Serial N° Order N°

DEMOCRATIC AND POPULAR ALGERIAN REPUBLIC

وزارة التعليم العالي و البحث العلمي

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

جامعة الشهيد حمه لخضر الوادي

ECHAHID HAMMA LAKHDAR UNIVERSITY OF EL-OUED

كلية العلوم الطبيعية والحياة

FACULTY OF NATURAL SCIENCES AND LIFE

قسم البيولوجيا الخلوية والجزيئية

DEPARTMENT OF CELLULAR AND MOLECULAR BIOLOGY

Master's Thesis

To obtain a diploma an

Academic Master In

biological sciences

Specialty: Applied Biochemistry

Eco-friendly and modern methods of waste recycling for enhancing farm profitability

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بسم الله الرحمن الرحيم

الإهداء

{ وَءَاخِرُ دَعْوَىٰهُمْ أَنِ ٱلْحَمْدُ لِلَّهِ رَبِّ ٱلْعَٰلَمِينَ}

الحمدلله حبا وشكرا وإمتنانا، الذي بفضله اليوم ها أنا أنظر إلى حلم طال إنتظاره وقد أصبح واقعا أفتخر به.

أهدي هذا العمل إلى نفسي الصابرة التي واصلت هذا الطريق بكل مشقاتها وعثراتها لم يكن سهلا ولكني فعلتها ونلتها

إلى سندايَ الثابتَيْن الذين لايملون ولا يميلون قوتي بعد الله داعميَّ الاولين والابديين، إلى ملاكي الطاهر قمر حياتي السيدة التي ضحت وجابهت الصعوبات من أجل ان نصل إلى أحلامنا التي غرست فينا المبادئ والقيم النبيلة أمي العزيزة "قمرة".

إلى بطلي من دعمني بلاحدود ولا مقابل من إستغنى عن راحته في سبيل نجاحنا أبي الغالي" الجموعي" أهديكما هذا الانجاز الذي لولاكما لما كان له وجود ممتنة لأن الله قد اصطفاكما من دون البشر والدي وجعلكما خير عوض وسند .

إلى اللاتي أمنّا بقدراتي من يذكرنني بقوتي ويقفن خلفي كظلي وأمان أيامي أخواتي تجانية، عبير، شفاء وزينب .

إلى إخوتي الأعزاء الصغير وعمر وأحمد.

إلى صديقاتي عزيزات قلبي أنيسات السهر والحزن والفرح في أيامي ومشواري الدراسي والجامعي:هناء، رانيا، سارة، تهاني، أمينة غانم، شيراز وكوثر .

إلى الفتيات الحلوات صغيراتي هديل، ندى خاصة حبيبتي ملاك طيبة.

إلى خالي عبد الكريم عشاب، أعمامي خالد وسعد .

شكر خاص إلى المؤطر الفاضل زعتر عبد المالك صاحب نجاح مذكرتنا كما أشكر الاستاذ ياسين بوراس نظرا لمجهوداته المبذولة ودعمه طوال هذا المشوار.

أم هانئ

الإهداء

يقول سبحانه وتعالى بعد بسم الله الرحمن الرحيم

(وقل رب أوزعني أن أشكر نعمتك التي أنعمت على وعلى والدي وأن أعمل صالحا ترضاه . . .) صدق الله العظيم

فخرا وشرفا أعتز بهما فوق الواجب، وأنا أهدي ثمرة هذا الجهد المتواضع

إلى مهجة القلب وهبة الرب وكمال الود وصفاء الحب

إلى من سهرت لأنام وصبرت لأنال وتعبت لأرتاح

إلى الشمس التي تضيء أيامي والقمر الذي ينير ليالي أحزاني

أمي الحنون

إلى الذي ينقدح عزما ويتقد قوة، إلى الذي أنجب وربي

إلى الذي حطم صعاب الحياة التي تعيقني وسهل لي المهام بعد الله

أبي العزيز

إلى كافة الأهل والأقارب وأخص بالذكر إخوتي وأخواتي كل باسمه .

إلى الوجوه المفعمة بالبراءة ورود البيت آية وملاك وآلاء ومحمد ودعاء ومريم وعبد الله ومروة . . .

إلى من عملن معي بكد بغية إتمام هذا العمل . إلى كل من سلك طريقا ينبغي فيه علم .

إلى كل مشايخي ، معلمي وأساتذتي ومن كان لهم فضل تلقيني العلم النافع،

إلى جميع أصدقائي وزملائي .

إلى هؤلاء جميعا أهدي هذا العمل المتواضع .

AZZA Nadjoua

الإهداء

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الحمدلله عند البدء وعند الختام، فما تناهى درب،ولاختم جهد ولا تم سعي إلا بفضلة .

•لم تكن الرحلة قصيرة ولا ينبغي لها ان تكون ،لم يكن الحلم قريبا ولاطريق كان محفوظا بالتسهيلات لكني فعلتها ونلتها .

أهدي بكل حب بحث تخرجي :

الى نفسي القوية التي تحملت كل العثرات واكملت رغم الصعوبات ....

الى من الجنة تحت اقدامها وكان دعائها سر نجاحي الى التي كانت لي نورا في عتمتي "أمي".

الى من كان عونا لي عند المحن الى من دعمني بلا حدود واعطاني بلا مقابل "ابي".

الى من قال فيهم : "سنشد عضدك بأخيك "

الى إخوتي و أخواتي الذين امدوني بالقوة وكانو موضع الأتكاء في كل عثراتي ،سندي في الحياة "سليم ،رزقي،بدرالدين،العروسي،زين الدين ، فائزة و رقية "

ادامكم الله ضلعا ثابتا لي .

الى من كان حاظر من خلال الدعم والنصائح طوال سنوات الدراسة زوج اختي " العايب محمد الأمين" .

الى الأخت التي انجبتها لي الحياة "كنزة".

الى صاحب الفضل بعد الله تعالى لنجاح هذا العمل الدكتور "زعتر عبد المالك "الذي اشرف على هذه المذكرة.

الى من ساهم و ساعد ودعمنا في انجاز هذا العمل الى من شاركنا عنا البحث الأستاذ "بوراس ياسين " .

رحمة

Acknowledgment

Our deepest gratitude goes to ALLAH for His blessings and kindness, guiding us to achieve our dreams. We are profoundly thankful to ALLAH for making our journey possible.

We would like to sincerely thank our supervisor, Dr. ABDELMALEK Zaatar, for his unwavering encouragement and support since the day we chose to specialize in biochemistry. His constant confidence in us and belief in our abilities have been invaluable. We are deeply grateful for the knowledge and experience gained under his guidance while preparing this work. His great patience and continued encouragement have been instrumental throughout this study, and it has been a privilege to work under his influence.

We extend our heartfelt thanks to our thesis committee members, PhD student BOURAS Yassin and Dr. HAMMAMI Hadia, for honoring us as discussion committee members and enriching our work with their constructive questions and comments.

Finally, we would like to thank all those who contributed to the success of this work and everyone who supported us, especially our families, in making this achievement possible.

Title. Eco-friendly and modern methods of wast recycling for enhancing fam profitability

Abstract

The processing of fruits and vegetables generates significant quantities of waste, which traditionally have been disposed of through landfilling or used as low-cost animal feed. This study explores the potential of converting these waste materials into biochar to enhance agricultural productivity and family profitability. Utilizing biochar derived from banana peels (RDB), onion peels (RDO), and bean peels (RDF), we conducted a pot culture experiment to evaluate its impact on the growth of bean (Phaseolus vulgaris) and chickpea (Cicer arietinum) plants.

Methodology: The experiment involved treating soil with aqueous (AqE) and methanolic (MeE) extracts of RDB, RDO, and RDF biochar, with untreated soil serving as a control. Growth performance was measured in terms of stem and leaf length over a 35-day period.

Results: Plants treated with RDF AqE biochar exhibited the highest growth, reaching 24 cm for bean and 9 cm for chickpea, followed by RDB AqE, RDB MeE, and RDO AqE treatments. Untreated plants showed significantly lower growth. These findings are consistent with previous studies highlighting biochar's benefits in improving soil fertility, microbial activity, and plant growth.

Conclusion: The results affirm the potential of waste-derived biochar as an eco-friendly and cost-effective approach to enhance agricultural productivity, reducing waste disposal issues and increasing family profitability.

Keywords: Biochar, Waste Recycling, Agricultural Productivity, Soil Fertility, Plant Growth

العنوان: الطرق الحديثة والصديقة للبيئة في إعادة تدوير النفايات

الملخص

تولّد معالجة الفواكه والخضروات كميات كبيرة من النفايات التي كانت تُطرح تقليديًا في المكبات أو تُستخدم كعلف منخفض التكلفة للحيوانات. تستكشف هذه الدراسة إمكانات تحويل هذه المواد النفايات إلى الفحم الحيوي لتعزيز الإنتاجية الزراعية وربحية الأسرة. باستخدام الفحم الحيوي المستخرج من قشور الموز(RDB) ، قشور البصل(RDO) ، وقشور الفاصولياء(RDF) ، أجرينا تجربة زراعة في أوعية لتقييم تأثيرها على نمو نباتات الفاصولياء Phaseolus vulgarisوالحمص.(Cicer arietinum)

المنهجية :تضمنت التجربة معالجة التربة بمستخلصات مائية (AqE) وميثانولية (MeE) من الفحم الحيويRDB ، RDO، وRDF، مع استخدام التربة غير المعالجة كعنصر تحكم. تم قياس أداء النمو من حيث طول الساق والأوراق على مدى فترة 35 يومًا.

النتائج :أظهرت النباتات المعالجة بفحم RDF AqE الحيوي أعلى نمو، حيث وصلت إلى 24 سم للفاصولياء و9 سم للحمص، تلتها المعالجات بفحمRDB AqE ، RDB MeE، و .RDO AqEأظهرت النباتات غير المعالجة نموًا أقل بشكل ملحوظ. تتفق هذه النتائج مع الدراسات السابقة التي تبرز فوائد الفحم الحيوي في تحسين خصوبة التربة، النشاط الميكروبي، ونمو النباتات.

الخلاصة :تؤكد النتائج على إمكانات الفحم الحيوي المستخرج من النفايات كنهج صديق للبيئة وفعال من حيث التكلفة لتعزيز الإنتاجية الزراعية، وتقليل مشاكل التخلص من النفايات وزيادة ربحية الأسرة.

الكلمات المفتاحية:

الفحم الحيوي، إعادة تدوير النفايات، الإنتاجية الزراعية، خصوبة التربة، نمو النباتات.

LIST OF ABRIVIATIONS

- **$AlCl_3$:** Aluminum chloride
- **$FeCl_3$:** Ferric chloride
- **Na_2CO_3:** Sodium carbonate
- **DPPH:** 2,2-diphenyl-1-picrylhydrazyl
- **ROD:** Red Dried Onion peels
- **RDB:** Raw Dried Banana peels
- **RDF:** Dried Bean peels
- **AqE:** Aqueous Extract
- **MeE:** Methanolic Extract
- **MDA:** Malondialdehyde
- **GSH:** Reduced Glutathione
- **TPC:** Total Polyphenols Content
- **TFC:** Total Flavonoid Content
- **IC_{50}:** Half Maximal Inhibitory Concentration
- **EC_{50}:** Effective Concentration 50%
- **SPF:** Sun Protection Factor
- **$K_3[Fe(CN)_6]$:** Potassium Ferricyanide
- **AAs:** Ascorbic Acid
- **GC:** Gas Chromatography
- **BHT:** Butylated Hydroxytoluene
- **EEM:** Erythemal Effect Spectrum
- **CF:** Correction Factor

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SUMMARY

Introduction

INTRODUCTION

The processing of fruits and vegetables has significantly increased over the past 25 years, leading to the generation of large quantities of waste by-products. Traditionally, these by-products have been disposed of through landfilling, incineration, or sold as low-cost animal feed. However, after the Kyoto Agreement, the issue of waste disposal has become more prominent due to its contribution to global environmental sustainability problems (Sharma, Oberoi et al. 2016, Benny, Shams et al. 2023).

Vast quantities of waste are generated worldwide from food processing operations. For instance, over 5 million tons of banana peels, approximately 3.5 million tons of onion peeling waste, and 3.5 million tons of bean peeling waste are produced annually. The waste from most fruits and vegetables can constitute 30% or more of the processed material, sometimes reaching up to 75% in certain processes (Abila and Kantola 2019).

According to the Food and Agriculture Organization (FAO), approximately 1.3 billion tons of food are wasted annually worldwide, representing one-third of total food industry production. The largest amount of loss occurs in fruits and vegetables, accounting for 0.5 billion tons. In developing countries, significant losses occur at the agricultural stage and the processing step, which accounts for 25% of losses (Pandey 2021, Sethi, Cassou et al. 2021).

The growth, processing, and preparation of fruits and vegetables result in varying degrees of waste material, such as leaves, fruit peels, and processing industry waste. This waste is diverse due to the variety of fruits and vegetables used, the broad range of processes, and the multiplicity of final products. Vegetables and some fruits yield between 25% and 30% of non-edible products, highlighting the need for low-waste technology in agribusiness. Fruit and vegetable waste materials are rich in bioactive compounds, including phenolic compounds, carotenoids, and vitamins, which can be used as sources of phytochemicals and antioxidants. Studies have shown that by-products can contain similar or even higher levels of antioxidants and antimicrobial compounds than the final products (Rudra, Nishad et al. 2015, Šovljanski, Travičić et al. 2023).

The new interest in using these wastes as by-products for producing food additives or supplements with high nutritional value is economically attractive. By-products represent important sources of sugars, minerals, organic acids, dietary fiber, and phenolics with a wide range of actions, including antiviral, antibacterial, cardio-protective, and anti-mutagenic activities (Gowe 2015).

Natural products provide unparalleled chemical diversity, presenting opportunities for new research in agriculture. Fruit and vegetable peels, often discarded as agro-waste, can be utilized as antimicrobial agents, presenting a significant opportunity for agribusiness (Freitas, Barbosa et al. 2021). The use of these by-products as valuable sources of natural plant food additives is a promising alternative to alleviate environmental problems and exploit food additives or nutritional supplements with high nutritional and economic value (Gowe 2015).

