volatile matter, ash content, and elemental analysis.

The laboratory incubation:

The soil was then incubated for 127 days at room temperature and relative humidity. The soil was then leached with deionized water at various times, and the resulting leachate was examined for mineral N concentration. After the leaching event, 120 g of soil was taken out, air dried, and shipped to the USDA Agricultural Research Service facility in Watkinsville, Georgia, for a study of the N fractions.

Results

Biochar treatments did not improve inorganic nitrogen retention after 127 days, and high pH and ash biochars decreased resistant nitrogen percentage. High pH and ash biochars caused undetectable nitrogen losses, while HT pecan shell, peanut hull, and poultry litter biochars caused volatilization.

Conclusion

Because it increases NH_4-N retention and decreases leaching losses, biochar has an impact on nitrogen cycle. However, initial volatilization losses were probably the cause of the decreases in HT peanut hull, HT pecan shell, and HT poultry litter that were noted. Although there was no proof that the LT peanut hull, HT switchgrass, and CQuest biochar treatments improved ion retention, they did lessen cumulative leaching.

III.4. Fourth study[4]

Based on the work done by the researchers: Houssou Assa Albert, Xiang Li, Paramsothy Jeyakumar, Lan Wei, Lianxi Huang, Qing Huang, Muhammad Kamran, Sabry M. Shaheen, Deyi Hou, Jörg Rinklebe, Zhongzhen Liu, Hailong Wang.

Which came under the title: Influence of biochar and soil properties on soil and plant tissue concentrations of Cd and Pb: A meta-analysis

The objective of this study is: Finding the levels of Cd and Pb in plant roots and shoots in response to applying biochar using meta-analysis

This study concluded as follows:

Searching the literature and choosing pertinent primary studies:

A study was conducted to analyze the impact of biochar on soil potentially harmful metals (Cd and Pb) in plants. The research focused on 65 research publications that discussed changes in soil qualities and the concentrations of Cd and Pb in the shoot and root of plants cultivated in diverse environments. The study used search terms like "biochar and contaminated soil," "soil+potentially toxic metal and biochar", "soil+heavy metal and biochar" and "shoot/root potentially toxic metal concentration and biochar"**.**

Meta-analysis:

The study used OpenMEE software for meta-analysis in ecology and evolutionary biology to investigate the effect size of biochar treatment on soil properties. The natural log of response ratio (R) was calculated to determine the effect size**.** ANOVAs were used to search for significant changes between the median or mean of soil Cd and Pb concentration ratio values in treatment and control groups**.**

Results:

The study found that adding biochar to soil significantly reduced Cd and Pb concentrations in shoots and roots, depending on plant type and soil characteristics. Biochar with a size of less than 2mm, pH greater than 10, pyrolysis temperature between 401 and 600 ^{o}C, and application rate greater than 2% showed the most effective reduction.

Conclusion:

By immobilizing PTEs in the soil, biochar application improves soil quality and lowers the concentration of Cd and Pb in shoots and roots. Therefore, biochar can be utilized to lower the health risks associated with harmful metals that consumers of roots and shoots collected from polluted soil may encounter.

III.5.Fifth study[5]

Based on the work done by the researchers: A.E Ajayi et R.Horn.

Which came under the title: Modification of chemical and hydrophysical properties of two texturally differentiated soils due to varying magnitudes of added biochar

The objective of this study is: The impact of distinct rates of biochar modification on a few chemicals, physical, as well as hydraulic characteristics of fine-sand and sandy loamy silt soils was investigated by including 20, 50, and one hundred grams of biochar per kilogram (by dry weight).

This study concluded as follows:

Sample preparation:

1. Base soil materials:

The study examined soil substrates Sandy Loamy Silt and Alright Sand. Sandy Loamy Silt was collected from calcic Gleysols in Schleswig-Holstein, Germany, while Alright Sand was a commercially available silica sand primarily composed of quartz. Both samples were air-dried, homogenized, and sieved.

2. Biochar material:

The study used commercial biochar, prepared from wood chips burned at 500-600 degrees Celsius, crushed into finer fractions, and rheologically measured before mixing it with soil substrates, following European standards.

3. Preparation of test substrates

The study aimed to assess the effects of biochar amendment on the mechanical and chemical properties of modified soils by incorporating different blend proportions of biochar into Sandy Loamy Silt or fine sand.

4. Preparation of test samples:

The study involved preparing samples of biochar by repackaging stainless steel cylinders with mixed substrates. Sandy substrates were packed to a large density of 1.65 g/cm³, equivalent to 32, 80, and 160 t/ha of biochar, while silty substrates were renewed to the same density**.** Unaltered samples of fine sand and sandy loamy silt were also packaged as controls.

Results:

The study found that biochar amendment improved total carbon and aggregate properties in agricultural soils. The water capacity was higher in amended substrates, particularly fine sand. The biochar amendment improved particle-to-particle bonding and developed weaker, more resilient aggregates. The addition of biochar dominated the internal soil strength, but most positive improvements were no longer significant. The study provides more insights into biochar's effect on agricultural soils.

Conclusion:

We finalize that the extensively stated enhancement in the agronomic performance of biochar changed substrates was motivated by the enhanced microstructural state in the changed soils, which relying on the kind and quantity of biochar, additionally, the texture of the soil being changed and the dampness state. But it must be highlighted that the supplementary of one hundred g per 1 kilogram of biochar to the soil as regarded in this research might not be possible beneath field state and has been displayed to provide no "extra" advantage in any instance

III.6.Sixth study[6]

Based on the work done by the researchers: A.E. Ajayi, D.Holthusenb, R.Horn.

Which came under the title: Changes in microstructural behaviour and hydraulic functions of biochar amended soils

The objective of this study is: The impact of biochar therapy on two distinct soil kinds is significant, especially when assessing its influence on hydrologic as well as mechanical characteristics. These characteristics play a crucial role in driving total soil creation and stability

This study concluded as follows:

1. Soil:

The research utilized Sand, Sandy Loamy Silt, and Calc Gleysol as foundation materials, with pre-treated Alright Sand from Germany's Calc Gleysols, which were air-dried, crushed, and sieved.

2. Biochar:

The study used high-temperature pyrolyzed biochar prepared from hardwood from Germany's Nachhaltig—Susterra, crushed into fine fractions using a centrifugal mill, and sieved to prepare different substrates.

3. Preparation of test substrates cores:

The study involved adding biochar to foundation soil materials like fine sand or sandy loamy silt at different dosages. The substrates were homogenized, packed in polythene bags, and stored at 10°C for 30 days. Test specimens were prepared by repackaging stainless steel cylinders. The sandy substrates were packed to a density of 1.65 g cm^3, while the silty substrates were renewed to a density of 1.45 g cm^3 and 1.30 g cm^3. Additional samples were prepared to measure saturated hydraulic conductivity and accumulation.

Results:

The study revealed that biochar modification significantly increased the pore framework, saturated hydraulic conductivity, repetition dampening and drying, and the repellent index of the modified substrates.

Conclusion:

The fact that reformation paired using the surface attributes I have demonstrated of the modified soil particles led to the development of superior soil surroundings along with roles of pores; consequently, enhancement within water-plant-soil interaction. The fact that research has shown that the consequences of comparable biochar change on moisture content preservation, porous operation, aggregation, along with combined steadiness, depends on the sum of biochar. Additionally, the texture of the soil had been modified along with the figure of the WD loops.

III.7.Seventh study[7]

Based on the work done by the researchers: M.C. Andrenelli, A. Maienza, L. Genesio, F. Miglietta, S. Pellegrini, F.P. Vaccari, N. Vignozzi.

Which came under the title: Field application of pelletized biochar: short term effect on the hydrological properties of a silty clay loam soil.

The objective of this study: examined the potential for using pelletized biochar as a soil conditioner during a tomato crop's single cropping season.

This study concluded as follows:

1. Biochar and field experiment:

A study in Parma, Italy, used pelletized wheat bran as a feedstock for biochar production, simulating a realistic production chain. Two different forms of biochars (B1 and B2) were produced using the same feedstock material but with different pyrolysis processes.

2. Soil sampling

24 undisturbed soil samples were collected at the end of crop-growing season, and bulk density and water retention characteristics were calculated using 122 cm^3 metal cylinders.

Results:

The study demonstrates the effectiveness of pelletized biochar as a soil conditioner for fine-textured soil, increasing macroporosity and improving air and water transport. The biochars also impacted the AWC range, with benefits depending on the type of biochar. However, longer-term studies are needed to evaluate the dynamics of accommodation pores and the development of amended soil AWC, as the fate of both pore classes depends on long-term interactions.

Conclusion:

The field experiment demonstrated the effectiveness of pelletized biochar as a soil conditioner for fine-textured soil. However, further studies are needed to confirm hydraulic efficiency and the evolution of amended soil AWC, considering biochar nature and coarse size.

III.8. Eighth study[8]

Based on the work done by the researchers: S. Barontia, F.P. Vaccari, F. Miglietta,C. Calzolari, E. Lugato, S. Orlandini,R. Pini, C. Zulian, L. Genesio.

Which came under the title: Impact of biochar application on plant water relations in Vitis vinifera (L.)