Transforming this waste into high-value-added products allows companies to reduce costs and achieve additional profits, improving competitiveness. The main objective of this study is to highlight the potential of fruit and vegetable processing by-products as sources of natural food additives for the plant food industry, identifying key knowledge gaps and areas for research and innovation to reduce waste and utilize what was previously considered waste effectively.

FIRST PART

Bibliographic synthesis

CHAPTER I

Theoretical aspect of samples and previous studies

I. Dried banana peels

I.1. Generality

Bananas arise as one of the most popular fruits consumed all around the world. Banana belongs to the genus Musa from the family *Musaceae*.

It is originally from tropical regions and presents a strong ability to protect itself from the oxidative stress caused by extreme climatic conditions such as intense sunshine and high temperatures.

For this protection, bananas increase the production of bioactive compounds with antioxidant activity, which protect the fruit from the oxidative damage.

I.2. Definition

The banana is a fruit of the genus Musa (family *Musaceae*), primarily cultivated for food and secondarily for the production of fibers used in textile manufacturing. Most modern edible banana varieties come from two wild species, *Musaacuminata* and *Musabalbisiana*. The scientific names for bananas are *Musaacuminata*, *Musabalbisiana*, or hybrids of *Musaacuminata* and *Musabalbisiana*, depending on their genome composition (Debnath, Khan et al. 2019, Maseko, Regnier et al. 2024).

Bananas are herbaceous plants with a single seed that grow vigorously. They are not trees but rather tall herbs that can reach heights of up to 15 meters. Varieties vary greatly in plant and fruit size, plant shape, fruit quality, disease resistance, and pest resistance. The banana is originally believed to have originated in Southeast Asia, including regions like southern China and northeastern India (Balraj, Preethi et al. 2021).

Banana peels are rich in polyphenols, carotenoids, and other antioxidants that protect your body from cancer-causing free radicals, reduce depression, may whiten teeth, treat acne and sun damage, hair care, remove splinters, lower cholesterol. Also, banana peels are highly beneficial for our plants. The organic fertilizer derived from banana peels is an excellent, natural, and cost-effective way to provide plants with the essential nutrients they need for growth and flourishing, and it can be easily prepared at home (Bhavani, Morya et al. 2023, V, S et al. 2023).

I.3. Chemical constituents

Previous reports stated that the banana peel is rich in chemical compounds as antioxidant and antimicrobial activities. The phenolic compounds amount found in the banana peel (*Musa acuminate Colla AAA*) range from 0.9 to 3.0 g/100 g dry weight. Also,

identified gallocatechin at a 160 mg/100 g dry weight concentration (Mohd Zaini, Roslan et al. 2022).

The peel contains 6-9% dry matter of protein and 20-30% fiber. Usually, the ripe banana peels contain 30% free sugar and 15% more starch than green banana peels. Moreover, banana peel is a good source of lignin, cellulose, and hemicellulose with variety of active functional groups (carboxyl, hydroxyl, and amine) (Mondal and Roy 2018, Hikal, Said-Al Ahl et al. 2022).

Ripe banana (*Musa acuminate Colla AAA*) peel also contains other compounds: anthocyanins (delphinidin and cyanidin) and catecholamines. On the other hand, carotenoids have been identified in the banana peel, such as β-carotene, α-carotene, and various xanthophylls, in the range of 300–400 µg lutein equivalent/100 g (Hikal, Said-Al Ahl et al. 2022), as well as sterols and triterpenes, such as β-sitosterol, stigmasterol, campesterol, cycloalkanol, cycloartenol, and 24-methylenecycloartanolIt has been shown that banana peel (*Musa sapientum*) contains many nutrients and minerals (Knapp and Nicholas 2006). They found crude proteins in the amount of 1.95 ± 0.14%, crude fat 5.93 ± 0.13%, and 11.82 ± 2.17% carbohydrate in the banana peel. The mineral composition of banana peel was phosphorus, iron, calcium, magnesium, and sodium. Zinc, copper, potassium (Fig. 1), and manganese were found in very low concentrations as mg/100 g (Hikal, Said-Al Ahl et al. 2022).

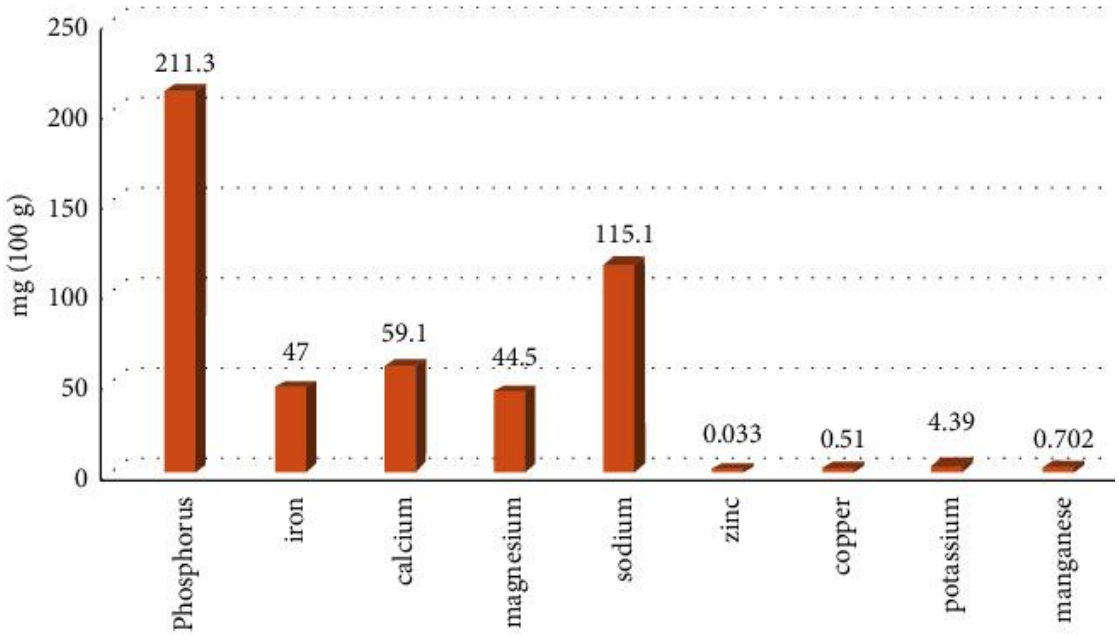


Figure 1: Mineral composition of banana peel (Anhwange, Ugye et al. 2009).

Phytochemical analysis of Musa paradisiaca and Musa acuminata peels revealed the presence of phenols, carbohydrates, terpenoids, and saponins (Kibria, Kamrunnessa et al. 2020). The presence of such potent phyto-constituents in banana makes it a great target for nutritional and therapeutic researches.

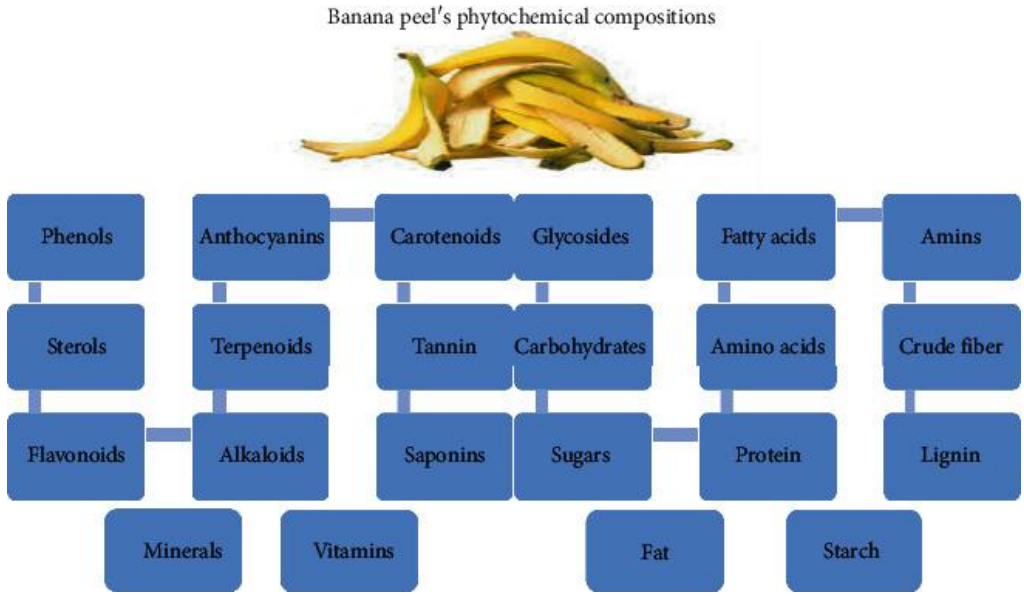


Figure 2: The chemical compositions of banana peels (Armi, Husainah et al. 2023).

II. Systematic and taxonomy

The banana plant is a gigantic herb that springs from an underground stem, or rhizome, to form a false trunk 3–6 metres (10–20 feet) high. This trunk is composed of the basal portions of leaf sheaths and is crowned with a rosette of 10 to 20 oblong to elliptic leaves that sometimes attain a length of 3–3.5 metres (10–11.5 feet) and a breadth of 65 cm (26 inches) (Britannica 2020).

A large flower spike, carrying numerous yellowish flowers protected by large purple-red bracts, emerges at the top of the false trunk and bends downward to become bunches of 50 to 150 individual fruits, or fingers. The individual fruits, or bananas, are grouped in clusters, or hands, of 10 to 20. After a plant has fruited, it is cut down to the ground, because each trunk produces only one bunch of fruit. The dead trunk is replaced by others in the form of suckers, or shoots, which arise from the rhizome at roughly six-month intervals. The life of a single rhizome thus continues for many years, and the weaker suckers that it sends up through the soil are periodically pruned, while the stronger ones are allowed to grow into fruit-producing plants (Britannica 2020).

I.4. Preparation

- **Dehydrator method (Júnior, Santiago et al. 2020):**

1. Place the banana peels in a single layer on the mesh sheets that come with the dehydrator.

2. Dehydrate at 115 degrees (F) for 4-8 hours or until dry (Fig. 3).

3. Allow them cool, they should literally snap when bent.

4. Break into pieces and place in a blender. Blend to a fine powder. When you remove the blender lid a fine dust will bellow out so be careful that you don't take a deep inhale at that exact moment.

5. Store in an airtight jar until ready to use.

- **Oven method (Brekke and Allen 1966):**

1. Preheat the oven to Its lowest temperature.

2. Place the banana peels on a cookie sheet that has been lined with foil. Make sure the outer skin is facing down they don't stick to the sheet (Fig. 4).

3. Bake until they turn black, not burnt. Once cooled they should be very stiff and snap.

Figure 3: The banana plant during flowering buds period.

Figure 4: Image of dried banana peels.

I.5. Distribution

There are over 1000 different varieties of bananas growing around the world (Fig. 5), subdivided into 50 groups. Some are sweet, like the Cavendish variety, which is the most common and most widely exported. It is named after *Musa Cavendishii* and was first grown at Chatsworth House in the UK in 1830. This variety of banana is currently under

threat from a disease called Sigatoka, which has reduced banana yields by 40% every year (Varma and Bebber 2019).

They were being grown in tropical and subtropical regions all around the world. Banana plants like warm and wet conditions, along with fertile soils. They grow best in the tropics, with an average temperature in the high- 20s Celsius, and can be found in plantations in a wide band between 30 degrees north and south of the equator (Reay and Reay 2019).

Commercial plants are usually grown to just a few metres tall and are replanted every six years or so using the bulbous shallow-rooted rhizomes (called corms) that the adult plants.

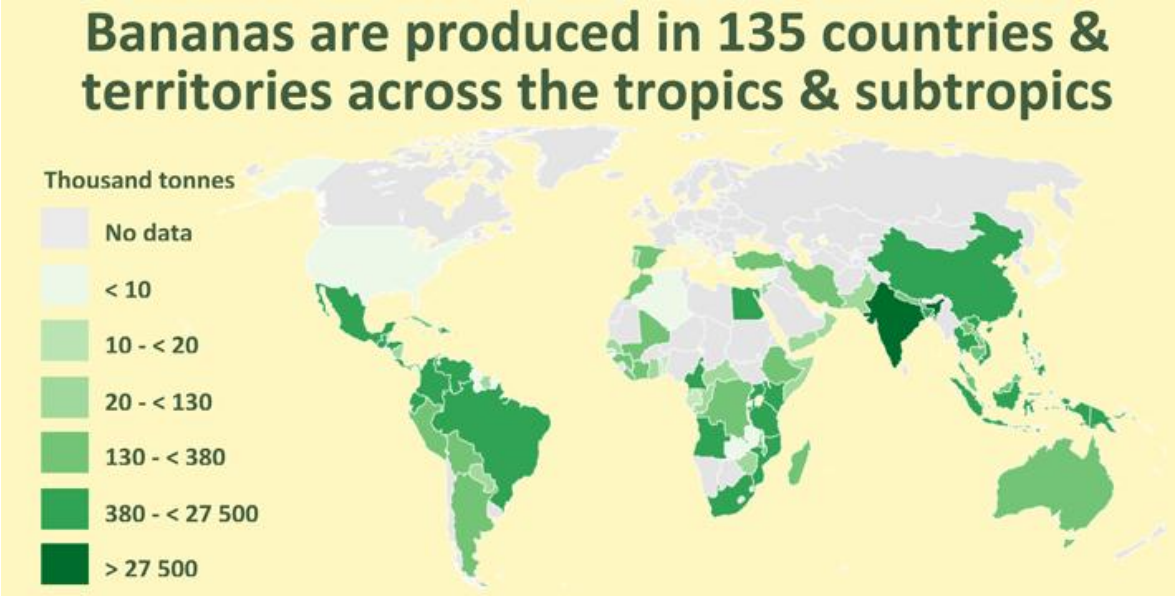


Figure 5: Distribution map of dried banana peels.

II. Dried onion peels

II.1. Generality

The global cultivation and consumption of onions (*Allium cepa*), predominantly by leading producers such as China, India, and the United States, generate significant amounts of onion peel waste. These peels, typically discarded, are rich in bioactive components like polyphenols, flavonoids, tannins, and other secondary metabolites, which offer substantial health benefits including antioxidant, anti-inflammatory, antimicrobial, and cardiovascular protective effects. Valorizing onion waste by isolating these compounds not only enhances agricultural sustainability but also boosts economic profitability. This bioactive-rich waste can be transformed into functional foods, nutraceuticals, and natural preservatives, thereby supporting the development of health supplements, food preservatives, and skincare

products. Utilizing onion peels in this manner aligns with waste minimization and resource optimization principles, offering an eco-friendly and economically viable model for the onion processing industry (Ochar and Kim 2023, Stoica, Rațu et al. 2023).

II.2. Definition

- **Definition of Terms Onion:**

An onion (*Allium cepa*) is a bulbous plant with long, rolled or straplike leaves and a spherical head of greenish-white flowers (Dictionary 2019). It is a widely cultivated vegetable known for its bulb shape, which is used extensively in culinary applications for its distinctive flavor and nutritional benefits. Onions are rich in essential nutrients, including vitamins C and B6, potassium, and dietary fiber, and they contain bioactive compounds such as flavonoids and sulfur-containing compounds that contribute to their health benefits, including anti-inflammatory, antioxidant, and cardiovascular protective properties (Griffiths, Trueman et al. 2002). The valorization of onion waste, particularly the peels, through the extraction of these bioactive components, presents an opportunity to enhance both environmental sustainability and economic profitability in the agricultural and food processing industries (Slimestad, Fossen et al. 2007, Benítez, Mollá et al. 2011).

- **Definition of Terms Dried Onion peels:**

Onion is one of the widely used vegetables in different food dishes for consumption. India is the second-largest producer of onion globally and accounts for about 22.43 million Tonnes per year (Choudhary 2018).

Onion peels are typically removed before usage, with the yield of the usable peeled onion varying from 73.5% to 81.6%, depending on the size of the onion, which ranges from 2.5 inches to 4.5 inches in diameter (Wozniak, Bieńczak et al. 2023). On average, onion peels account for about 10-25% of the total weight of the onion, producing significant quantities of vegetable waste. In India, this translates to approximately 2.3 to 4.5 million tonnes of onion peels generated annually. This substantial amount of waste not only poses environmental challenges for disposal but also diminishes the economic value of onions as an agricultural product. However, these agricultural wastes present significant opportunities for developing countries like India to create value-added and eco-friendly products, thus generating economic benefits and employment. The utilization of onion peels for beneficial purposes, such as the extraction of natural dyes, has been explored as a

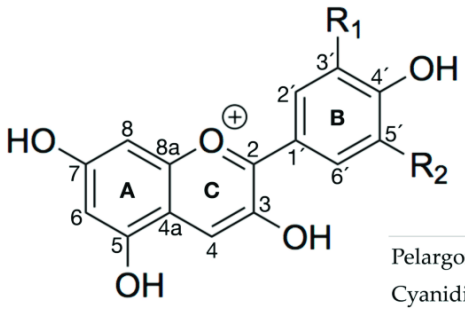
viable solution. Studies have shown that onion peels are rich in flavonoids and phenolic compounds, which can be effectively used in natural dyeing processes, offering an eco-friendly alternative to synthetic dyes and adding economic value to what would otherwise be waste (Deveoglu 2022, Shabir, Pandey et al. 2022).

II.3. Chemical constituents

Onion peel possesses a high content of carbohydrates (88.56%) and low levels of protein (0.88%), ash (0.39%), and crude fiber (0.15%). Mechanical analyses reveal that the mechanical strength of the papery scales is higher than that of the fleshy scales of the onion. The papery scales of onion contain quercetin, an anti-inflammatory compound, and are composed of three layers: the epidermis, parenchyma tissue, and lower epidermis. The lower epidermis contains galactose and calcium cross-linking pectic polysaccharides, which play a crucial role in cell-cell adhesion. Additionally, onion peel contains the dyestuff pelargonidin (3,5,7,4-tetrahydroxyantocyanidol) as depicted in (Fig.6). Pelargonidin is linked with glucosides, specifically quercetin-4'-glucoside and quercetin-3,4'-diglucoside (Tab.1), which contribute to the peel's bioactive properties. These components make onion peels a valuable resource for extracting bioactive compounds with potential applications in food, pharmaceuticals, and cosmetics (Zubairu and Madu Mshelia 2015, Zhao, Lin et al. 2021). Research has demonstrated the potential of utilizing onion peels for developing natural dyes, owing to their rich content of flavonoids and anthocyanins, offering an eco-friendly alternative to synthetic dyes (Samota, Sharma et al. 2022).

Table 1: Components of Anthocyanidins.

Anthocyanidins	**R'3**	**R'5**
Pelargonidin (Pg)	H	H
Cyanidin (Cy)	OH	H
Peonidin (Pn)	OCH_3	H
Delphinidin (Dp)	OH	OH
Petunidin (Pt)	OCH_3	OH
Malvidin(Mv)	OCH_3	OCH_3



	R_1	R_2
Pelargonidin	H	H
Cyanidin	OH	H
Peonidin	OCH_3	H
Delphinidin	OH	OH
Malvidin	OCH_3	OCH_3
Petunidin	OH	OCH_3

Figure 6: Structure of Pelargonidin

II.4. Systematic and taxonomy

Creating a systematic taxonomy for dried onion peels involves categorizing them based on botanical classification, chemical composition, culinary uses, and potential applications. Dried onion peels are derived from the common onion (Fig.7,8), *Allium cepa*, which belongs to the kingdom Plantae, division Angiosperms, class Monocotyledons, order Asparagales, family Amaryllidaceae, and genus Allium. These peels contain various bioactive compounds, including flavonoids, phenolic acids, and sulfur-containing compounds such as allyl sulfides, which contribute to their distinct aroma, flavor, and potential health benefits. In culinary contexts, dried onion peels are used as a flavoring agent in soups, stews, sauces, and marinades, imparting a savory and slightly sweet taste (Fritsch and Friesen 2002).

Additionally, their rich content of bioactive compounds and pigments suggests potential applications in herbal medicine and natural dyeing. Research has shown that onion peels can be an excellent source of natural antioxidants and antimicrobial agents, making them valuable for developing eco-friendly products and enhancing the profitability of agricultural waste (Kumar, Barbhai et al. 2022, Samota, Sharma et al. 2022).

Figure 7: The onion plant during flowering bud's period (Alan, Brants et al. 2004).

Figure 8: Image of dried onion peels (Alan, Brants et al. 2004).

II.5. Distribution

Onions (*Allium cepa*) are cultivated extensively around the world, with over 9,000,000 acres (3,642,000 hectares) dedicated to their growth annually. Approximately 170 countries cultivate onions primarily for domestic use, while about eight percent of the global production is traded internationally. This widespread cultivation underscores the significant role onions play in global agriculture and trade (Fig. 9). The international trade of onions contributes to the global economy, with major exporters including the Netherlands, India, and China, which supply onions to various regions, enhancing food security and nutritional diversity (Niftiyev 2023, Ochar and Kim 2023).

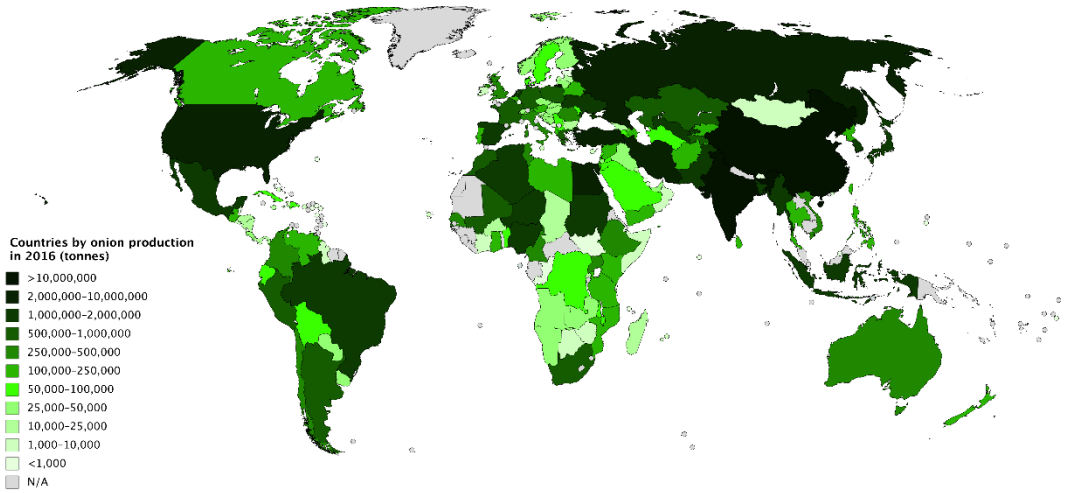


Figure 9: Countries by onion production in 2016 (Tripathi, Sankar et al. 2017).

II.6. Efficacies of dried Onion peel extracts

To maximize the efficacies of dried onion peel extracts, proper harvesting and handling of onion bulbs are crucial. Onions should only be topped when the neck is dry and no green tissue remains. This can be determined by rolling the neck of the onion bulb between your fingers—if the tissue doesn't slide, it's ready for topping. It is important to stop irrigation one to two weeks before harvest to prevent the bulbs from becoming water-logged. Harvesting should be done during the cooler parts of the day, either early morning or late evening, and not on wet days to prevent brown stains and black mold. Use a fork to gently loosen the bulbs before pulling them by hand to avoid damaging them. If the plant comes out of the ground easily, it indicates it is ready for harvest. If not, it suggests the root is still very active and bulbing is not complete. Proper handling during harvesting ensures that the onion peels retain their high content of bioactive compounds, such as flavonoids and phenolic acids, which contribute to their potential health benefits and applications in natural dyeing and antimicrobial products (Sharma, Mahato et al. 2016, Ren and Zhou 2021).

III. Dried bean peels

III.1. Generality

Beans are among the oldest crops cultivated in human history, serving as a significant food source for many cultures worldwide. They are highly valued for their rich nutritional content, which includes high levels of protein, fiber, vitamins, and minerals. The types of beans vary widely, including kidney beans, green beans, white beans, and others, each cultivated and utilized according to cultural preferences and geographical regions. This diversity in bean varieties not only provides essential nutrients but also contributes to dietary diversity and food security globally. The cultivation of beans has been integral to various agricultural systems, highlighting their importance in both historical and contemporary diets (Bitocchi, Rau et al. 2017).

III.2. Definition of bean

The legume family is considered one of the largest crops spread across various parts of the world, including the broad bean, which dates back to 6000 BC and was a popular food among ancient Romans and Greeks. Broad beans are among the legumes rich in fiber and vitamin A, and they are an excellent source of protein in the diet. In addition to protein, they provide a range of secondary compounds such as saponins, flavonoids, and phenolic

compounds. These latter compounds act as antioxidants and anti-inflammatory agents in our bodies' metabolism (Stoddard 2017).

III.3. Chemical constituents

Beans are rich in both insoluble and soluble fiber, high in protein content, cholesterol-free, and low in fat. They are abundant in vitamins A, C, and K, folate, thiamine, and essential minerals. Additionally, beans contain antioxidants and various bioactive compounds such as carotenoids, phenols, and flavonoids (Oso and Ashafa 2021). These nutrients contribute to reducing the risks of many chronic diseases. Green beans, in particular, offer significant amounts of plant proteins, fibers, thiamine, folic acid, and phytochemical compounds with analgesic and neuroprotective properties (Dias 2012).

Beans also contain substantial quantities of polyphenols with antioxidant properties, which help prevent degenerative diseases such as cancer and metabolic syndromes. Furthermore, green beans are rich in vitamins and carotenoids, including vitamin C (Tab.2)

, β-carotene, lutein, zeaxanthin, α-tocopherol, and phylloquinone. Seventy-two phenolic compounds have been identified in beans, including 10 phenolic acids and 59 flavonoids, with notable compounds such as quercetin, kaempferol, catechin, epicatechin, chlorogenic acids, and procyanidins (Jaganath and Crozier 2010).

Table 2: Nutritive value of raw green beans (Phaseolus vulgaris) per 100 g.

Principle	Nutrient Value	Percentage of RDA (%)
Energy	31 kcal	1.5
Carbohydrates	7.13 g	5.5
Protein	1.82 g	3
Total Fat	0.34 g	1
Cholesterol	0 mg	0
Dietary Fiber	3.4 g	9
Vitamins		
Folates	37 µg	9
Niacin	0.752 mg	5
Pantothenic Acid	0.094 mg	2
Pyridoxine	0.074 mg	5.5
Riboflavin	0.105 mg	8
Thiamin	0.084 mg	7
Vitamin A	690 IU	23
Vitamin C	16.3 mg	27
Vitamin K	14.4 µg	12
Electrolytes		
Sodium	6 mg	0.4
Potassium	209 mg	5.5
Minerals		
Calcium	37 mg	3.7
Iron	1.04 mg	13
Magnesium	25 mg	6
Manganese	0.214 mg	9
Phosphorus	38 mg	6
Zinc	0.24 mg	2
Phytonutrients		
Carotene-β	379 µg	-
Carotene-α	69 µg	-
Lutein-zeaxanthin	**III**	-

III.4. Systematic and taxonomy of beans

Beans (*Phaseolus spp.*) (Tab.3) are herbaceous plants characterized by a surrounding stem. The roots and nodules penetrate the soil to a depth of 1 to 1.5 meters, with lateral roots branching off from the upper part and hosting nitrogen-fixing bacterial nodules. The stem is upright and ribbed, with heights ranging from 20 to 180 centimeters. It branches directly from beneath the ground surface into 2-6 branches (Fig.10). The compound leaves consist of 2-6 pairs of elongated oval leaflets with entire margins. The flowers bloom from the leaf axils in racemes containing 2-6 grayish-white flowers. The flowers are hermaphroditic, predominantly self-pollinating with a slight chance of cross-pollination.

The fruit is a pod ranging from 4 to 30 centimeters in length, typically containing 4-5 seeds. The shape, size, and color of beans vary according to the variety, contributing to the diversity seen in different species and cultivars (Holm, Doll et al. 1997, Bitocchi, Rau et al. 2017).