The objective of this study is: the effect of two rates of biochar application (22 and 44 ton ha−1) on plant water relations of V. vinifera in a field experiment in central Italy.

1. Biochar:

The field experiment utilized commercial biochar from Romegna Carbone, Italy, made from orchard biomass. The biochar was crushed into smaller particles before soil application, and dry-sieving was used to determine its particle size distribution.

2. Soil:

In 2011, four soil samples were taken at different dates and times, and their water content was determined volumetrically using the core method. The samples were then sieved, placed on pressure plate equipment, and placed into pressure chambers.

Results:

The hydrophobicity of the soil did not significantly increase as a result of the treatments. Furthermore, during droughts, there were significant relative increases in the available soil water content (from 3.2% to 45% in the 22 and 44 ton ha−1 application rates, respectively) and in the leaf water potential (24–37%) when compared to control soils, according to soil analysis and ecophysiological measurements.

Conclusion:

Therefore, the addition of biochar may be viewed as a potentially useful adaptation strategy that, when combined with other adaptation practices, could help to alleviate periods of water stress, which would have a major impact on production stability and water savings. However, before endorsing the widespread use of biochar, the potential effects on the quantity and quality of products must be thoroughly considered.

III.9. Ninth study[9]

Based on the work done by the researchers: M. Castellinia, L. Giglio, M. Niedda, A.D. Palumbo, D. Ventrella.

Which came under the title: Impact of biochar addition on the physical and hydraulic properties of a clay soil.

The objective of this study is: evaluate the impact of biochar addition on saturated (Kfs) and unsaturated (K(h)) hydraulic conductivity, water retention, capacitive indicators such as macroporosity (Pmac), air capacity (AC).

Biochar and soil:

The USDA-classified Vertisol soil used in the study was gathered and kept in seed sacks. Fruit tree prunings were used to make biochar, which was then examined with a CHN Elemental Analyzer. Sample screening, oven drying, and ashing in a muffle furnace were all part of the chemical analysis process. Using an ICP optical spectrometer, the total amounts of P, K, S, Ca, Mg, Na, Mn, and Fe were ascertained.

Results:

The study found no significant differences in Kfs values between changed and unchanged soils, and biochar did not significantly impact K(h) principles. However, significant rises in soil water retention were found near water saturation for the highest concentration of biochar**.**

Conclusion:

The study found that biochar, when added to low-macroporosity soils, significantly reduced water availability and field capacity, enhanced macroporosity and air capacity, and may cause an imbalance between liquid and gas phases.

III.10. Tenth study[10]

Based on the work done by the researchers: Wan Azlina Wan Abdul Karim Ghania, Ayaz Mohd, Gabriel da Silva, Robert T. Bachmann, Yun H. Taufiq-Yap, Umer Rashid, Ala'a H. Al-Muhtaseb.

Which came under the title: Biochar production from waste rubber-wood-sawdust and its potential use in C sequestration: Chemical and physical characterization

The objective of this study is: The produced biochars were characterized by Brunauer–Emmett–Teller (BET) gas porosimetry, scanning electron microscopy (SEM), X-ray diffraction (XRD), thermogravimetric analysis (TGA), and Fourier transform infrared spectroscopy (FTIR).

1. Sample preparation:

In Selangor, Malaysia, sawdust from rubber wood (Heveabrasilensis) was sourced locally. Samples were chopped, dried for 24 hours at 110°C to eliminate moisture, and then ground in a wood crusher (Model MXJ-500) to a size of 2-3 mm.

2.Biochar:

A thermocouple was used to examine the dried sawdust sample after it had been heated to 450–850°C in a stainless-steel reactor. A temperature controller was used to regulate the temperature, and the sample was taken for examination.

Results:

The thermal and chemical characteristics of biochar samples are greatly influenced by the pyrolysis temperature. Five percent water can be absorbed at lower temperatures, but aromatic chemicals at higher temperatures stabilize them. As the temperature rises, the amount of carbon increases, indicating unsaturated carbon. Biochars made from sawdust feature aromatic functional groups and surface areas. Temperature causes CO2 adsorption rates to rise, whereas production causes them to fall. One possible substitute for carbon sequestration is derived biochar.

Conclusion:

Pyrolysis temperature significantly impacts biochar's thermal and chemical properties, with sawdust-derived biochar showing wide composition and chemistry ranges. Rising temperatures increase carbon content, suggesting biochar made at higher temperatures may lock up soil carbon.

III.11. Eleventh study [11]

Based on the work done by the researchers: L. Manzato, L.C.A. Rabelo, S.M. de Souza, C.G. da Silva, E.A. Sanches, D. Rabelo, L.A.M. Mariuba, J. Simonsen.

Which came under the title: new approach for extraction of cellulose from tucumã's endocarp and its structural Characterization

The objective of this study is: One environmentally friendly way to stop environmental issues is to recycle plant waste materials into valuable items.

This study concluded as follows:

Cellulose Extraction:

An almond variety known as tucumã was gathered near Manaus, Brazil. It underwent centrifugation, delignification, drying, milling, bleaching, and breaking into endocarps. Washing, adding a buffer, and doing the bleaching procedure twice were all part of the procedure. The antioxidant qualities of the resultant substance were then examined.

Results:

The cellulose from the endocarp of tucumã was successfully removed by the study, exposing a naturally occurring crystalline substance embedded in a non-crystalline matrix. Type II structure was confirmed by the presence of cellulose nanocrystals in the extracted cellulose. The percentage of crystallinity was estimated using two different approaches; the first way yielded 48.5%, while the second method produced 31.5%. A cellulose type II structure was verified by FTIR spectroscopy, and SEM pictures revealed micrometric fibers of varying thicknesses. Low thermal stability was found via thermal analysis as a result of poorly organized chains.

Conclusion:

This study confirms the removal of non-cellulosic material and shows how to extract cellulose type II from Tucumã's endocarp while also effectively removing hemicellulose and lignin.

III.12. twelfth study [12]

Based on the work done by the researchers: X. Wang, H. Li, Y. Cao, and Q. Tang.

Which came under the title: Cellulose extraction from wood chip in an ionic liquid 1-allyl-3-methylimidazolium chloride (AmimCl).

The objective of this study is: In the present study, 1-allyl-3-methylimidazolium chloride (AmimCl), an ionic liquid (IL), was used to extract cellulose from pine, poplar, Chinese parasol, and catalpa wood chips.

This study concluded as follows:

1.Material and reagents:

Wood samples from Shandong Province, China, were sun-dried, ground into a powder, sieved, and dried overnight in an oven set to 105 C for use.

2.Wood dissolution:

AmimCl was mixed with imethyl sulfoxide to produce a transparent solution. A dark, amber-colored, viscous wood suspension with a 5 weight percent wood concentration was achieved by dispersing dried wood powder into the fluid, stirring it, and then heating it.

Results:

Pine has a high extraction rate of 62% and a cellulose content of 85%, making it ideal for cellulose extraction utilizing ILs. By breaking the hydrogen bonds that hold lignocelluloses together, IL degrades pine wood. Reaction time is shortened by microwave radiation.

Conclusion:

The work offers a new biomass resource by presenting an eco-friendly technique for mildly cellulose extraction from wood. Its drawbacks include toxicity, corrosion, and ineffectiveness for some wood kinds; further research is necessary for potential future uses.

III.13. Thirteenth study [13]

Based on the work done by the researchers: C. U. Maheswari, K. O. Reddy, E. Muzenda, B. Guduri, and A. V. Rajulu.

Which came under the title: Extraction and characterization of cellulose microfibrils from agricultural residue e Cocos nucifera L.

The objective of this study is: The purpose of this work was to use an alkaline extraction method and chlorination to extract cellulose microfibrils from the agricultural residue of coconut palm leaf sheath.

This study concluded as follows:

1. Materials:

Sheath of coconut palm leaves, ethanol, acetic acid, sodium hydroxide, sodium bisulphite, nitric acid, sodium chlorite, and toluene (Merck Chemicals) (Sd-Fine Chemicals). Every chemical utilized was of analytical grade.

2. Fiber processing:

In order to be cleaned, dried, and stored in polyethylene bags, leaf sheaths from 10-year-old coconut trees in Penakacherla village, Andhra Pradesh, India, were gathered and brought to a laboratory. One t hectare is the average yield.

3. Extraction of the cellulose microfibrils:

Alkaline extraction and chlorination techniques were used to remove cellulose from leaf sheaths. After drying for eight hours at 105 degrees Celsius, the dried sheaths were crushed and screened. After being dewaxed, the sample was dried and lignified. After applying a NaOH solution to the residue, it was filtered, cleaned, and dried. After being treated with acetic and nitric acids, the crude cellulose was cleaned and purified. Sun et al.'s method was used, and it was repeated until the weight remained constant.

Results:

The study examines the shape of cellulose microfibrils from the sheaths of coconut palm leaves and finds that the majority of the hemicellulose and lignin were eliminated by chemical treatments. Improved thermal stability was demonstrated by thermogravimetric measurement, indicating a novel strategy for the effective use of coconut palm leaf sheaths in biocomposite applications.