Beans play a significant role in both agricultural and ecological systems due to their nitrogen-fixing ability (Fig.11), enhancing soil fertility and supporting sustainable farming practices. The diversity in bean varieties allows for adaptation to various climates and growing conditions, making them a vital crop in many regions worldwide (Uebersax, Cichy et al. 2022).

Figure 10: The beans plant during the flowering buds period.

Figure 11: Image of dried bean peels.

III.5. Scientific classification

Table 3. Scientific and phylogenetic classification of *Vicia faba L.*

Category	Classification
Scientific Classification	
Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Fabales
Family	Fabaceae
Genus	Vicia
Binomial Name	*Vicia faba L.*
Phylogenetic Classification	
Order	Fabales
Family	Fabaceae

III.6. Distribution of beans

In the global context, the Asia-Pacific region is a major producer of fava beans, accounting for 35.3% of global fava bean production in 2021, amounting to 2.7 million metric tons. This marked an increase from 2.5 million metric tons in 2019, driven by rising consumption demand and increased export potential due to their high nutritional value. China is the leading producer in the region, with production reaching 1.9 million metric tons in 2021, representing 69.1% of the region's output. Fava beans are integral to Sichuan cuisine, used both as vegetables and spices, and the increasing consumption of roasted seeds as a low-fat snack in India and neighboring countries has further driven demand in the region (Singh, Bharati et al. 2013, Artanti, Chayana et al. 2023).

Despite a decline in the profitability of food legume crops leading to reduced area and production within China, the rising demand for plant-based food legumes has led to attractive market prices and significant increases in domestic production. Fava beans, with their short growth periods and ability to fix atmospheric nitrogen, play a crucial role in agricultural systems in the region by enhancing soil fertility and increasing crop productivity and economic benefits. By 2023 (Fig.12), global fava bean production continued to grow, fueled by their nutritional benefits, the shift towards plant-based diets, and their role in sustainable agriculture. Their integration into various culinary traditions worldwide, coupled with advancements in agricultural practices, has cemented fava beans as a vital crop in the global food system (Artanti, Chayana et al. 2023).

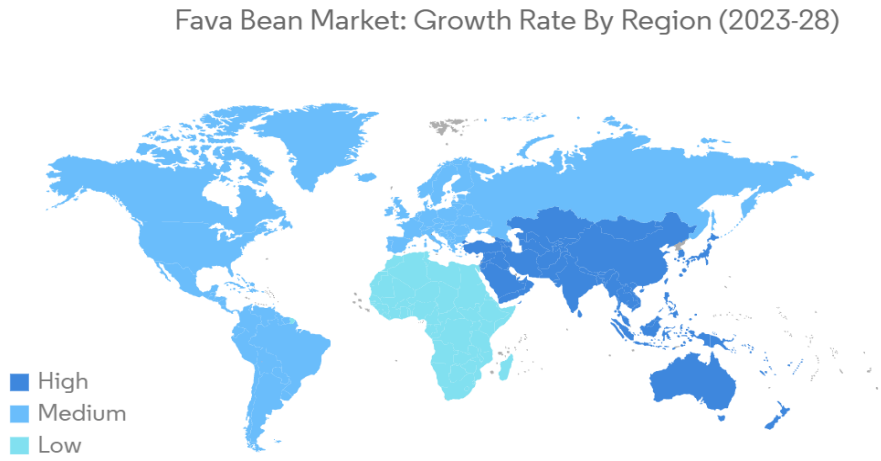


Figure 12: Distribution map of bean and shallot output in 2023 (Artanti, Chayana et al. 2023).

CHAPTER II

Biological and therapeutic properties of samples

I. Dried banana peels

Banana peels (*Musa paradisiaca L.*) have various pharmacological effects, prominently their antioxidant activity, which is highly relevant to health care (Pereira and Maraschin 2015).

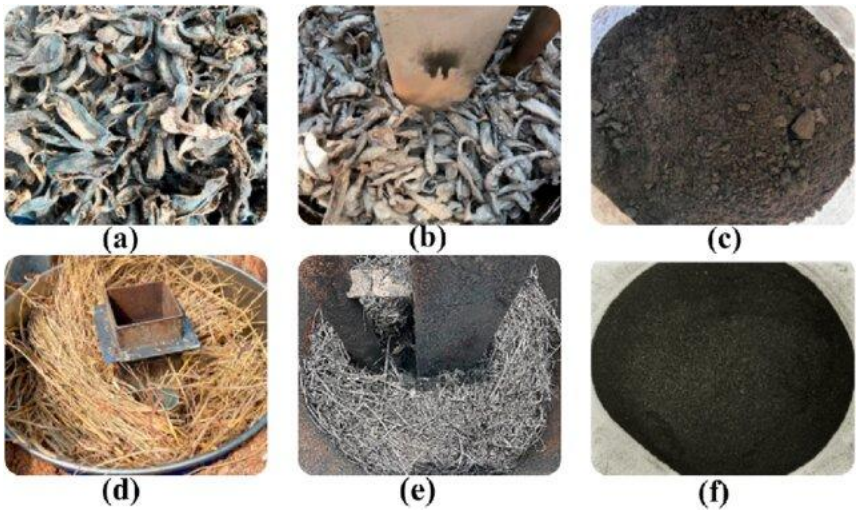


Figure. 13. Agricultural residue. (a) dried banana peel; (d) dried rice straw; (b) and (e) banana peel and rice straw, respectively, after carbonization; (c) fine charcoal from banana peel; (f) fine charcoal from rice straw (Duangkham and Thuadaij 2023).

I.1.Antioxidant Activity

Reactive oxygen species (ROS) are oxygen radicals with unpaired electrons involved in physiological and pathological conditions. Antioxidants prevent free radical damage by scavenging these radicals. Banana peels contain compounds that exhibit significant antioxidant activity (Fatemeh, Saifullah et al. 2012). The antioxidant properties of banana peel extracts were explored using a group of rats, where one group was fed a normal diet and another a fatty acid-rich diet. Oxidation markers like malondialdehyde (MDA) were measured. Subjects treated with banana peel extract showed a significant decrease in the concentrations of peroxidation products (MDA), peroxides, and conjugated dienes. Additionally, antioxidant enzymes such as catalase and superoxide dismutase activities were significantly elevated in the treated subjects. The level of an important antioxidant, reduced glutathione (GSH), also increased significantly (Sindhu, Koo et al. 2004).

I.2.Antidiabetic effect

Diabetes, which can be insulin dependent or non-insulin dependent, poses a great threat to humanity. High level of glucose is prominent in diabetic patients and attempts have been made to counteract that using several plants including banana. Investigation into the anti-hyperglycemic effect of ethanol extract of *Musa sapientum* (*EMS*), *M. paradisiaca (EMP),*

Musa cavendish (EMC), and *M. acuminata (*EMA) peels by oral glucose tolerance test in glucose-loaded (2 g/kg p.o) normoglycemic (having normal concentration of glucose) rats was done by [24]. It was observed from this study that animals treated with EMC (500 and 1000 mg/kg, p.o) and EMA (200 and 400 mg/kg p.o) showed marked anti-hyperglycemic effect ($p < 0.01$). Also, both EMS (200 mg/kg, p.o) and EMP (500 mg/kg, p.o) depicted significant ($p < 0.01$) decrease in blood glucose level (Jideani and Anyasi 2020).

Another study aimed at evaluating the *in vitro* antidiabetic activity of methanol extracts of three kinds of fruit peels (lemon, pomegranate, and banana) showed that banana peel exhibited maximum alpha amylase inhibitory activity (80.87% at 1000 µg/mL). Hence, banana peel is more potent among the three, having the highest hypoglycemic effect. Thus, it can be utilized as antidiabetic supplement as compared to the others (Modak, Dixit et al. 2007).

I.3.Antibacterial Activity

The antimicrobial properties of banana peels have shown significant effectiveness against various bacterial strains. Ethanol and acetone extracts of banana peels exhibit potent antibacterial activity, with 80% acetone extract demonstrating inhibition against Gram-positive bacteria such as *Bacillus subtilis* (20.60%) and *Staphylococcus aureus* (19.75 mM), as well as Gram-negative bacteria including *Escherichia coli* (18.15 mM) and *Pseudomonas aeruginosa* (19.57 mM). The presence of phytochemicals, such as phenolic compounds and tannins, contributes to this antibacterial property. Fresh green and yellow banana peels treated with 70% acetone and fractionated with chloroform and ethyl acetate also showed high antimicrobial activity, particularly in the ethyl acetate and water-soluble fractions of the green peel. Previous studies have confirmed that banana peel extracts effectively inhibit a range of bacterial strains, highlighting their potential as natural antimicrobial agents. For instance, research has demonstrated that banana peel extracts can inhibit the growth of pathogenic bacteria like *Salmonella typhi* and *Shigella dysenteriae*, further supporting their use in combating bacterial infections (Kapadia, Pudakalkatti et al. 2015, Hikal, Said-Al Ahl et al. 2022).

I.4.Antifungal Property

In addition to their antibacterial properties, banana peels exhibit notable antifungal activity. Dried extracts of *Musa paradisiaca* peel, including powder and ash, have shown a

strong antifungal effect against *Aspergillus niger*. This antifungal property is attributed to the presence of various bioactive compounds within the peel extracts, which effectively inhibit fungal growth. Studies have shown that banana peel extracts can disrupt the cell membrane integrity of fungi, leading to cell death. Furthermore, previous research has indicated that these extracts can inhibit other fungal species, such as *Candida albicans* and *Penicillium expansum*, demonstrating a broad spectrum of antifungal activity. The antifungal efficacy of banana peels highlights their potential as a natural and sustainable option for managing fungal infections, contributing to their role in integrated pest management and food preservation (Behiry, Okla et al. 2019).

I.5.Wound healing attribute

Banana peel was reported to have wound healing activity through its predominant effects on mucosal defensive factor that enhances DNA synthesis and promotes mucosal cell proliferation.

The wound healing activity of both methanol and aqueous extracts of plantain banana (*M. sapientum* var. *paradisiaca*) was assayed in rats. Both extracts were found to increase hydroxyproline, hexuronic acid, hexosamine, superoxide dismutase levels as well the wound tensile strength. The extracts also decreased the wound and scar areas, and lipid peroxidation.

These effects were attributed to the antioxidant property of the plantain (Agarwal, Singh et al. 2009).

I.6.Effect on atherosclerosis

Atherosclerosis is a disease characterized by accumulation of plaque inside the arteries. In a study, Ambon *(Musa paradisiaca)* peel was used to ascertain its effectiveness as anti-atherosclerotic agent by the inhibition of NF-κB (nuclear factor kappa beta) and increasing e-NOS (endothelial nitric oxide synthase) expression in atherogenic rats using immunohistochemical method.

It was observed that the extract significantly decreases NF-κβ activity and increased e-NOS activity in a dose-dependent manner. Linear regression showed that the extract can lower NF-κβ activity by 82.1% and increase e-NOS expression by about 95.2%.

Therefore, the extract of Ambon banana peel was proven to be effective in preventing atherosclerosis. This finding revealed the effectiveness of the peel extract in inhibiting the

atherosclerotic process via suppressing the expression of chemo-attractant molecules and monocyte adhesion and thus the peel extract may be considered a novel therapeutic agent in preventing atherosclerosis (Jideani and Anyasi 2020).

A related study was conducted by (Berawi and Bimandama 2018), in which the effect of saponin, tannin, and flavonoid present in Kepok banana peel against total cholesterol level in obese male mice was measured. The researchers divided 20 obese male mice (*Mus musculus L.)* into four groups and treated them for 14 days. Total cholesterol level of each group was measured using spectrophotometer. It was observed that the Kepok banana peel lowered the total cholesterol level in the tested animals, with more effect in a group administered 8.4 mg/day of the peel extract than in the group administered 16.8 mg/day. It was thus concluded that banana peel extract is effective in lowering the total cholesterol level of obese mice reflecting its anti-atherosclerotic effect (Fig. 14). The researchers obtained 8.4 and 16.8 mg/day based on the conversion of the effective doses of banana peel extract for rats. By this, 200 mg/kg body weight of banana peel extract can reduce total cholesterol level of rats.

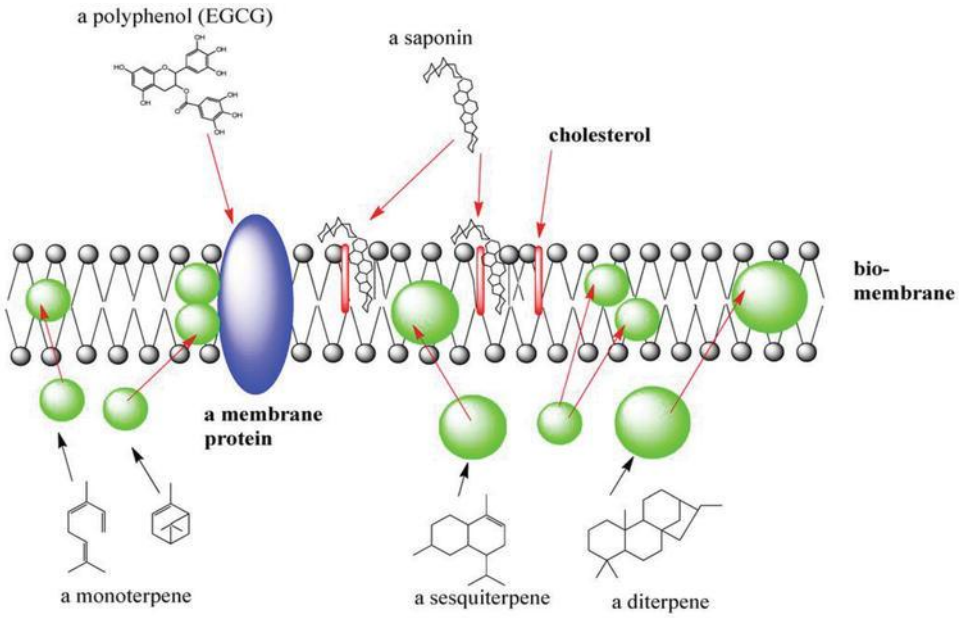


Figure 14: The cholesterol-lowering activity of banana may be because of the phyto-constituents on cellular membranes. For example, saponins can form complex with membrane cholesterol; polyphenols influence 3D structure of membrane proteins like receptors, transporters, and ion channels); small lipophilic terpenoids assemble in the inner lipophilic core of the biological membrane (Berawi and Bimandama 2018).