Conclusion:

The sheath of coconut palm leaves, a plentiful and renewable resource, presents a potential source of cellulose for a number of uses. Cellulose microfibrils were extracted chemically, revealing a higher cellulose content and reduced hemicellulose and lignin levels. The cellulose microfibrils shown improved thermal stability and might be utilized as raw materials for cellulose derivatives, fillers in paper, composites, or water absorbents. This strategy might offer a fresh method for making extensive use of the fibers found in coconut palm leaf sheaths.

III.14. Fourteenth study[14]

Based on the work done by the researchers: T. Prakongpan, A. Nitithamyong, and P. Luangpituksa.

Which came under the title: Extraction and Application of Dietary Fiber and Cellulose from Pineapple Cores

The objective of this study is: Alkali extraction using a bleaching method produced pineapple core cellulose (PC), whereas alcoholic extraction produced pineapple core dietary fiber (PDF).

This study concluded as follows:

1. Materials:

Using reagent-grade chemicals from a nearby pineapple canning facility in Thailand, pineapple cores were removed from pineapples.

2. Fiber extraction:

To get rid of extra water, pineapple cores were cleaned, cut into slices, mixed, and squeezed. Thumthanarak (1996) modified the process of alcoholic extraction to generate pineapple core dietary fiber (PDF). 95% ethanol was used to press and remove the pulp, which was then filtered and allowed to air dry. Alkali extraction, which entailed heating, filtration, and bleaching, was used to extract pineapple core cellulose (PC). The weight of fiber following extraction was divided by the weight of fresh pineapple cores to determine the extraction yield. After two iterations of the procedure, the residual dry fraction was allowed to air dry.

Results:

The findings showed that the extracted cellulose had significant lignin and hemicellulose removal. It was discovered that the sizes of the isolated cellulose and cellulose nanocrystals ranged from 5 to 80 m and 5 to 25 nm, respectively. When compared to the raw material, it was discovered that the leaves' thermal stability increased at different purification stages.

Conclusion:

Both PC and PDF are high in dietary fiber; PC has a pH of 4.0 and 91.2% cellulose. Better emulsifying activity, settling volume, pH, water, and oil retention are all provided by larger particle sizes.

III.15. Fifteenth study [15]

Based on the work done by the researchers: N. Dinh Vu, H. Thi Tran, N. D. Bui, C. Duc Vu, and H. Viet Nguyen.

Which came under the title: Lignin and Cellulose Extraction from Vietnam's Rice Straw Using Ultrasound-Assisted Alkaline Treatment Method

The objective of this study is: In order to increase economic efficiency and lessen environmental damage, a method of extracting cellulose and lignin from rice straw in Vietnam without paraffin pretreatment was presented.

This study concluded as follows:

1. Materials and chemicals:

A study employing chemical agents of reagent grade or above from Merck Chemicals used rice straw from TienKienCommune, LamThaoDistrict, PhuTho Province, Vietnam.

2. Ultrasound-Assisted Alkaline Extraction Method of Lignin and Cellulose:

Utilizing alkaline and ultrasound-assisted techniques, lignin and cellulose were extracted from rice straw, yielding cellulose and lignin fractions.

Results:

Current analytical techniques demonstrate that the application of the ultrasonic-assisted alkaline treatment method from Vietnam's rice straw produces high-purity lignin with a larger molecular weight and greater thermal stability for cellulose and lignin.

Conclusion:

Ultrasonic irradiation enhances the extraction of lignin and cellulose from rice straw, increasing yields with sonication time. The lignin recovered is highly pure and larger in molecular weight. Although not significantly altering the composition or structure, ultrasound may improve thermal stability, making it beneficial for industrial use.

III.16. Sixteenth study [16]

Based on the work done by the researchers: Q. Lin, Y. Huang, and W. Yu.

Which came under the title: Effects of extraction methods on morphology, structure and properties of bamboo cellulose

The objective of this study is: This study examines the impact of four extraction techniques—hydrothermal extraction (HT), standard alkali extraction (SA), ambient condition extraction (AC), and two-stage extraction (TS)—on the morphology, structure, and characteristics of bamboo cellulose.

This study concluded as follows:

Materials:

Moso bamboo stems were conditioned at 20°C to 10% moisture content after being purchased from a Chinese forest center. Small pieces of raw bamboo were prepared, while Beijing Chemical Works and Aladdin provided AR-grade chemicals such as acetic acid, ethanol, and benzene.

Extraction of cellulose:

After being prepared with benzene-alcohol solvents, bamboo slivers were subjected to a water bath. After that, the cellulose was dried, filtered, and heated. Hydrothermal extraction cellulose (HT-Cell) was the end product. SA-Cell, a traditional technique, was also used to extract the cellulose. Following delignification, the cellulose underwent repeated dehydration.

Results:

While HT-extracted hemicellulose residues perform better in mechanical and thermal properties, SA-extracted cellulose displays entire cell shape, mixed cellulose I and II structures, exceptional toughness, and thermal stability.

Conclusion:

Four techniques—hydrothermal extraction, standard alkali extraction, ambient condition extraction, and two-stage extraction—are used in this study to compare cellulose samples from bamboo. Standard alkali extraction creates a hybrid structure with improved toughness and thermal stability, but two-stage extraction preserves superior shape and crystallinity. While ambition condition extraction is not appropriate for intact single cell morphology, hydrothermal extraction offers superior mechanical qualities and thermal stability.

III.17 .Seventeenth study [17]

Based on the work done by the researchers: P. Penjumras, R. B. A. Rahman, R. A. Talib, and K. Abdan.

Which came under the title: Extraction and Characterization of Cellulose from Durian Rind

The objective of this study is: Delignification with acidic sodium chlorite and mercerization with 17.5% (w/v) sodium hydroxide were used to remove cellulose from durian rind.

This study concluded as follows:

1. Materials:

The rind of durian was gathered from Thailand's Phatthalung region. We bought 80% pure technical sodium chlorite ($NaClO_2$) and reagent-grade sodium hydroxide (NaOH) and acetic acid (CH_3COOH) from Fisher Chemicals Sdn. Bhd. (Malaysia).

2. Extraction of cellulose from durian rind:

A two-step procedure is used to create durian rind cellulose, beginning with the synthesis of holocellulose using the bleaching or chlorination method. After grinding, washing, and soaking the rind for five hours, CH3COOH and NaClO2 are added to a beaker. After that, the holocellulose is mercerized at ambient temperature to produce cellulose. After stirring and filtering, the mixture is treated with 10% acetic acid and 8.3% NaOH. After that, the cellulose is cleaned, dried, and filtered

Results:

After non-cellulosic components were eliminated, the cellulose that was recovered from the durian rind had a density of 1.59 g/cm^3. The diameter and aspect ratio of the cellulose were 100-150 µm and 20-25 µm, respectively, indicating the possibility of reinforcing using composite materials.

Conclusion:

By eliminating non-cellulosic components using mercerization and chlorination, cellulose was successfully extracted from durian rind. With dimensions of 100-150 µm in diameter, 1.59 g/cm3, and an aspect ratio of 20-25, the cellulose exceeded the minimum required for effective strength transfer in reinforcing materials.

III.18. eighteenth study [18]

Based on the work done by the researchers: I. Bicu and F. Mustata.

Which came under the title: Cellulose extraction from orange peel using sulfite digestion reagents.

The objective of this study is: The effect of the main process parameters, sulfite agent dosage and reaction duration, on cellulose yield.

This study concluded as follows:

1.Plant materials and chemicals:

Peeling, segmenting, air drying, coarsely grinding, and sieving were all done on navel oranges. Experiments were conducted using the peel fraction, which had a particle size distribution between 1.0 and 3.0 mm. A trichloromethane–hexane azeotrope was used for ten hours to defatten and extract the ground and dried orange peel. After being defatted, the peel was dried and extracted once again for thirty-two hours using a water/ethanol/toluene azeotrope. The water-soluble pectin fraction and flavonoids, such as hesperidin, were effectively extracted from the peel using this ternary azeotrope. Because hesperidin is not very soluble and must be extracted entirely from the peel, the extraction process took a little longer than expected.

Results:

The optimal yields for sodium sulfite and sodium metabisulfite digestion were 40.4% and 45.2%, respectively. Bleaching crude celluloses with hypo chlorite and oxygen yielded celluloses with good purity, low crystallinities, and moderate molecular weights.

Conclusion:

The response surface methodology uses partially defatted orange peel in sulfite pulping to forecast cellulose extraction yields, benefiting paper fillers, water absorbents, and cellulose derivatives.

III.19. Nineteenth study [19]

Based on the work done by the researchers: S. M. Rosa, N. Rehman, M. I. G. de Miranda, S. M. Nachtigall, and C. I. Bica.

Which came under the title: Chlorine-free extraction of cellulose from rice husk and whisker isolation.

The objective of this study is: This study describes the separation of cellulose whiskers from rice husk (RH) using an environmentally friendly method for bleaching and cellulose extraction.

This study concluded as follows

1. Materials:

Rice husk was supplied by Engenho Meirebe, while solvents and reagents were analytical grade. Microcrystalline cellulose was supplied by Quimsul.

2. Isolation of cellulose:

A Soxhlet device was used to grind, dehydrate, and delignify rice husks. A process outlined by Sun et al. (2004) was then used to bleach and purify the resultant pulp. After that, ethanol and distilled water were used to wash the cellulose pulp in order to get rid of nitric acid and the breakdown products of the extraction process. After purification, the cellulose was dried at 60°C in an oven until its mass remained constant. The extracted cellulose yield was 28 weight percent.

3. Isolation of the cellulose whiskers:

At 25°C for 60 minutes, 64% sulfuric acid was combined with the purified cellulose in a 1:18.75 ratio. Centrifugation and extended dialysis were used to remove surplus sulfuric acid after the combination was stopped by putting it into cold water. An ultrasonic treatment was then used to spread the resultant cellulose.

Results:

The methods of thermogravimetric analysis (TGA), modulated differential scanning calorimetry (MDSC), scanning electron microscopy (SEM), infrared absorption spectroscopy (ATR-FTIR), and X-ray diffraction (XRD) demonstrated that the entire procedure is sufficient to produce cellulose with high purity and crystallinity. The purpose of hydrolyzing this cellulose with sulfuric acid was to isolate the whiskers. According to atomic force microscopy (AFM) and transmission electron microscopy (TEM), they displayed the characteristic elongated rod-like feature.

Conclusion:

This study offers a 74% yield for cellulose separation from rice husk using a chlorine-free method. The technique yields about 16 weight percent cellulose and doesn't produce any harmful effluents. Rice husk has a 16-weight percent ash content. Analysis using FTIR, TGA, and MDSC all confirm that lignin and hemicellulose have been removed from rice husk. Compared to microcrystalline cellulose (MCC), rice husk cellulose has a 67% lower crystallinity. Sulfuric acid hydrolysis was successfully used to produce cellulose whistles, which can be employed as nanoofillers in polymer matrices. The availability of nanostructured materials for polymer nanocomposites is expanded by this new material source.

III.20. Twentieth study[20]

Based on the work done by the researchers: M. E. Malainine, A. Dufresne, D. Dupeyre, M. Mahrouz, R. Vuong, and M. R. Vignon.

Which came under the title: Structure and morphology of cladodes and spines of Opuntia ficus-indica. Cellulose extraction and characterization.

The objective of this study is: Transmission and scanning electron microscopy, in conjunction with electron and X-ray diffraction analysis, were used to examine the morphology and structure of the cladodes and spines of the cactus Opuntia ficus-indica (OFI).

This study concluded as follows:

Materials and chemical analysis:

The spines of fresh cladodes were manually removed after they were gathered from a trial plantation in Amezmiz, Morocco. Through Seaman hydrolysis, neutral sugars were liberated, and GLC was used for analysis. The mhydroxydiphenyl technique was used to determine the amount of uric acid. Overnight measurements of the ash concentration revealed that just 66% of the minerals were present. After 24 hours, weight reduction yielded fats and waxes. The TAPPI standard T222-03-75 was followed for performing the lignan analysis.

Results:

A compact parallel arrangement of thin cellulose fibers (0.4 mm long, 6–10 mm diameter) with extremely tiny lumens made up the spines adorning the OFI cactus' cladodes. Tensile tests at different conditioning relative humidities were used to examine the mechanical characteristics of these natural spines. These spines' remarkable mechanical qualities are due to their structure and morphology; as moisture content rises, their tensile modulus decreases.

Conclusion

The significance of utilizing plant waste to improve soil and promote the green economy is summed up in these studies. Among the many benefits of contemporary cellulose extraction and biochar production technologies are better agricultural output and resource efficiency. To manage these resources in these activities, a sustainable, effective, and efficient strategy must be used.

References:

[1] C. I. Kammann, S. Linsel, J. W. Gößling, and H.-W. Koyro, "Influence of biochar on drought tolerance of Chenopodium quinoa Willd and on soil–plant relations," Plant and soil, vol. 345, pp. 195-210, 2011.

[2] J. Ippolito, J. Novak, W. Busscher, M. Ahmedna, D. Rehrah, and D. Watts, "Switchgrass biochar affects two Aridisols," Journal of environmental quality, vol. 41, pp. 1123-1130, 2012.

[3] H. H. Schomberg, J. W. Gaskin, K. Harris, K. Das, J. M. Novak, W. J. Busscher, et al., "Influence of biochar on nitrogen fractions in a coastal plain soil," Journal of environmental quality, vol. 41, pp. 1087-1095, 2012.

[4] H. A. Albert, X. Li, P. Jeyakumar, L. Wei, L. Huang, Q. Huang, et al., "Influence of biochar and soil properties on soil and plant tissue concentrations of Cd and Pb: A meta-analysis," Science of the Total Environment, vol. 755, p. 142582, 2021.

[5] A. Ajayi and R. Horn, "Modification of chemical and hydrophysical properties of two texturally differentiated soils due to varying magnitudes of added biochar," Soil and Tillage Research, vol. 164, pp. 34-44, 2016.

[6] A. Ajayi, D. Holthusen, and R. Horn, "Changes in microstructural behaviour and hydraulic functions of biochar amended soils," Soil and Tillage Research, vol. 155, pp. 166-175, 2016.

[7] M. Andrenelli, A. Maienza, L. Genesio, F. Miglietta, S. Pellegrini, F. Vaccari, et al., "Field application of pelletized biochar: Short term effect on the hydrological properties of a silty clay loam soil," Agricultural Water Management, vol. 163, pp. 190-196, 2016.

[8] S. Baronti, F. Vaccari, F. Miglietta, C. Calzolari, E. Lugato, S. Orlandini, et al., "Impact of biochar application on plant water relations in Vitis vinifera (L.)," European Journal of Agronomy, vol. 53, pp. 38-44, 2014.

[9] M. Castellini, L. Giglio, M. Niedda, A. Palumbo, and D. Ventrella, "Impact of biochar addition on the physical and hydraulic properties of a clay soil," Soil and Tillage Research, vol. 154, pp. 1-13, 2015.

[10] W. A. W. A. K. Ghani, A. Mohd, G. da Silva, R. T. Bachmann, Y. H. Taufiq-Yap, U. Rashid, et al., "Biochar production from waste rubber-wood-sawdust and its potential use in C sequestration: chemical and physical characterization," Industrial Crops and Products, vol. 44, pp. 18-24, 2013.

[11] L. Manzato, L. Rabelo, S. De Souza, C. Da Silva, E. Sanches, D. Rabelo, et al., "New approach for extraction of cellulose from tucumã's endocarp and its structural characterization," Journal of Molecular Structure, vol. 1143, pp. 229-234, 2017.

[12] X. Wang, H. Li, Y. Cao, and Q. Tang, "Cellulose extraction from wood chip in an ionic liquid 1-allyl-3-methylimidazolium chloride (AmimCl)," Bioresource technology, vol. 102, pp. 7959-7965, 2011.

[13] C. U. Maheswari, K. O. Reddy, E. Muzenda, B. Guduri, and A. V. Rajulu, "Extraction and characterization of cellulose microfibrils from agricultural residue–Cocos nucifera L," Biomass and bioenergy, vol. 46, pp. 555-563, 2012.

[14] T. Prakongpan, A. Nitithamyong, and P. Luangpituksa, "Extraction and application of dietary fiber and cellulose from pineapple cores," Journal of food science, vol. 67, pp. 1308-1313, 2002.

[15] N. Dinh Vu, H. Thi Tran, N. D. Bui, C. Duc Vu, and H. Viet Nguyen, "Lignin and Cellulose Extraction from Vietnam’s Rice Straw Using Ultrasound-Assisted Alkaline Treatment Method," International Journal of Polymer Science, vol. 2017, p. 1063695, 2017.

[16] Q. Lin, Y. Huang, and W. Yu, "Effects of extraction methods on morphology, structure and properties of bamboo cellulose," Industrial Crops and Products, vol. 169, p. 113640, 2021.

[17] P. Penjumras, R. B. A. Rahman, R. A. Talib, and K. Abdan, "Extraction and characterization of cellulose from durian rind," Agriculture and Agricultural Science Procedia, vol. 2, pp. 237-243, 2014.

[18] I. Bicu and F. Mustata, "Cellulose extraction from orange peel using sulfite digestion reagents," Bioresource technology, vol. 102, pp. 10013-10019, 2011.

[19] S. M. Rosa, N. Rehman, M. I. G. de Miranda, S. M. Nachtigall, and C. I. Bica, "Chlorine-free extraction of cellulose from rice husk and whisker isolation," Carbohydrate Polymers, vol. 87, pp. 1131-1138, 2012.

[20] M. E. Malainine, A. Dufresne, D. Dupeyre, M. Mahrouz, R. Vuong, and M. R. Vignon, "Structure and morphology of cladodes and spines of Opuntia ficus-indica. Cellulose extraction and characterisation," Carbohydrate Polymers, vol. 51, pp. 77-83, 2003.

Chapter Four: Practical Part/Results and Discussion

IV.1. Tools and Materials

Table (IV.1): Tools and materials.