II. Dried onion peels

Changing dietary habits worldwide with increased consumption of processed foods, lack of exercise, sedentary lifestyle and exposure to polluted environments has resulted in rising incidences of disorders such as obesity, cardiovascular disorders, diabetes, neurodegenerative dis- orders and cancers, with oxidative stress being among the prime agents causing these diseases.

Research has established that plant-based bioactive compounds/phytonutrients can play protective roles in preventing the damage caused by excessive free radical formation and oxidative stress. Extensive research on onion peel/ waste and their extracts shows that they are a rich source of phytoconstituents with various therapeutic potentials and pharmaco logical activities. In this section, various studies highlighting the prop erties of onion peel extracts, such as anticancer, antimicrobial, antiobesity, neuroprotective, cardioprotective, antidiabetic, and erectile dysfunction properties, are discussed in in detail. Understanding these biological activities can pave the way for further research and potential utilization of onion waste in biomedical fields and pharma industries (Clemente-Suárez, Beltrán-Velasco et al. 2023).

II.1. Antibacterial Effectiveness

Dried onion peels (*Allium cepa*) exhibit significant antibacterial properties due to their rich content of bioactive compounds such as flavonoids, phenolic acids, and sulfur-containing compounds. Studies have demonstrated that extracts from onion peels possess potent antibacterial activity against a variety of pathogenic bacteria, including *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. These effects are largely attributed to the presence of quercetin, a flavonoid known for its strong antibacterial properties. Quercetin disrupts bacterial cell walls and inhibits nucleic acid synthesis, leading to bacterial cell death. Additionally, the sulfur compounds in onion peels, such as allicin, contribute to their antibacterial activity by interfering with the bacterial cell metabolism and enzyme function. The use of onion peel extracts as natural antibacterial agents presents an eco-friendly alternative to synthetic antibiotics, which can contribute to the growing issue of antibiotic resistance (Zhao, Lin et al. 2021).

II.2. Antifungal Effectiveness

Dried onion peels also show promising antifungal properties, making them effective against a range of fungal pathogens. Research indicates that the phenolic compounds and

flavonoids present in onion peels, such as quercetin and kaempferol, exhibit strong antifungal activities. These compounds can inhibit the growth of common fungi such as *Candida albicans* and *Aspergillus niger* by disrupting the fungal cell membrane integrity and inhibiting ergosterol synthesis, which is essential for fungal cell membrane structure.

Moreover, sulfur-containing compounds like thiosulfinates contribute to the antifungal activity by generating reactive oxygen species (ROS) that cause oxidative stress in fungal cells, leading to cell death. The application of onion peel extracts in antifungal treatments offers a sustainable and natural alternative to chemical fungicides, reducing environmental impact and promoting the use of agricultural waste in biocontrol strategies (Joković, Matejić et al. 2024).

III. Dried beans peels

III.1. Antioxidant potential

Free radicals are oxidants which are continuously generated in our body as a by-product of normal metabolism. Under normal physiological conditions, the endogenous defense system, comprising antioxidant enzymes and antioxidant molecules, neutralizes these free radicals and protects us from their deleterious effects. However, under condition of excessive free radical generation, such as stress, exposure to pollution, cigarette smoking, alcohol consumption, radiation, or medication, the endogenous antioxidant system becomes insufficient.

The disturbance in balance between free radical generation and endogenous antioxidants causes oxidative stress, which has been known to be a major contributory factor in the etiology of various chronic and degenerative dis- eases, for example, diabetes, cancer, cardiovascular diseases, autoimmune disorders, neurodegenerative diseases, aging, etc. (Bandyopadhyay et al., 1999).

When endogenous antioxidants become insufficient, exogenous antioxidants help to prevent the oxidative stress. A wide range of exogenous antioxidants are present in fruits and vegetables. Therefore, the consumption of dietary antioxidants from fruits and vegetables is beneficial for the prevention of free radical-borne diseases (Cuzzocrea et al., 2001; Fang et al., 2002; Sumazian et al., 2010; Faujan et al., 2009).

Recent studies have highlighted that green bean possess impressive antioxidant capacity. Chaurasia and Saxena (2014) have studied four common varieties of fresh produce of green beans, viz., French beans *(P. vul- garis*), broad beans (*Vicia faba*),

cowpea beans (*Vigna unguiculata*), and cluster beans (*Cyamopsis tetragonoloba*), for their antioxidant properties. As shown, all four varieties of beans are rich in phenols and flavonoids content.

III.2. Antibacterial Activity

Dried bean peels have been found to exhibit substantial antibacterial properties against a wide array of bacterial pathogens. Extracts from bean peels are rich in bioactive compounds such as alkaloids, saponins, and glycosides, which contribute to their antimicrobial efficacy. Research has indicated that these extracts can inhibit the growth of Gram-positive bacteria, including *Streptococcus pneumoniae* and *Clostridium perfringens*, as well as Gram-negative bacteria like *Klebsiella pneumoniae* and *Proteus mirabilis*. The antibacterial mechanism involves disrupting the bacterial cell membrane integrity, leading to leakage of cellular contents and eventual cell death. Additionally, studies have shown that the aqueous extracts of bean peels can effectively combat methicillin-resistant *Staphylococcus aureus* (MRSA), highlighting their potential role in addressing antibiotic-resistant bacterial infections (Joković, Matejić et al. 2024).

III.3. Antifungal Property

The antifungal properties of dried bean peels are equally noteworthy, with studies highlighting their effectiveness against a diverse range of fungal pathogens. Bean peel extracts contain significant amounts of anthocyanins and terpenoids, which are known to exhibit strong antifungal activity. These extracts have been found to inhibit the growth of fungi such as *Trichophyton rubrum*, which causes skin infections, and *Fusarium oxysporum*, a plant pathogen responsible for wilting diseases. The antifungal action is thought to involve disrupting the fungal cell membrane and interfering with ergosterol synthesis, which is crucial for fungal cell membrane integrity. Moreover, recent studies suggest that bean peel extracts can inhibit the mycotoxin production of *Aspergillus flavus*, which is important for food safety. These findings demonstrate the potential of bean peels as a natural antifungal agent that can be used in medical, agricultural, and food industry applications to prevent and control fungal infections (Aboody and Mickymaray 2020).

III.4. Diabetes

Green beans are high in fiber which helps to control diabetes by reducing insulin and the pace of sugar entering the blood stream. Research has shown that high-fiber diets

control blood sugar levels, decrease excess insulin levels, and lower lipid concentrations in patients with type 2 diabetes. Green beans also reduce the need for insulin by considerably 40%. Patients suffering from noninsulin-dependent diabetes can eliminate the need of insulin by eating beans in their regular diet. Research at the University of Oxfor in the UK has reported that the bean-rich diet helps to control diabetes by lowering blood sugar level and by improving the ratio of blood fats. Diabetes is a situation that requires constant maintenance of blood sugar levels to a normal level to enable the body to perform necessary tasks. Certain studies have shown a definitive hypoglycemic influence of beans on patients with diabetes (Jaiswal 2020).

CHAPTER III

Production, Characteristics, and Agricultural Applications of Biochar

I. Generality

Biochar is a solid material rich in carbon produced from the thermal decomposition of organic biomass in an oxygen-limited environment. Research on its use in agriculture has advanced significantly in the past two decades due to its benefits in improving soil fertility and crop productivity.

Additionally, biochar offers other advantages such as waste management, carbon sequestration, reduction of greenhouse gas emissions, and contributing to climate change mitigation (Jaiswal 2020).

The chemical composition of the raw materials and the conditions of thermal decomposition affect the characteristics of biochar. Biomass with a high lignin content produces biochar with alkaline pH, higher carbon and aromaticity, but lower ash and nutrient content such as N, P, K, and Ca (Fig. 15). Conversely, biomass with high cellulose and hemicellulose content yields biochar with a high concentration of volatile compounds and nutrients.

Biochar produced from sewage sludge contains a high proportion of nutrients and heavy metals, characterized by increased hydrophobicity and porosity at temperatures above 500 degrees Celsius, making it suitable for absorbing organic pollutants. Meanwhile, biochar produced at temperatures below 500 degrees Celsius contains oxygen-functional groups, making it more suitable for immobilizing non-organic pollutants (Vithanage, Gunarathne et al. 2013).

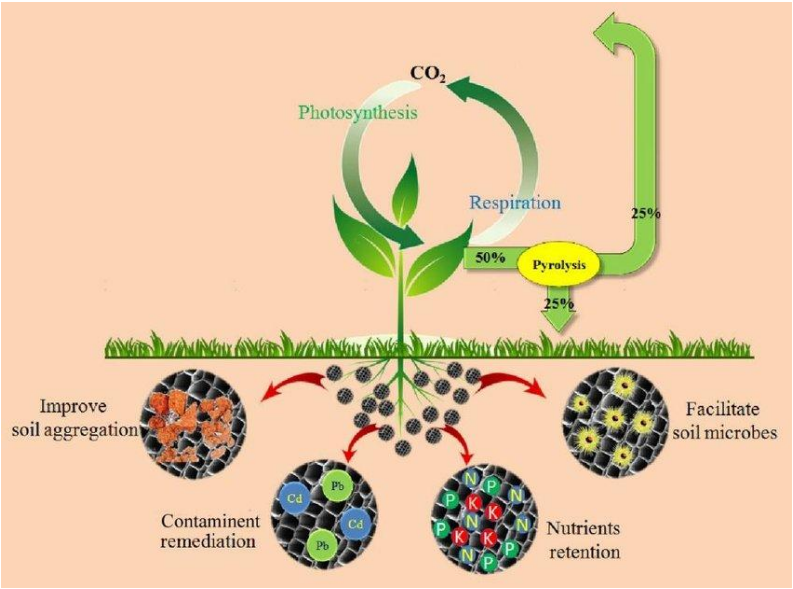


Figure 15: Overall agricultural benefits of biochar (Vithanage, Gunarathne et al. 2013).

Biochar has positive effects in agricultural systems, but there is still debate regarding its absolute benefits in nutrient cycling, as its addition to soils doesn't always result in consistent crop productivity increases. This is partly due to variations in the nutrient content of biochar, which can affect plant growth and limit nutrient availability. Moreover, indiscriminate biochar use can increase soil toxicity due to heavy metal content, negatively impacting plant growth and causing nutrient imbalances. Biochar is considered one of the best organic fertilizers due to its stability and ability to retain nutrients that reduce leaching (Niazi, Hekmatullah et al. 2023).

II. Definition

Biochar is a material that involves using burnt organic material as an additive to improve soil. Biochar is prepared by heating organic material in an oxygen-limited or oxygen-free environment at temperatures ranging from 300 to 900 degrees Celsius. This process is called pyrolysis (Amalina, Razak et al. 2022).

Currently, there are no precise standards that define the conditions for pyrolysis, the type of organic material to be used, or the optimal temperatures for this process. It is important not to confuse the biochar technique with the addition of ash to soil, either directly or by burning plants. When ash is added, only minerals are added to the soil, not the burnt organic material as in the case of biochar.

The use of burnt materials to improve soil is not a new practice, as traces of this technique can be found in various ancient texts, such as in Japan under the name "fire fertilizer," and in China where Liebig (1878) described charcoal production practices and its use in soil.

Among the prominent historical examples of this technique is the discovery of "terra preta" in the Amazon, where a high concentration of burnt carbon was measured, likely added by indigenous populations over centuries. Studies have shown significant positive effects of these additions, such as an increase in soil organic matter and its nutrient exchange capacity, ultimately leading to a substantial increase in agricultural productivity compared to unmodified soil (Johnston, Poulton et al. 2008).

III. Methods of synthesizing Biochar

III.1. Pyrolysis

During pyrolysis, the biomass undergoes thermal treatment to yield biochar and various by-products. Depending on the conditions, this process can generate biogas, liquid bio-oil,

and biochar. It's crucial to prepare the biomass by drying and grinding it beforehand. You obtain a high-quality and productive carbonaceous material. The heating process is conducted at high temperatures (400-800 degrees Celsius) without oxygen, allowing the conversion of biomass into by-products for various applications, such as energy and environmental improvement. These by-products can be utilized as energy or residual heat to contribute to pyrolysis or the thermal treatment of raw materials, with this thermal process releasing the lowest percentage of carbon back into the atmosphere.

According to the literature, there are two types of pyrolysis: slow and fast pyrolysis, which depend on the temperature conditions and the heating rate. Slow pyrolysis is conducted at temperatures ranging from 250 to 600°C using heating rates of 1–10°C/min, while fast pyrolysis is based on the thermal conversion of biomass at temperatures above 600°C, using heating rates higher than 50°C/min.

The concentration and physicochemical properties of the products formed (e.g., biogas, bio-oil, and biochar) can vary depending on the type of pyrolysis. Thus, during slow pyrolysis of biomass, a large amount of biochar can be produced, generating low concentrations of gases and liquids with a high content of highly contaminant volatile organic compounds (VOCs). While fast pyrolysis is primarily used to produce a high concentration of liquids, such as biofuel, with better physicochemical quality than that produced by slow pyrolysis, the latter achieves a lower content of volatile organic compounds and a higher concentration of long-chain hydrocarbons.

Both types of pyrolysis can be used to produce biochar, but the properties and applications of the carbonaceous materials will differ. Slow pyrolysis can be the optimal method to obtain biochar for water and soil remediation, whereas fast pyrolysis can be preferred to produce biochar as fuel or precursor to other materials. The pyrolysis of biomass modifies the size and arrangement of the carbonaceous structures, enhancing the physicochemical properties of the products obtained during the process (Escalante, Chen et al. 2022, Igliński, Kujawski et al. 2023).