Tools	Materials
• Plastic pipes • Pipe carrier • Empty butter cans • Refrigerator • 30ml glass bottles • UV Spectroscopy • Infrared spectroscopy • graphite furnace atomic absorption analytical spectroscopy (GFAAS)	• Vicia faba • Cicer arietinumL • Vigna • Pisum sativum • soil • Activated organic solutionwater • Crumb watermelon peels • Ground watermelon peels • Burnt red watermelon peels • Ground lemon peels • Ground red egg shells • Burnt red egg shells

IV.2. Obtaining the raw material

The peels were obtained from the popular market in El Oued, Algeria, as shown in **Figure (IV.1)**. The aerial parts of the studied samples (Watermelon, Eggs, Lemon) were cleaned, purified of impurities, and thoroughly washed with cold distilled water to remove dust and debris. They were then dried in a well-ventilated room away from humidity and sunlight at room temperature.

Fig (IV.1): Peels of the studied samples.

IV.2.1. Watermelon peels

After collecting dried watermelon rind samples, they were divided into three types :The first type is crumb, cut into small pieces. The second type is rind powder, ground into a powder. The third type is rind ash, burned as shown in the **Figure (IV.2)** below:

Watermelon peels Watermelon ground Watermelon ash

Fig (IV.2): different watermelon samples.

IV.2.2. Eggshells

After collecting the egg samples, they are divided into two halves. The first half is ground and the second half is burned to ash, as shown in **Figure (IV.3):**

Eggs ground Eggs ash

Fig (IV.3): different eggs samples.

IV.2.3. Lemon peels

After collecting the lemon samples, they are ground into a powder, as shown in **Figure (IV.4):**

Fig (IV.4): Lemon ground.

IV.3. Work Steps

1) Preparation Stage

The soil was obtained from the area of Al-Rimal neighbourhood and 10 grams of it is taken and kept in the freezer to determine the composition of the soil later as shown in **Figure (IV.5)**.

Fig (IV.5): Sample of Soil.

2) Fertilizer Preparation

In the stage of fertilizer preparation, we take each time 50 grams of each residue and mix it with 50 grams of soil, moistening the mixture with a little water. We take from each residue mixed with the soil sample and keep it in the refrigerator to analyze the minerals of the residue later. The rest of the quantity is fermented by leaving it for two or three days without exposing it to microbes as shown in **Figure (IV.6).**

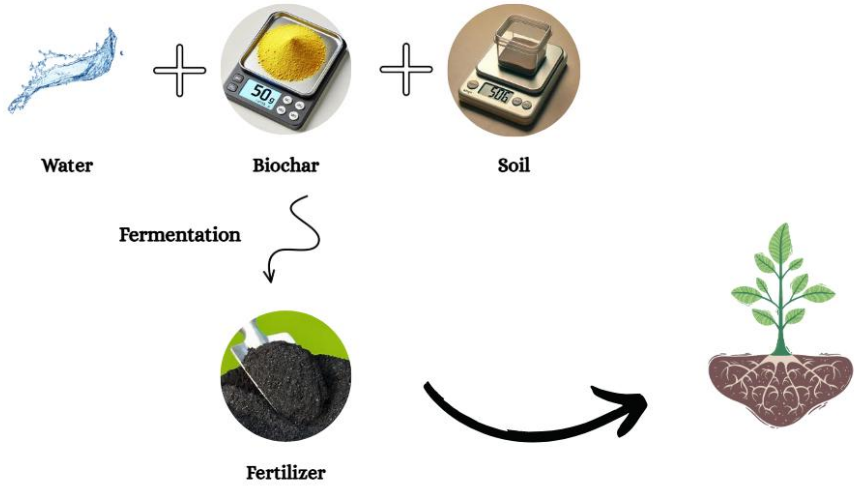


Fig (IV.6): Method of fertilizing.

3) Planting Stage

After the fermentation stage, each residue mixed with the soil (fertilizer) is divided into four to be distributed later on the four plants: Vicia Faba, Cicer arietinum, Vigna, Pisum sativum and planting is done in planting cans, where a layer of soil is first placed about three centimeters, then a layer of residues is placed and we complete the rest of the box with soil and instill grains according to their distribution on fertilizers as shown in **Figure (IV.7)**. Cultivation boxes are also placed with evidence (soil and seeds) to know the effect of fertilizer on growth later.

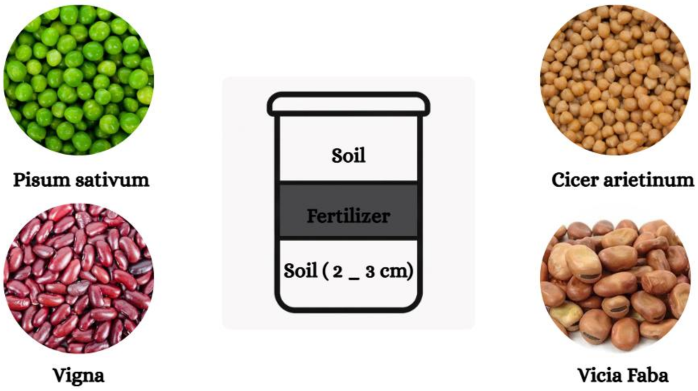


Fig (IV.7): method of planting.

4) Watering Stage

For the watering process, water is used with organic stimulating solution as follows:

A volume of 50 ml of the activated organic solution was added to a 1-liter bottle, and the rest was filled with water. The bottle is punctured at the top with a small hole, and only the upper layer is watered for each pot as shown in **Figure (IV.8)**. A quantity of the organic solution and water is kept for later analysis.

Fig (IV.8): Method of watering.

5) Sample Collection:

After planting, the plant is followed up daily for watering and recording the date of germination, as well as measuring the length of its stem and leaves. Every five days, samples must be taken from the cans containing fertilizers using an empty sucker, and the samples are kept in the freezer to analyze the minerals absorbed by the plant by comparing them with the samples taken before planting for fertilizers taking into account the coding of cans as shown in **Figure (IV.9).**

Fig (IV.9): samples collection.

Table (IV.2): Shortcut of Plants.

Shortcut	**Seeds**	**Soil**	**Cas of fertiliser**	**Fertiliser**
SF	Vicia faba	Without treatment	_	**Without**
SC	Cicer arietinum			
SV	Vigna			
SP	Pisum sativum			
WCF	Vicia faba	treatment	Crumbs	**Watermelon**
WGF			Grind	
WAF			Ash	
WCC	Cicer arietinum	treatment	Crumbs	
WGC			Grind	
WAC			Ash	
WCV	Vigna	treatment	Crumbs	
WGV			Grind	
WAV			Ash	
WCP	Pisum sativum.	treatment	Crumbs	
WGP			Grind	
WAP			Ash	

EGF	**V**icia faba	treatment	Grind	**Eggs**
EAF			Ash	
EGC	**C**icer arietinum	treatment	Grind	
EAC			Ash	
EGV	**V**igna	treatment	Grind	
EAV			Ash	
EGP	**P**isum sativum.	treatment	Grind	
EAP			Ash	
LGF	Vicia faba	treatment	Grind	**Lemon**
LGC	**C**icer arietinum	treatment	Grind	
LGV	**V**igna	treatment	Grind	
LGP	**P**isum sativum.	treatment	Grind	

IV.4. Characterization techniques

IV.4.1. UV spectrometer

- ✓ **Definition**

The UV visual absorption spectrometer plays a very important role in the study of the optical properties of materials, depending on the study of the interaction of electromagnetic waves and matter. The measurement of the visible absorption spectrum of ultraviolet light depends on the transfer of electrons from the valence band that passes from the normal to the excited state after photon absorption in visible ultraviolet light[1].

When electrons encounter a light wave at a frequency consistent with their vibrational frequencies, the energy of the light wave is absorbed and acquires vibrational motion, and the vibrating electron reacts to nearby electrons and converts vibration into thermal energy, so spectroscopy indicates absorption to measure the absorption of light by the material as a function of the wavelength; the greater the number of particles that absorb light at a given wavelength, the absorption of light increases and the peak intensity of the absorption spectrum increases[1] as shown in **Figure (IV.10)**.

This spectrophotometer works according to the Beer-Lambert principle which indicates that the absorbed part of the incident radiation is proportional to the number of absorbed particles in its path. Mathematically, this law can be interpreted as follows:

$$A = \log10\ (I0 / I) = \varepsilon\ L\ c\ \ldots\ldots..\ (1)$$

Where:

I0: the intensity of the incident light.

I: the intensity of light transmitted by the sample solution.

c: sample concentrationn.

l: the length of the sample path.

ε: Molar absorption coefficient.

The ratio (I/I 0) is known as permeability (T) and the logarithm of the inverse ratio (I 0/I) is defined as absorbance (A).

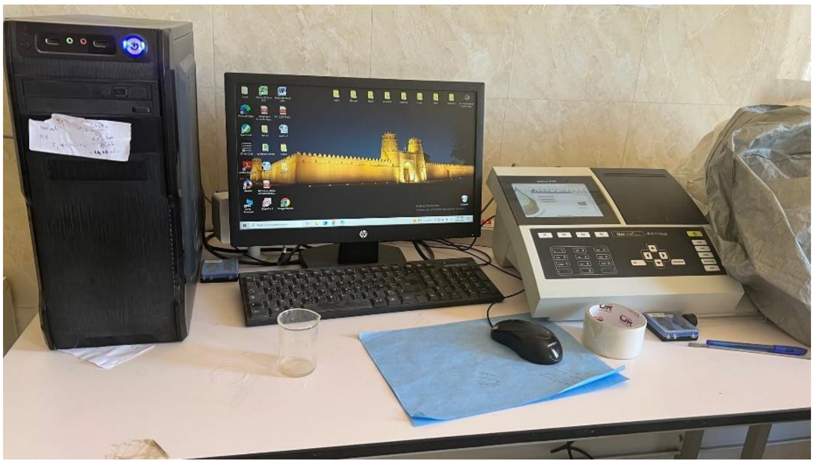


Fig (IV.10): UV Spectroscopy.

- ✓ **Method of work**

The previously preserved fertilizer samples in the cooler are mixed with an amount of distilled water to wash the fertilizer by shaking and then the mixture is filtered and the liquid is retained. Takes the liquid to the UV spectroscopy to determine the absorbency as shown in **Figure (IV.11)**.

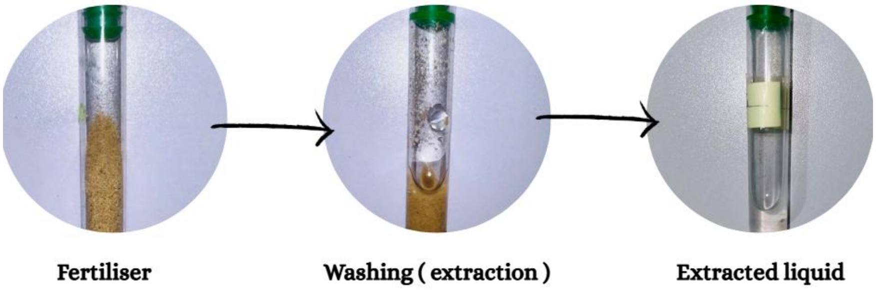


Fig (IV.11): method of preparation.

IV.4.2. Infrared spectroscopy

- ✓ **Definition**

One of the most popular spectroscopic methods employed by both organic and inorganic chemists is infrared (IR) spectroscopy. In short, it involves measuring the absorption of various infrared frequencies using a sample that is placed in the path of an infrared beam. Identifying the chemical functional groups in the sample is the primary objective of IR spectroscopic investigation. Various functional groupings absorb distinct infrared radiation wavelengths. IR spectrometers can accept a variety of sample types, including gases, liquids, and solids, by using a variety of sampling accessories. As a result, IR spectroscopy is a widely used and significant method for compound identification and structural clarification[2] as shown in **Figure(IV.12).**

Fig (IV.12): infrared spectroscopy.

- ✓ **Method of work**

Previously frozen fertilizers samples are taken in powder form to identify their structure.

IV.4.3. graphite furnace atomic absorption analytical spectroscopy (GFAAS)

- ✓ **Definition**

A popular technique for micro-, trace-, and extra-trace element analysis in many different applications is modern graphite furnace atomic absorption analytical spectroscopy (GFAAS). The flame method has advanced rapidly since 1953 because of its superior selectivity and reduced interference. Graphite curable atomizers and the Model HGA-70 Atomic Absorption Spectrophotometer with Graphite Furnace, the first commercial graphite furnace atomic absorption spectrophotometer, were among the atomization devices created to improve analytical sensitivity[3] as shown in **Figure (IV.13)**.

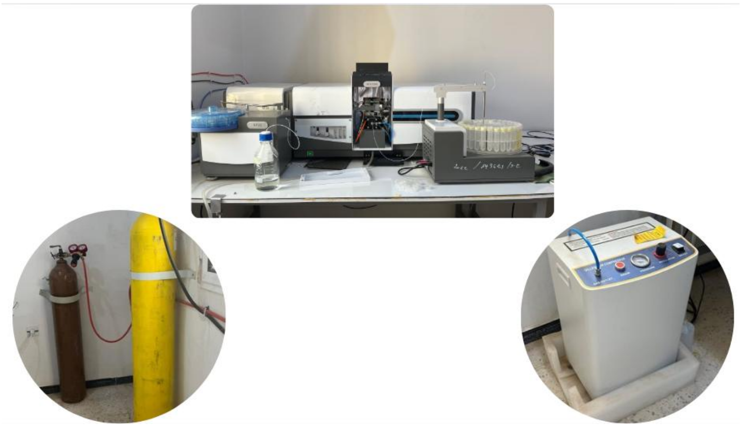


Fig (IV.13): graphite furnace atomic absorption analytical spectroscopy (GFAAS).

- ✓ **Method of work**

The samples are extracted from the freezer and prepared by thawing a little soil mixed with fertilizers in 20 ml of distilled water in order to wash them and dissolve the minerals they contain and then save them in 20 ml glass vials. Then the samples are placed in the device, which in turn reads the selected metal in each sample as shown in **Figure (I.14)**.

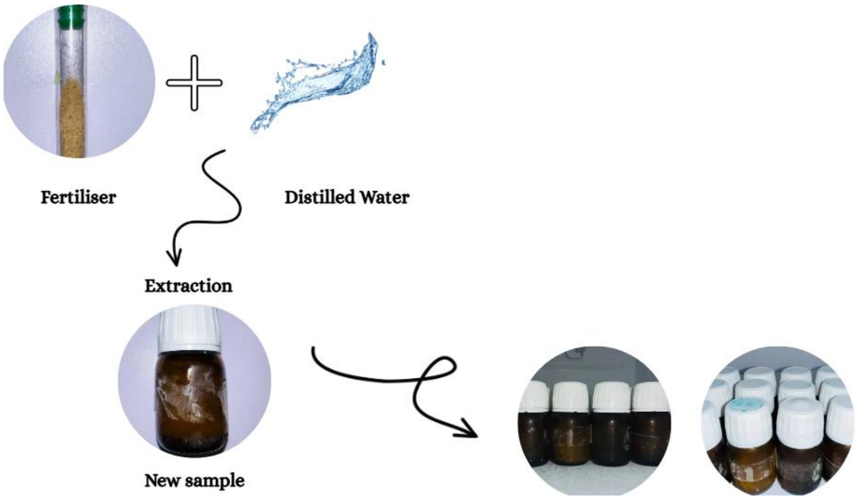


Fig (IV.14) : Method of preparation.

IV.5. Results and discussions of UV spectrometer

IV.5.1. Analyze of Watermelon peels

Figure (IV.15) is a UV-vis analysis of a burnt watermelon rind sample with a peak of 283 nm [4], And the ground watermelon peel sample with a 280 nm apex [5]. The difference in these peaks is due to the burning process, which produced new chromophore groups, giving the burned sample a higher peak. In the range 280 to 290 nm, the spectra of the two samples are similar due to the presence of thermally stable compounds that are not affected by heat treatment such as aromatic compounds [4-6].

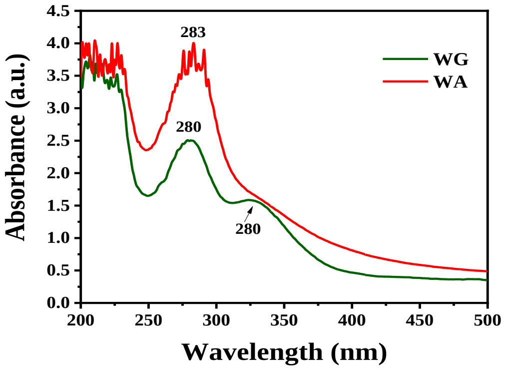


Fig (IV.15) : UV-Vis spectroscopy of ground and burnt watermelon rinds.

IV.5.2. Analyze of UV-Vis's spectra of eggshells

The UV-Vis spectrum of a ground and burned eggshell sample is depicted in the **Figure (IV.16)** Compared to the burnt sample, the ground sample absorbs more. This is due to the formation of less absorbing inorganic components during combustion[7, 8]. The similarity of the two spectra at 230 nm is explained by the presence of some partially stable inorganic compounds that are unaffected by this treatment[9].

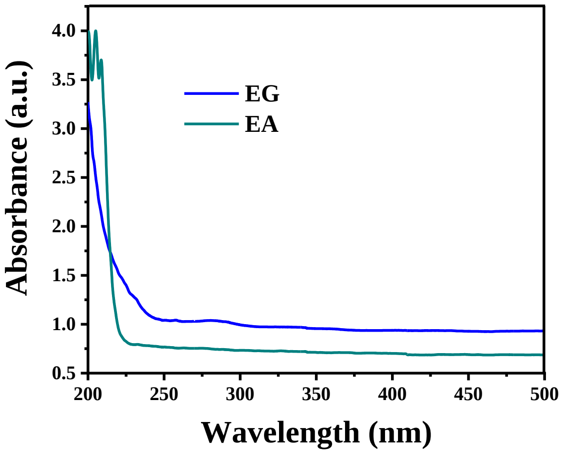


Fig (IV.16): UV-Vis spectroscopy of eggshell and ash.