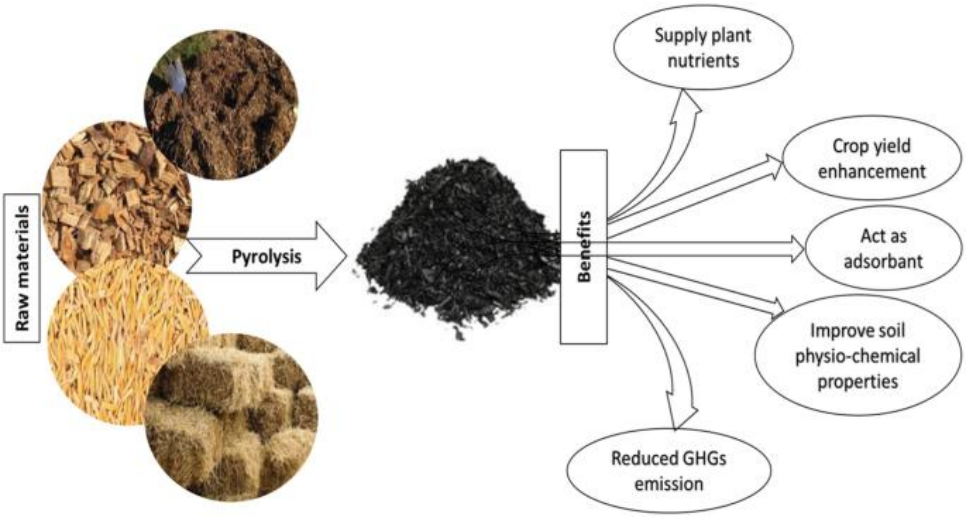


Figure 16: Use of biochar in sustainable agriculture (Gogoi, Sarma et al. 2019).

In general, this impact becomes more robust at higher treatment temperatures. To obtain a higher biochar production yield, the temperature interval for pyrolysis should be around 400–800°C. Lua et al. reported that by raising the pyrolysis temperature from 250 to 500°C, the specific surface area can increase from 170 to 480 m2/g, which has been related to the increased evolution of volatile matter in pistachio nut shells, resulting in an improved pore growth at the biochar surface, reaching total pore volume values of 0.47 cm3/g (at 500°C), which were much higher than those obtained at a pyrolysis temperature of 250°C (0.193 cm3/g). This has been related to elevated temperatures supplying activation energy, which can favor conversion reactions, resulting in higher degrees of order in the carbonaceous structures (Igliński, Kujawski et al. 2023)."

III.2. Torrefaction

Similarly, to pyrolysis, torrefaction is a thermochemical process based on biomass conversion into value-added products, e.g., biochar, biogas, and bio-oil.

However, this process differs from pyrolysis in operating conditions and formed product types. Torrefaction is a thermal process based on biomass dehydration, carbonization, and caramelization at relatively low temperatures (i.e., 200 to 300 ◦C) without oxygen. Biochar is the only product generated during this process. However, the physicochemical properties (e.g., structural characteristics) of the carbonaceous material produced are inferior to those of pyrolysis (Yadav, Singh et al. 2023).

III.3. Hydrothermal Carbonization

Hydrothermal carbonization (HTC) (Tab.4) is a thermochemical technology used to process biomass with high moisture content in a hot compressed water system. The main product of HTC is hydrochar, a type of biochar produced in this way.

Additionally, aqueous (nutrient-rich) and gaseous phases, mainly consisting of carbon dioxide, can be produced depending on the operating conditions. The carbon-rich hydrochar can be utilized as fuel, a substitute for coal, a feedstock for gasification, a soil additive for nutrient enrichment, or as an adsorbent or precursor of activated carbon.

The HTC (Hydrothermal Carbonization) process offers several advantages. Biomass can be converted into carbonaceous solids without the need for energy-intensive drying procedures or an oxygen-free atmosphere. Similarly, toxic chemical compounds and residual micropollutants are also avoided during hydrothermal carbonization. The HTC is a thermochemical process that utilizes heat to convert wet biomass feedstock into hydrochar. HTC is conducted in a reactor at temperatures ranging from 120 to 300°C under autogenous (self-generated) pressure or pressure (2–6 MPa) with feedstock residence periods ranging from 0.5 to 8 hours (Czerwińska, Śliz et al. 2022, Iwuozor, Emenike et al. 2023).

Table 4: Thermochemical conversion processes to obtain biochar used in different fields (Iwuozor, Emenike et al. 2023).

Process	Temperature Interval (°C)	Feedstock	Final Product	Uses
Torrefaction	200–300	Rice husk, cocoa husk	Biochar	Soil conditioner
Pyrolysis	300–800	Wood, agricultural waste	Syngas, biochar	Fuel (cooking, heat), soil amendment
Slow pyrolysis	350–700	Compost (green waste) woody prunings, grass clippings	Activated biochar	Water filtration and adsorption of contaminants (gasses, solids, liquids)
Fast pyrolysis	450–550	Agricultural waste and crops	Biochar	Soil conditioner, plant growth
HTC	150–400 (High pressure)	Rice husk, manure, algae, corn stover, biosolids, food waste	Hydrochar	Solid fuel, soil amendment, adsorbent
Gasification	>800	Agricultural waste, manure, food residues, sewage	Combustible, ethane, methane	Biochemicals, fuel (low yield, high reactivity)

Process	Temperature Interval (°C)	Feedstock	Final Product	Uses
		sludge		

IV. Role of biochar in combating drought

Biochar enters the plant's body through the roots and leaves, and upon entry, it induces changes in the biochemical, morphological, molecular, and physiological characteristics of crops. These changes significantly affect plant growth depending on the concentration, volume, and application method of biochar. Additionally, the size, chemical nature, and reactivity of biochar can greatly influence plants. Available evidence suggests that biochar mitigates the negative effects of drought and significantly enhances plant growth and development (Rasheed, Li et al. 2022).

V. Biochar protects the photosynthetic apparatus and enhances the photosynthetic process under drought stress

Biochar has been shown to protect the photosynthetic apparatus and enhance the photosynthetic process under drought stress by mitigating the adverse effects of water scarcity on plants. Drought stress typically reduces chlorophyll synthesis, leaf area, and electron transport, thereby hindering photosynthesis. Biochar application promotes the synthesis of growth-regulating substances and enhances plant function under drought conditions by increasing chlorophyll content and antioxidant activities (Fig.17). Research indicates that biochar modification compensates for drought effects on carbon assimilation and the photosynthetic process by improving chlorophyll synthesis and reducing significant declines in electron transport efficiency. Furthermore, biochar enhances water use efficiency, leading to an improved net photosynthetic rate and reduced non-stomatal limitations. Studies have shown that biochar application increases productivity and reduces oxidative damage by boosting chlorophyll synthesis, enhancing the photosynthetic rate, and minimizing electron leakage. By improving water use efficiency, biochar also facilitates better water transport and chlorophyll synthesis in plants, thereby sustaining photosynthetic activity and plant growth under drought stress conditions (Tayyab, Khalil et al. 2018).

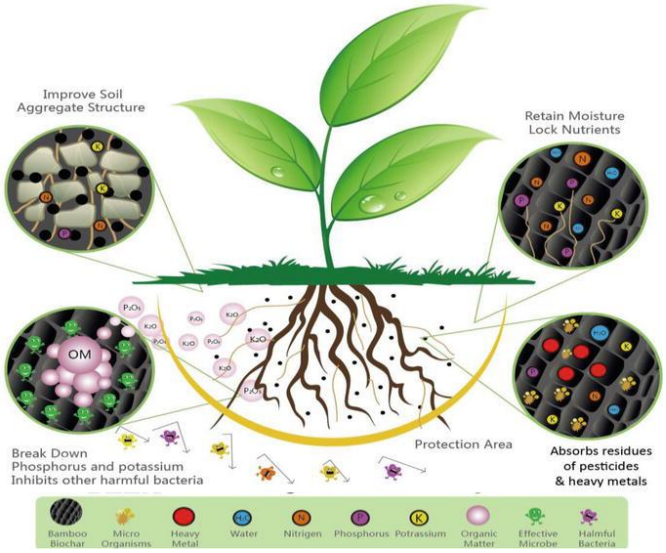


Figure 17: Effect of biochar on the soil mineral component (Chukwuka, Akanmu et al. 2020).

Additionally, biochar carries out structural changes to enhance the photosynthetic process, such as improving stomatal length, width, and density, significantly improving water use efficiency and photosynthetic rate under drought conditions.

Application of biochar increased leaf relative water content, leading to improved rates of transpiration and photosynthesis, as well as enhanced leaf osmotic potential under drought stress conditions. Another study examined the impact of drought stress on the drought tolerance of quinoa plants, finding that biochar application improved soil properties, leaf water status, and photosynthesis, and resulted in a significant increase in overall plant photosynthetic efficiency and assimilation production under water-deficient conditions.

Biochar application to poor sandy soil enhances plant water relations, photosynthesis, and growth by mitigating toxic effects or reactive oxygen species.

Additionally, Lyu et al. observed that biochar application enhances electron transport and enzymatic activities, thereby mitigating the detrimental effects of drought stress on the photosynthetic apparatus. Essentially, biochar protects the photosynthetic apparatus from drought-induced oxidative stress and enhances the synthesis of photosynthetic pigments, resulting in a significant increase in photosynthesis under drought conditions (Wu, Wang et al. 2023).

VI. Biochar maintains the stability of the membrane and water relations in plants under drought stress

Drought stress causes detrimental effects on the plasma membrane, leading to cytoplasmic dehydration, thus increasing electrolyte leakage and lipid peroxidation. The addition of biochar and chitosan enhances plant tolerance to drought stress by reducing electrolyte leakage and lipid peroxidation, improving membrane stability, relative water content, and water pressure.

In another study, drought-stressed purslane plants treated with biochar showed a significant decrease in MDA concentration. Additionally, biochar reduces MDA accumulation in Brassica oleracea by increasing antioxidant enzyme activity.

There is a controversial role of biochar in plant water status; for example, it has been observed to improve water use efficiency and biomass production but does not enhance relative water content. The assumption is that biochar improves plant nutrition and increases potassium uptake, thereby enhancing its resistance to stresses.

However, it is worth noting that the application of biochar has not only improved water use efficiency but also enhanced soil water retention capacity, thereby improving plant water status. Adding biochar to sandy loam soil enhances plant-available water and improves leaf water content under water stress. Additionally, another study found that biochar application to frozen soil mitigates the adverse effects of water stress by improving soil water content, and photosynthetic and leaf respiration processes. Furthermore, in maize plants, it has also been reported that biochar application (2% and 3%) significantly improves leaf water potential and photosynthetic activity under water stress.

Biochar application has been found to enhance leaf water content in poor sandy soil, while the study also showed that biochar addition enhances antioxidant activities and water relations in plants. However, it was also found that the response of biochar to water stress varies depending on the plant species, soil type, and biochar type (Lihong, Jianing et al. 2023, Wu, Wang et al. 2023).

In conclusion, Biochar application significantly enhances plant drought tolerance by improving water uptake, maintaining leaf water content, and stabilizing the membrane under stress conditions. This is achieved through reduced electrolyte leakage and lipid peroxidation, increased antioxidant enzyme activity, and improved soil water retention. However, the effectiveness of biochar varies based on plant species, soil type, and biochar

characteristics. Overall, biochar promotes better physiological functions in plants, aiding their resilience to drought.

SECOND PART

Experimental Part

CHAPTER I

Materials and Methods

I. MATERIALS AND METHODS

I.1. Chemicals

Sigma-Aldrich (USA) supplied aluminum chloride ($AlCl_3$), ferric chloride ($FeCl_3$), sodium carbonate (Na_2CO_3), and trichloroacetic acid. Merck KGaA (Darmstadt, Germany) provided Folin-Ciocalteu reagent, Folin-Denis reagent, and hydrogen peroxide. Thermo Fisher Scientific (USA) supplied methanol (99.7% GC), 2,2-diphenyl-1-picrylhydrazyl (DPPH), potassium ferricyanide ($K_3[Fe(CN)_6]$), and ascorbic acid.

I.2. Plant material collection

The plant materials, specifically Red Dried Onion (*Allium cepa L.*) peels, and Raw Dried Banana (*Musa spp*.) peels were collected from local markets. The onion peels were sourced from red onion varieties known for their rich phenolic content, which has been linked to various health benefits (Benítez, Mollá et al. 2011). Banana peels were chosen for their high antioxidant properties and potential applications in waste valorization (Happi Emaga, Andrianaivo et al. 2007). The collected materials were thoroughly cleaned to remove any dirt and impurities, then air-dried in a controlled environment to preserve their bioactive compounds.

I.3. Preparation of aqueous and methanolic extracts

The dried plant materials were finely ground using a laboratory mill to obtain a uniform powder. For the extraction process, 10 grams of each powdered sample were divided into two portions for aqueous and methanolic extraction. For the aqueous extraction, the powdered samples were soaked in 100 mL of distilled water and subjected to constant agitation at room temperature for 24 hours. For the methanolic extraction, 10 grams of powdered samples were soaked in 100 mL of 70% methanol solution and similarly agitated for 24 hours (Patel, Dave et al. 2021).

After the extraction period, the mixtures were filtered using Whatman No. 1 filter paper to remove solid residues. The aqueous and methanolic extracts were then concentrated under reduced pressure using a rotary evaporator. The concentrated extracts were further dried to obtain the crude extracts. The yield of each extract was calculated based on the initial weight of the dried plant material. The crude extracts were stored at -20°C until further analysis.

The yield of the extracts was determined using the following formula (Harborne 1998) modified by Chouikh *et al.* 2015 (Atef, Anouar et al. 2015):

$$\text{Yield (\%)} = (W_1 / W_2) \times 100.$$

where:

W_1 = weight of the extract dried (g).

W_2 = weight of the plant starting material (g).

I.4. Chemical screening

To identify the major classes of compounds (tannins, saponins, flavonoids, alkaloids, phenols, reducing sugars, and terpenoids) present in the extracts of **Red Dried Onion (ROD)** and **Raw Dried Banana (RDB)**, a confirmatory qualitative phytochemical screening was performed using standard protocols (Evans 2009).

- ✓ **Phenols**

Introduce 5 ml of extract in a test tube and drops few of natural 5% ferric chloride solution. A dark green color indicates the presence of phenolic compounds

- ✓ **Flavonoids**

In a test tube, introduce 5ml of extract, 5ml of diluted ammoniac and 1ml of H_2SO_4. The appearance of a yellow color indicates the presence of flavonoids.

- ✓ **Alkaloids**

1 ml of aqueous extract were treated with a few drops of hydrochloric acid then 1–3 drops of Wagner reagent were added. The appearance of brown precipitate reveals the presence of alkaloids in the sample.