IV.5.3. Analyze of lemon extract's (LG) UV-Vis's spectrum

The UV-Vis spectrum of a sample of ground lemon peel is depicted in the **Figure (IV.17)**. The absorption peak of this sample is located at 258 nm. Absorption then decreases with increasing wavelength due to the absence of pigments capable of absorbing at higher wavelengths[10, 11]. Flavonoids and phenolic acids are a major reason for the peak at 283 nm, which is in the ultraviolet range, unlike the visible range of 400-700 nm, which is poor in these wavelengths[12].

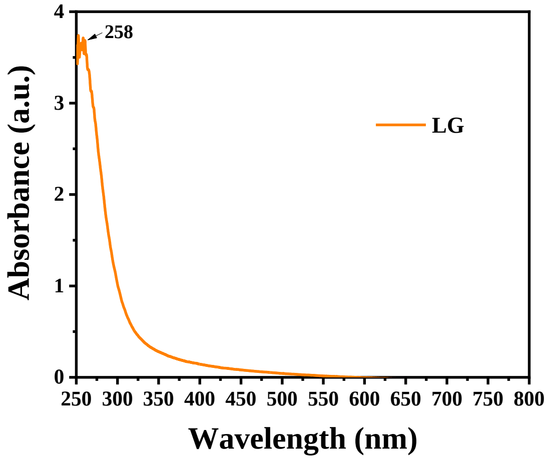


Fig (IV.17): UV-Vis spectroscopy of lemon peels.

IV.6. Results and discussions FTIR

IV.6.1. FTIR Analysis of ground and burnt watermelon rinds

Figure (IV.18) shows the effect of burning using infrared analysis of a sample of watermelon peels before and after heat treatment. The burned sample has absorption peaks at 2900 cm^{-1} and 3400 cm^{-1}, indicating the presence of C-H and O-H bonds, respectively. These peaks differ in the ground sample due to the presence of cellulose and its derivatives [13]. After burning, a decrease in absorbance was observed due to the appearance of biochar, reinforcing the importance of burning in changing the chemical structure [14].

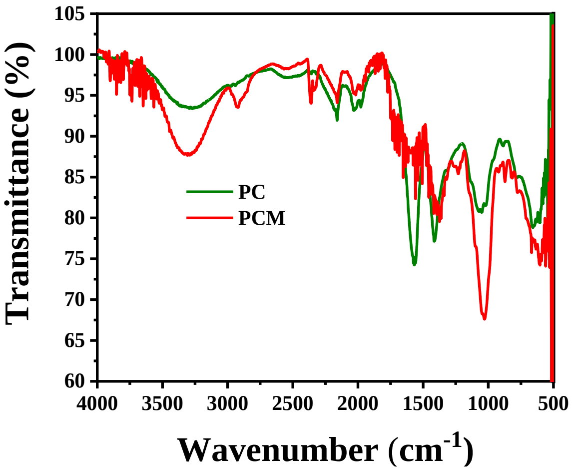


Fig (IV.18): FTIR analysis of watermelon peels ground and ash.

IV.6.2. FTIR Analysis of ground and burnt eggshell

Figure (IV.19) shows the FTIR analysis of the ground and burnt eggshell samples. The ground sample showed absorption peaks at 1400 cm^{-1} (C = O) and 870 cm^{-1} (C = O out of plane). This is due to calcium carbonate, which is its main component[15]. These peaks lose their values upon combustion due to the absence of carbon dioxide and the formation of calcium oxide. This reinforces the idea of heat treatment in producing effective alkalis in the industrial and environmental fields [16].

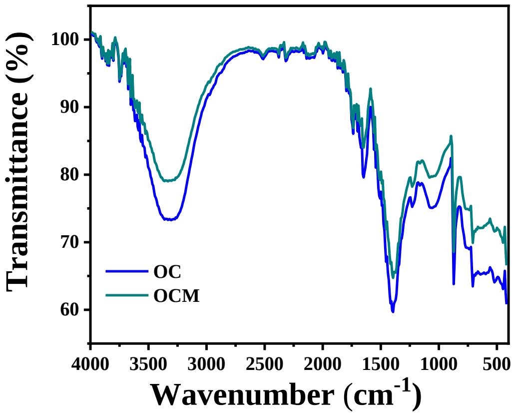


Fig (IV.19): FTIR analysis of eggshell and ash.

IV.6.3. FTIR analysis of ground lemon peels

Figure (IV.20) represents the FTIR analysis of a ground sample of lemon peels. A broad peak appears in the ranges 3400-3200 cm^{-1} due to the appearance of O-H present in alcohols and carboxylic acids [17]. A peak appears in the range 2920-2850 cm^{-1} (C-H) due to the presence of hydrocarbon compounds such as limonene [18]. A peak appears at the range 1740- 1700 cm^{-1} due to the (C=O) bond, indicating the presence of volatile compounds and aromatic oils. A peak appears at the range 1500-1600 cm^{-1} due to the (C=C) bond, which is due to the presence of phenolic compounds. At the range 1250-1000 cm^{-1}, there is the (C-O) bond, which contains alcohols and ethers[19].

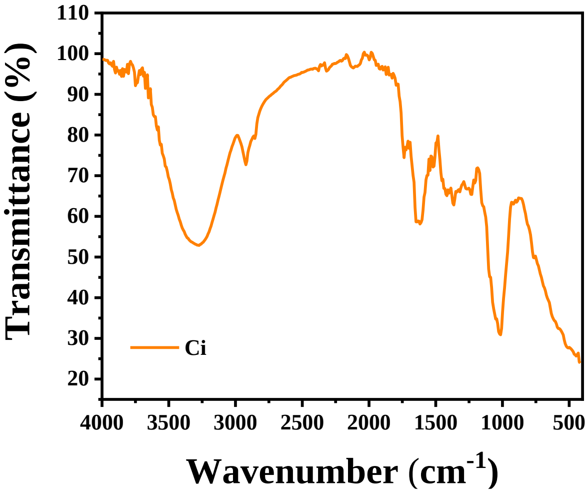


Fig (IV.20): FTIR analysis of lemon peels.

IV.7. Results and analysis of plant development and growth follow-up

The development of Pisum sativum and Cicer arietinum plants was monitored with different fertilizers and the results are recorded in the **Table (IV.3)**. Based on the data in the table, EA fertilizer was more suitable for Pisum sativum plants, as they reached a height of 10 cm, while WA was less effective with a stem length of 7 cm[20]. Regarding LG fertilizer, it was more suitable for Cicer arietinum plants, which reached a height of 10.2 cm, unlike Pisum sativum plants, which benefited more from EA [21]. The table summarizes the importance of choosing the appropriate fertilizer based on the type of plant and the chemical reactions that occur between it and the fertilizer [22].

Table (IV.3): plant development and growth follow-up.

Samples	**Pisum sativum with WA**	**Pisum sativum with EA**	**Pisum sativum with LG**	**Cicer arietinum LG**
Days				
After 6 days	0.1 cm	0.1 cm	0.1 cm	
After 8 days	0.3 cm	0.5 cm	0.5 cm	
After 10 days	1 cm	0.7 cm	0.5 cm	
After 13 days	1 cm	0.7 cm	1 cm	0.5 cm
After 19 days	1.5 cm	1 cm	1.5 cm	2.5 cm
After 20 days	1.6 cm	2.5 cm	1.7 cm	4.5 cm
After 22 days	3 cm	4 cm	3 cm	6.5 cm
After 23 days	3.2 cm	4.7 cm	3 cm	6.5 cm
After 24 days	3.6 cm	6 cm	3 cm	7.2 cm
After 28 days	4 cm	8.1 cm	3 cm	9 cm
After 29 days	5 cm	9 cm	3.2 cm	9.2 cm
After 30 days	5 cm	9.7 cm	3.5 cm	9.5 cm
After 33 days	5.5 cm	10 cm	3.8 cm	10 cm
After 35 days	7 cm	10 cm	4 cm	10 cm
After 37 days	7 cm	10 cm	4 cm	10.2 cm

IV.8. Changes in Zn and Fe concentrations in treated soil in terms of days

IV.8.1. Zn Analyze

Table (IV.4) shows the zinc concentration in the soil of Pisum sativum and Cicer arietinum plants treated with different fertilizers for 35 days. Pisum sativum soil treated with WA showed its highest concentration after five days (50.64 mg/L), then decreased to 7.73 mg/L after two weeks, before rising again to 49.04 mg/L after a month [23]. This is due to the slow decomposition of zinc in the soil. EA was more stable The slow zinc supply from the ash made EA more stable after 27 days[24]. Because zinc is regularly absorbed by the plant, LG stayed steady for 35 days before gradually dropping from 40.09 mg/L to 31.70 mg/L[25]. Regarding Cicer arietinum treated with LG, it showed strong concentrations after 5 to 17 days, then decreased from 47.93 mg/L to 30.15 mg/L due to the supplementation of this fertilizer with zinc during the early growth periods. In short, the type of fertilizer is important and affects zinc release and absorption, which enhances permanent organic fertilization.

Table(IV.4): Zinc levels in treated soil as a function of time

Samples **Days**	**Pisum sativum with WA**	**Pisum sativum with EA**	**Pisum sativum with LG**	**Cicer arietinum LG**
After 5 days	50.6437mg/L	34.4068mg/L	40.9789mg/L	7.7319mg/L
After 10 days	42.5252mg/L	38.2727mg/L	38.2727mg/L	30.9274mg/L
After 17 days	7.7319mg/L	27.8347mg/L	36.7263mg/L	47.9375mg/L
After 27 days	8.8916mg/L	55.2828mg/L	42.1386mg/L	40.9789mg/L
After 35 days	49.0973mg/L	16.2369mg/L	31.7006mg/L	30.1543mg/L

IV.8.2. Fe analyze

The **Table (IV.5)** represents the iron concentration in the soil of Pisum sativum and Cicer arietinum plants over a period of 35 days. The highest value for Pisum sativum in the soil treated with EG was 1.5589 g/L after 10 days, indicating iron availability at that point. The other values remained in a narrow range, demonstrating iron uptake[26]. In the presence of EA, the highest peak was observed after 10 days as well (1.5707 g/L) and began to decline, demonstrating the speed of the reactions[27]. Meanwhile, the iron values at LG remained constant, indicating slow iron release[28]. Cicer arietinum plants treated with LG showed the highest percentage in the table at 1.5799 g/L after 27 days, indicating its high iron uptake capacity at that stage. In conclusion, LG is considered a good and stable fertilizer over the long term, and the treated soil helps provide iron to plants well, making it an important option for increasing iron levels in the soil.

Table (IV.5) : Iron levels in treated soil as a function of time

Samples **Days**	**Pisum sativum with WA (g/L)**	**Pisum sativum with EA(g/L)**	**Pisum sativum with LG(g/L)**	**Cicer arietinum LG(g/L)**
After 5 days	1.5297	1.5306	1.5507	1.5662
After 10 days	1.5589	1.5707	1.5370	1.5644
After 17 days	1.5397	1.5625	1.5270	1.5552
After 27 days	1.5215	1.5580	1.5306	1.5799
After 35 days	1.5361	1.5397	1.5315	1.5507

Reference

[1] M. F. Vitha, Spectroscopy: Principles and instrumentation: John Wiley & Sons, 2018.

[2] C.-P. S. Hsu, "Infrared spectroscopy," Handbook of instrumental techniques for analytical chemistry, vol. 249, 1997.

[3] D. J. Butcher and J. Sneddon, A practical guide to graphite furnace atomic absorption spectrometry: John Wiley & Sons, 1998.

[4] J. Saxena, P. K. Sharma, M. M. Sharma, and A. Singh, "Process optimization for green synthesis of silver nanoparticles by Sclerotinia sclerotiorum MTCC 8785 and evaluation of its antibacterial properties," SpringerPlus, vol. 5, pp. 1-10, 2016.

[5] A. C. Akinmoladun, E. Ibukun, E. Afor, E. M. Obuotor, and E. Farombi, "Phytochemical constituent and antioxidant activity of extract from the leaves of Ocimum gratissimum," Sci Res Essay, vol. 2, pp. 163-166, 2007.

[6] V. Kumar, S. Singh, B. Srivastava, R. Bhadouria, and R. Singh, "Green synthesis of silver nanoparticles using leaf extract of Holoptelea integrifolia and preliminary investigation of its antioxidant, anti-inflammatory, antidiabetic and antibacterial activities," Journal of Environmental Chemical Engineering, vol. 7, p. 103094, 2019.

[7] T. Witoon, "Characterization of calcium oxide derived from waste eggshell and its application as CO2 sorbent," Ceramics International, vol. 37, pp. 3291-3298, 2011.

[8] E. Ostertag, M. Scholz, J. Klein, K. Rebner, and D. Oelkrug, "Pigmentation of white, brown, and green chicken eggshells analyzed by reflectance, transmittance, and fluorescence spectroscopy," ChemistryOpen, vol. 8, pp. 1084-1093, 2019.

[9] J. M. Vonnie, C. S. Li, K. H. Erna, K. W. Yin, W. X. L. Felicia, M. N. N. Aqilah, et al., "Development of eggshell-based orange peel activated carbon film for synergetic adsorption of cadmium (II) Ion," Nanomaterials, vol. 12, p. 2750, 2022.

[10] S. Choton, N. Gupta, J. D. Bandral, N. Anjum, and A. Choudary, "Extrusion technology and its application in food processing: A review," The Pharma Innovation Journal, vol. 9, pp. 162-168, 2020.

[11] S. Kumar, "Spectroscopy of organic compounds," ed, 2008.

[12] E. de Barros Santos, N. V. Madalossi, F. A. Sigoli, and I. O. Mazali, "Silver nanoparticles: green synthesis, self-assembled nanostructures and their application as SERS substrates," New Journal of Chemistry, vol. 39, pp. 2839-2846, 2015.

[13] B. H. Stuart, Infrared spectroscopy: fundamentals and applications: John Wiley & Sons, 2004.

[14] J. Lehmann and S. Joseph, Biochar for environmental management: science, technology and implementation: Taylor & Francis, 2024.

[15] M. T. Hincke, Y. Nys, J. Gautron, K. Mann, A. B. Rodriguez-Navarro, and M. D. McKee, "The eggshell: structure, composition and mineralization," Front Biosci, vol. 17, pp. 1266-1280, 2012.

[16] X. Wang, Y. Ye, X. Wu, J. R. Smyth, Y. Yang, Z. Zhang, et al., "High-temperature Raman and FTIR study of aragonite-group carbonates," Physics and Chemistry of Minerals, vol. 46, pp. 51-62, 2019.

[17] E. González-Molina, R. Domínguez-Perles, D. Moreno, and C. García-Viguera, "Natural bioactive compounds of Citrus limon for food and health," Journal of pharmaceutical and biomedical analysis, vol. 51, pp. 327-345, 2010.

[18] H. Schulz, B. Schrader, R. Quilitzsch, and B. Steuer, "Quantitative analysis of various citrus oils by ATR/FT-IR and NIR-FT Raman spectroscopy," Applied spectroscopy, vol. 56, pp. 117-124, 2002.

[19] C. Soto, E. Caballero, E. Pérez, and M. E. Zúñiga, "Effect of extraction conditions on total phenolic content and antioxidant capacity of pretreated wild Peumus boldus leaves from Chile," Food and bioproducts processing, vol. 92, pp. 328-333, 2014.

[20] H. Marschner, "Mineral nutrition of higher plants. Academic," ed: Elsevier, 2012.

[21] J. Zhao, T. Ni, J. Li, Q. Lu, Z. Fang, Q. Huang, et al., "Effects of organic–inorganic compound fertilizer with reduced chemical fertilizer application on crop yields, soil biological activity and bacterial community structure in a rice–wheat cropping system," Applied soil ecology, vol. 99, pp. 1-12, 2016.

[22] L. V. Kochian, O. A. Hoekenga, and M. A. Pineros, "How do crop plants tolerate acid soils? Mechanisms of aluminum tolerance and phosphorous efficiency," Annu. Rev. Plant Biol., vol. 55, pp. 459-493, 2004.

[23] B. J. Alloway, "Zinc in soils and crop nutrition," 2008.

[24] W. Lindsay, "Solid phase-solution equilibria in soils," Chemistry in the soil environment, vol. 40, pp. 183-202, 1981.

[25] M. R. Broadley, P. J. White, J. P. Hammond, I. Zelko, and A. Lux, "Zinc in plants," New phytologist, vol. 173, pp. 677-702, 2007.

[26] N. Fageria, V. Baligar, and R. Clark, "Micronutrients in crop production," Advances in agronomy, vol. 77, pp. 185-268, 2002.

[27] W. Chen, P. Westerhoff, J. A. Leenheer, and K. Booksh, "Fluorescence excitation−emission matrix regional integration to quantify spectra for dissolved organic matter," Environmental science & technology, vol. 37, pp. 5701-5710, 2003.

[28] Z. Rengel, "Cycling of micronutrients in terrestrial ecosystems," in Nutrient cycling in terrestrial ecosystems, ed: Springer, 2007, pp. 93-121.

General conclusion

With increasing population growth, the world today is facing a challenge with the proliferation and worsening of waste in all its forms, amidst economic challenges. To counter this worsening situation, the idea for this project emerged, highlighting the recycling of organic waste to create natural organic fertilizers and support agriculture in an economical and environmentally safe manner.

Lemon and watermelon eggshells were used to extract biochar from them. They all showed satisfactory results in treating the soil and providing the plants with the necessary nutrients such as iron (Fe) and zinc (Zn) by spraying them with a natural alkaline solution. This was confirmed by some spectral analyses such as UV-Visible, as well as FTIR.

By examining the results obtained and explained in the previous chapters, it was found that the fertilizer extracted from eggshell ash (EA) was effective with the Pisum sativum plant, while the fertilizer extracted from lemon peels (LG) was effective with the Cicer arietinum plant. This is due to the fertilizers supplying the soil and plant with nutrients continuously for a period of 35 days.

In addition, this work is a solution for developing countries to invest their agricultural waste in their quest to find sustainable solutions. It also contributes to reducing unemployment, creating new job opportunities, and strengthening the local economy.

In conclusion, it can be said that investing in agricultural waste is a promising solution for creating environmental and developmental balance. We also assume that fertilizers extracted from this waste will be a solution for promoting sustainable agriculture while preserving environmental and economic characteristics.