- ✓ **Tannins**

In a test tube, introduce 5 ml of extract and add 1 ml of a 2% aqueous solution of ferric chloride ($FeCl_3$). The presence of tannins was indicated by a greenish or bluish-blackish coloration.

- ✓ **Terpenoids**

The formation of a reddish-brown color indicates the presence of terpenoids, through the addition of chloroform (2ml) and concentrated sulfuric acid (3 ml) to 5 ml of plant extract.

- ✓ **Reducing compound**

Add Fehling's liquor (1ml of reagent A and 1ml of reagent B) to the extract and incubate the whole in a boiling water bath, the appearance of a brick-red precipitate indicates the presence of reducing sugars.

- ✓ **Saponins**

In a test tube, introduce 5ml of extract, mixed with 5ml of distilled and with vigorous manual agitation. The formation of a steady foam indicates the presence of saponins.

- ✓ **Steroids**

For 1ml of plant extract, add 0.5ml of acetic acid solution, followed by 0.5ml of concentrated H_2SO_4. If the solution does not give any green color, it proves the presence of unsaturated steroids. In a second tube, the same volume of H_2SO_4 was added. The presence of the red color indicates the presence of steroid derivatives.

I.4.1. Determination of total polyphenols (TPC)

Determination of the total polyphenols was carried out according to the Folin-Ciocalteu (FC) method (Boizot and Charpentier 2006): Take 100 µl of the extract of ROD or RDB and mixed with 500 µl of the FC reagent and 400 µl of Na_2CO_3 at 7.5% (w / v). The mixture is stirred and incubated in the dark and at room temperature for ten minutes and the absorbance is measured at 760 nm by a UV spectrophotometer. The results are expressed in mg gallic acid equivalent/ g of dry vegetable material concerning the calibration curve of gallic acid. A calibration curve is carried out by gallic acid at different concentrations (20 - 40 - 60 - 80 - 100 – 120 µg/ml) under the same conditions and the same steps of the assay. The results are thus expressed in milligrams of gallic acid per gram of dry extract (mg of EAG / g). All measurements are repeated 3 times.

I.4.2. Determination of total flavonoids (TFC)

The determination of total flavonoids was carried out according to the method described by (Dehpour, Ebrahimzadeh et al. 2009): 500 µl of each extract ROD or RDB, 100 µl $AlCl_3$, 100 µl of 1 M sodium acetate and 2.8 ml of distilled water. The mixture is stirred and then incubated in the dark and at room temperature for 30 minutes. The blank is made by replacing the extract with 95% methanol and the absorbance is measured at 415 nm using a UV spectrophotometer. The results are expressed in mg equivalent quercetin / g of dry vegetable material concerning the quercetin calibration curve. The quercetin calibration

curve is performed by quercetin at different concentrations (20 - 40 - 60 - 80 - 100 – 120 µg/ml) under the same conditions and the same steps of the assay.

I.5. Antioxidant activity

I.5.1. DPPH free radical scavenging assay

The free radical scavenging activity was measured by a modified DPPH assay. Briefly, the DPPH assay was carried out as described by (Cuendet, Hostettmann et al. 1997), 100 µL of various concentrations of the extract of ROD or RDB sample in methanol was added to 1.9 mL of a methanol solution of DPPH (0.004 %). The mixture was shaken and then allowed to stand at room temperature for 30 min in the dark. The absorbance was measured at 517 nm. The scavenging activity on the DPPH radical was expressed as inhibition percentage using the following equation:

$$\textbf{DPPH scavenging-radical (\%)} = [(A_0 - A_s) / A0] \times 100$$

$\mathbf{A_0}$: is the absorbance of control reaction

$\mathbf{A_s}$: is the absorbance of sample solution containing the test compound.

BHT were used as a positive control.

The IC_{50} of extract was calculated from the graph of inhibition percentage plotted against extract concentrations.

$$IC_{50} = [1-(\text{Absorbance of sample/Absorbance of control})] \times 100$$

I.5.2. The Ferric Reducing Antioxidant Power (FRAP) Assay

The Reducing power assay was prepared following the method of Benzi and Strin with some modifications (Benzie and Strain 1999). To both extracts (aqueous and metabolic) of ROD and RDB extracts, phosphate buffer (2.5 mL, 0.2 M, pH 6.6) and 1% potassium ferricyanide water solution (2.5 mL, K_3 [Fe $(CN)_6$]) were added at different quantities (mg/mL). A 10% aqueous solution of trichloroacetic acid (2.5 mL) was added to the mixture, and it was incubated for 20 minutes at 50°C before being centrifuged for 10 minutes at 3000 rpm. The absorbance was measured at a wavelength of 700 nm after mixing freshly prepared $FeCl_3$ (0.5 mL, 0.1%) solution with 2.5 mL of filtered water and the supernatant. Ascorbic acid was used as a positive control. The results are expressed as EC_{50} (Effective Concentration 50%), after calculating the inhibition percentage values according to Yazdani et al. (2019) as follows:

$$EC_{50} = [1-(\text{Absorbance of sample/Absorbance of control})] \times 100$$

I.5.3. Sun Protection Factor (SPF) assays

The effectiveness of UV protection assessed through laboratory analysis of sunscreen products, measuring their Sun Protection Factor (SPF) values using a UV-Vis spectrophotometer. This scientific method allows the evaluation of various experimental sunscreens for their ability to safeguard against harmful UV rays.

Mansur et al. (1986) (Mansur, Breder et al. 1986), devised a straightforward mathematical equation that replaces the *in vitro* method proposed by Sayre et al. (1979) (Sayre, Agin et al. 1979), employing UV spectrophotometry as follows:

$$SPF = CF \times \sum EE(\lambda) \times I(\lambda) \times Abs(\lambda)$$

Where: EE(λ): erythemal effect spectrum; I(λ): solar intensity spectrum; Abs(λ): absorbance of the sunscreen product; CF: correction factor (= 10). The correction factor was determined so that a standard sunscreen formulation containing 8% homosalate yielded an SPF value of 4, as measured by UV spectrophotometry (Mansur, Breder et al. 1986).

Table 5 displays the normalized product function utilized in SPF calculation, based on the constants determined by Sayre et al. (1979)(Sayre, Agin et al. 1979).

Table 5. Normalized product function used in the calculation of SPF.

Wavelength (nm)	290	295	300	305	310	315	320	**Total**
EEM x I (normalized)	0.0150	0.0817	0.2874	0.3278	0.1864	0.0839	0.0180	1

EEM: erythemal effect spectrum; **I**: solar intensityspectrum.

According to the European recommendation in 2006 (Verheugen 2006), sunscreen products should possess an SPF value of at least 6 and not exceed 50 . Furthermore, the SPF value should be accompanied by a qualitative description denoting the level of protection, categorized as low, medium, high, or very high protection (Table 2).

Table 6. The category of sunscreen products protection factor (Verheugen 2006).

Protection Level	**SPF Value**
Low protection	6, 10
Medium protection	15, 20, 25
High protection	30, 40
Very high protection	50+

I.6. Evaluation of biochar effectiveness (RDB, RDO, RDF) on growth of bean and chickpea plants in desert sandy soil

I.6.1. Collection and processing of biomass samples

The protocol described by the author (Hardin, Fu et al. 2013). Banana and onion peels, common kitchen waste products, were systematically collected to serve as the primary biomass for biochar production. Additional biomass was gathered from local vegetable markets within the study area to ensure a sufficient sample size. The collected materials were then cleaned to remove any contaminants and sorted to segregate the different types of peels. This step is crucial to maintain the consistency of the biochar produced from each distinct type of biomass.

I.6.2. Production and processing of biochar by pyrolysis

The protocol described by the author (Leng and Huang 2018). Following the initial preparation, the banana and onion peels were subjected to a drying process to reduce moisture content, optimizing them for pyrolysis. The dried biomass was then pyrolyzed in an electric oven set to a high temperature, typically between 250°C and 300°C, to ensure thorough carbonization. This process was conducted in an oxygen-limited environment to prevent combustion and maximize char yield. After pyrolysis, the resultant biochar was allowed to cool in a sealed container to prevent oxidation. The cooled biochar was then ground into a fine powder to standardize the particle size for subsequent experiments, ensuring uniformity in application and analysis.

I.6.3. Preparation of aqueous and methanol extracts from biochar

The protocol described by the author (Jing, Wang et al. 2014).The ground biochar was subjected to both aqueous and methanol extraction processes to isolate soluble compounds, which may influence plant growth and soil interaction. An equal weight of biochar was steeped in distilled water and methanol separately under controlled conditions to ensure maximum extraction efficiency. The mixtures were agitated periodically and allowed to stand for 24 hours, following which they were filtered to separate the liquid extracts from the solid residue. The yield of the biochar was calculated using the formula:

$$\textbf{Biochar Yield (\%)} = (m/m_0) \times 100$$

where 'm' represents the mass of biochar obtained post-pyrolysis and 'm_0 ' the original mass of the dry biomass. This yield calculation helps in assessing the efficiency of the pyrolysis process and the potential output rate of usable biochar from given biomass quantities.

I.6.4. Pot Culture Experiment

To assess the impact of biochar derived from various sources on plant growth, an experimental study was implemented using biochar produced from dried red onion peels (RDO), dried raw banana peels (RDB), and dried bean peels (RDF). *Phaseolus vulgaris* (bean) and *Cicer arietinum* (chickpea) seeds were sown in agricultural containers filled with desert sandy soil. These containers were organized into three distinct groups, each receiving a treatment of 3.5 grams of a specific type of biochar (RDB, RDO, RDF). Within these, the groups treated with RDB and RDO served as experimental groups, while the RDF-treated group was designated as a positive control group to gauge biochar's baseline effects. Additionally, control subgroups within each main group received no biochar treatment to provide comparative data. The setup and distribution of these containers are delineated in Table 1, 2, and 3. The primary objective of this study was to explore the influence of these biochars on plant growth over a 35-day period, enabling a comparative analysis of biochar effects derived from different biomass sources.

Table 7. The protocol used to evaluate the effectiveness of biochar RDB in the growth of bean and chickpea plants in desert sandy soil.

The studied plant	**Bean**			**chickpea**	
Type of soil treatment	RDB AqE biochar	RDB MeE biochar	Untreated soil	RDB AqE biochar	Untreated soil
Observation method	Recording stem length, leaf quality, and flowering process, over 35 days				

Table 8. The protocol used to evaluate the effectiveness of biochar RDO in the growth of bean and chickpea plants in desert sandy soil.

The studied plant	**Bean**		**chickpea**	
Type of soil treatment	ROD AqE biochar	Untreated soil	ROD AqE biochar	Untreated soil
Observation method	Recording stem length, leaf quality, and flowering process, over 35 days			

Table 9. The protocol used to evaluate the effectiveness of biochar RDF (as a positive control group) in the growth of bean and chickpea plants in desert sandy soil.

The studied plant	**Bean**		**chickpea**	
Type of soil treatment	RDF AqE biochar	Untreated soil	RDF AqE biochar	Untreated soil
Observation method	Recording stem length, leaf quality, and flowering process, over 35 days			

I.7.Statistical analysis

All assays were conducted in triplicate, with results presented as mean ± SEM. In vitro assay data were analyzed using Excel 2021 software, Python and MATLAB, for Windows to determine EC_{50} and IC_{50} values. A significance level of $\alpha = 0.05$ was established, with $p < 0.05$ considered statistically significant. P-values are depicted in the figures as follows: ***, $p < 0.001$; **, $p < 0.01$; and ns, $p > 0.05$.

CHAPTER II

Results and Discussion

I. Chemical screening Study

1.1.Phytochemical Study

The screening indicates that ROD MeE generally has higher concentrations of metabolites compared to ROD AqE, especially for phenols (Tab.10), saponins, and steroids. RDB MeE shows high concentrations of terpenoids and saponins, while RDB AqE has high concentrations of reducing sugars. Flavonoids are absent in RDB extracts but present in ROD extracts, particularly in ROD MeE. This analysis highlights significant variations in metabolite content based on extraction method.

Table 10. Preliminary phytochemical screening of ROD and RDB, using chemical test methods. (+++ High concentration, ++ moderate concentration, + low concentration), -: unavailable or not detected; (AqE: aqueous extract, MeE: methanolic extract).

Secondary Metabolite	Observation	ROD AqE	ROD MeE	RDB AqE	RDB MeE
Alkaloids	White precipitate	+	++	+	+
Flavonoids	Intense red	+	++	-	-
Terpenoids	Purple ring	+	++	++	+++
Phenols	Dark blue-green	++	+++	+	++
Tannins	Bluish-green color	++	++	++	++
Saponins	Forms foam in all tubes	++	+++	++	+++
Reducing sugars	Brown	++++	+	++++	+
Steroids	Red	++	+++	+	++

1.2.Total polyphenol and flavonoid contents

The yields of extracts show that RDB AqE has the highest yield at 18.2 ± 0.6%, followed by RDB MeE at 14.9 ± 0.3%, ROD AqE at 7.3 ± 0.5%, and ROD MeE at 4.7 ± 0.4% (Tab.11). In terms of polyphenol content, ROD MeE exhibits the highest concentration (45.2 ± 0.114 mg GAEq/g), while RDB AqE has the lowest (28.9 ± 0.231 mg GAEq/g). For flavonoid content, ROD MeE also shows the highest value (20.3 ± 0.144 mg QEq/g), whereas RDB AqE has the lowest (8.7 ± 0.123 mg QEq/g). The standard deviations indicate variability within the measurements, with RDB extracts generally having higher yields but lower concentrations of polyphenols and flavonoids compared to ROD extracts.

Table 11. Yield; Polyphenols and flavonoids contents in ROD and RDB extracts.

Extract		Yield (%)	Polyphenols (mg of GAEq/g of extract)	Flavonoïds (mg QEq/g of extract)
ROD	**AqE**	7.3 ± 0.5	35.6 ± 0.102	12.5 ± 0.122
	MeE	4.7 ± 0.4	45.2 ± 0.114	20.3 ± 0.144
RDB	**AqE**	18.2 ± 0.6	28.9 ± 0.231	8.7 ± 0.123
	MeE	14.9 ± 0.3	38.4 ± 0.154	14.1 ± 0.022

±, Standard Deviation (SD)

II. Biological Activity in vitro

II.1. Antioxidant activity

The antioxidant potency of ROD and RDB extracts, as measured by DPPH and FRAP assays, shows that ROD MeE has the lowest IC50 value (0.045 ± 0.01 mg/ml) in the DPPH activity test (Tab.12), indicating higher antioxidant activity compared to ROD AqE, RDB AqE, and RDB MeE, which have IC50 values of 0.08 ± 0.01, 0.09 ± 0.01, and 0.05 ± 0.01 mg/ml, respectively. In the FRAP activity test, ROD MeE also demonstrates a lower EC50 value (0.09 ± 0.01 mg/ml) compared to ROD AqE (0.15 ± 0.01 mg/ml), RDB AqE (0.18 ± 0.01 mg/ml), and RDB MeE (0.10 ± 0.01 mg/ml). The reference compound (AAs) shows the highest antioxidant activity with the lowest IC50 (0.0145 ± 0.005 mg/ml) and EC50 (0.068 ± 0.001 mg/ml) values.

Table 12. Comparative Antioxidant Potency of ROD and RDB extracts and reference compounds using DPPH, FRAP.

Test	factor	ROD AqE	ROD MeE	RDB AqE	RDB MeE	AAs
DPPH activity	IC_{50}**(mg/ml)**	0.08 ± 0.01	0.045 ± 0.01	0.09 ± 0.01	0.05 ± 0.01	0.0145 ± 0.005
FRAP activity	EC_{50}**(mg/ml)**	0.15 ± 0.01	0.09 ± 0.01	0.18 ± 0.01	0.10 ± 0.01	0.068 ± 0.001

±, Standard Deviation (SD)

II.2. Sun Protection Factor SPF assay

The measured SPF values indicate that ROD MeE exhibits the highest SPF value among the biochar extracts (18 ± 3), followed by RDB MeE (15 ± 2), ROD AqE (12 ± 2), and RDB AqE (8 ± 1). The commercial sunscreen Avene® demonstrates significantly higher SPF protection (41 ± 4) compared to all the tested extracts (Tab.13). The standard deviations indicate variability in the measurements, with ROD MeE showing the highest variability and RDB AqE showing the least. This comparison highlights the relative effectiveness of the different extracts in providing sun protection, with methanolic extracts generally showing higher SPF values than aqueous extracts.

Table 13. Measured SPF values of ROD and RDB extracts and commercial sunscreens Avene®

SPF	ROD AqE	ROD MeE	RDB AqE	RDB MeE	Avene® (Control)
	12 ± 2	18 ± 3	8 ± 1	15 ± 2	41±4

±, Standard Deviation (SD)

III. Evaluation of biochar effectiveness (RDB, RDO, RDF) on growth of bean and chickpea plants in desert sandy soil

1. Yield of biochar mass

The yield of biochar from different biomass types indicates that RDF (dried bean peels) has the highest yield at 35 ± 5.25%, followed by RDB (dried raw banana peels) with a yield of 30 ± 4.5%, and RDO (dried red onion peels) with a yield of 25 ± 3.75% (Tab.14). All biochars were produced from an initial biomass of 300 grams. The standard deviations show the variability in yield, with RDF displaying the highest variability. This data suggests that RDF is the most efficient biomass for biochar production among the three types studied.

Table 14. Yield of biochar (RDB, RDO, and RDF).

Biochar type	Initial biomass (g)	Final biochar mass (g)	Yield (%)
RDB	300	90	30 ± 4.5
RDO	300	75	25 ± 3.75
RDF	300	105	35 ± 5.25

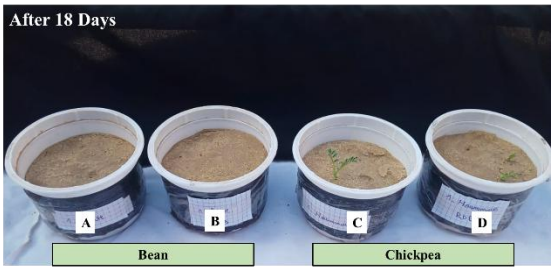
±, Standard Deviation (SD)

2. Results of Pot Culture Experiment

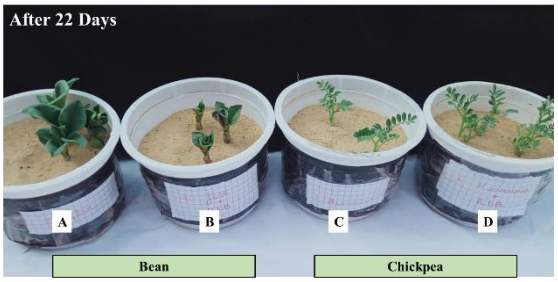
2.1. The effect of RDB biochar on the growth of bean and chickpea plants

The photos presented in (Fig.18) demonstrate that, at all observed time points (18-, 22-, 33-, and 35-days post-planting and watering), both bean and chickpea plants grown in soil treated with RDB AqE biochar consistently exhibited superior stem and leaf growth compared to their counterparts grown in untreated soil. This trend was consistently observed across all stages of the experiment, indicating a positive effect of RDB AqE biochar treatment on the growth performance of both plant types.

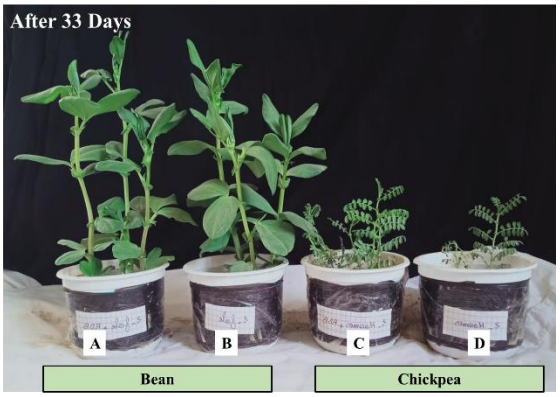
(a)



(b)



(c)



(d)

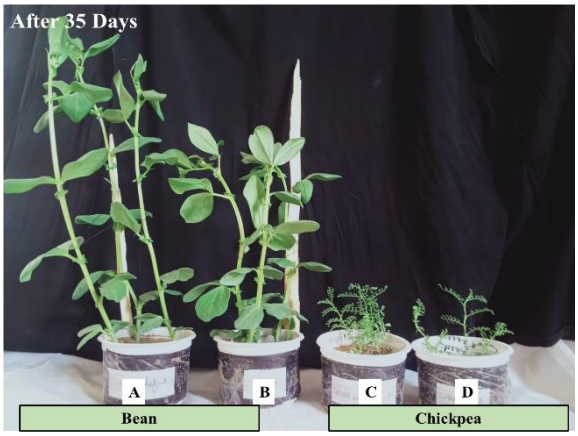


Figure 18: Comparative analysis of stem and leaf growth in bean and chickpea plants with RDB biochar treatment. A: Bean plants in soil treated with RDB AqE biochar, B: Bean plants in untreated soil, C: Chickpea plants in soil treated with RDB AqE biochar, D: Chickpea plants in untreated soil. Observations at (a) 18 Days, (b) 22 Days, (c) 33 Days, and (d) 35 days post-planting and watering.

Additionally, similar observations were recorded for other experiments using different types of biochar (RDO and RDF). Although images of these tests are not included, the results are represented graphically (Fig, 19, 20, and 21). These graphical curves consistently show that biochar treatments (RDO and RDF) also resulted in superior growth of both bean and chickpea plants compared to untreated controls at all measured intervals. This comprehensive data set reinforces the conclusion that biochar treatments, regardless of the specific type, enhance plant growth performance in both bean and chickpea plants.

The data illustrate (Fig. 19) the leg length growth of bean and chickpea plants over a 35-day period with different soil treatments. Bean plants grown in soil treated with RDB AqE biochar showed the most significant growth, reaching 18 cm by day 35, while those treated with RDB MeE biochar reached 12.8 cm, and those in untreated soil reached 10 cm. Similarly, chickpea plants treated with RDB AqE biochar and RDB MeE biochar both reached a maximum leg length of 9 cm, compared to 7.6 cm in untreated soil. This trend is consistent across all time points, with treated soils (both RDB AqE and RDB MeE) consistently outperforming untreated soils in terms of leg length growth for both plant types, highlighting the positive effect of biochar treatment on plant growth.

(a) **(b)**

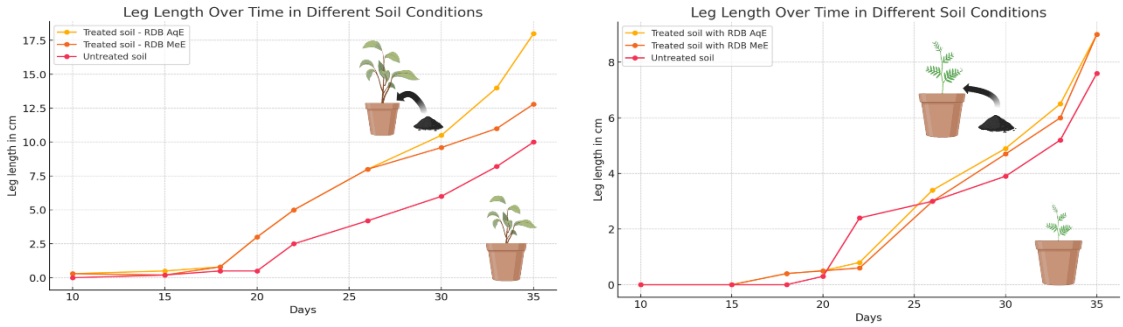


Figure 19: Comparative Study of Stem Growth in Bean (*Phaseolus vulgaris*) and Chickpea (*Cicer arietinum*) Plants with RDB Biochar Treatment. (a): Bean Plants, (b): Chickpea Plants.

2.2. The effect of RDO biochar on the growth of bean and chickpea plants

The data illustrate (Fig. 20) the leg length growth of bean and chickpea plants over a 35-day period with different soil treatments. Bean plants grown in soil treated with RDO AqE biochar showed significant growth, reaching 16.7 cm by day 35, while those in untreated soil reached 15 cm. Similarly, chickpea plants treated with RDO AqE biochar

achieved a maximum leg length of 8 cm, compared to 7 cm in untreated soil. This trend is consistent across all time points, with treated soils (RDO AqE biochar) consistently outperforming untreated soils in terms of leg length growth for both plant types, further highlighting the positive effect of biochar treatment on plant growth. Additionally, the previous analysis showed similar trends for RDB biochar treatments, indicating a general positive impact of biochar on the growth of both bean and chickpea plants across different biochar types.

(a) **(b)**

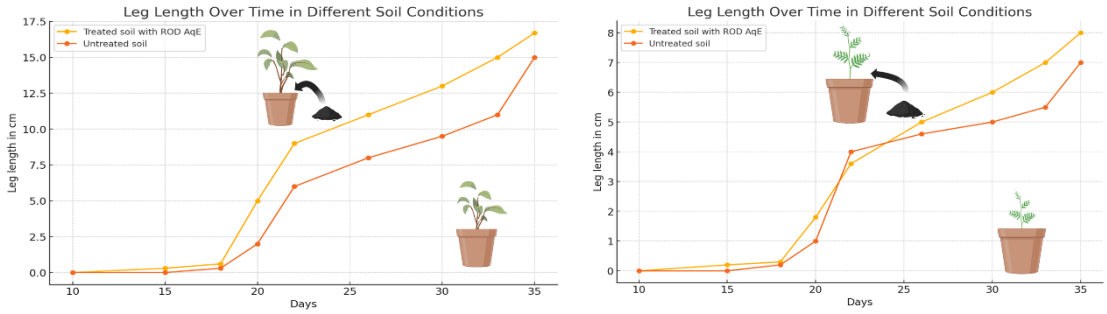


Figure 20: Comparative study of stem growth in bean (*Phaseolus vulgaris*) and chickpea (*Cicer arietinum*) plants with RDO biochar treatment. (a): Bean plants, (b): Chickpea plants.

2.3. The effect of RDF biochar on the growth of bean and chickpea plants

The data illustrate (Fig. 21) the leg length growth of bean and chickpea plants over a 35-day period with different soil treatments. Bean plants grown in soil treated with RDF AqE biochar showed the most significant growth, reaching 24 cm by day 35, while those in untreated soil reached 16 cm. Similarly, chickpea plants treated with RDF AqE biochar achieved a maximum leg length of 9 cm, compared to 7.5 cm in untreated soil. This trend is consistent across all time points, with treated soils (RDF AqE biochar) consistently outperforming untreated soils in terms of leg length growth for both plant types. These findings are consistent with previous observations using RDB and RDO biochar treatments, further highlighting the positive effect of biochar on the growth of bean and chickpea plants.

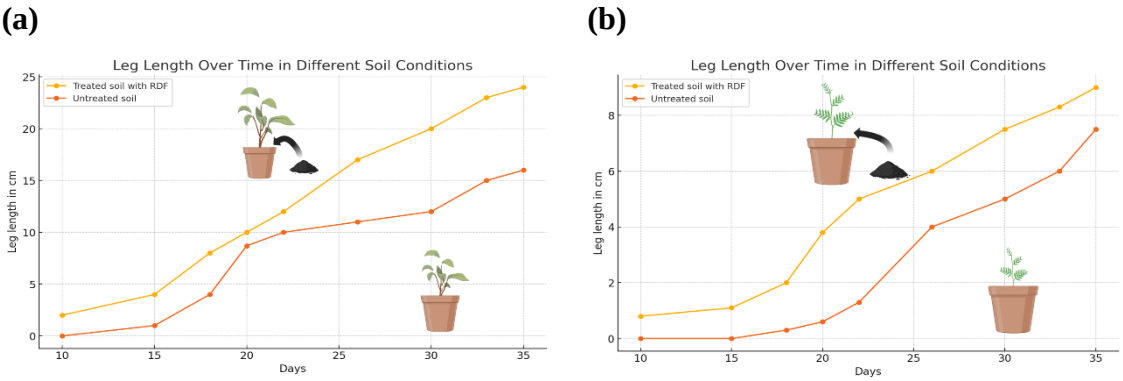


Figure 21: Comparative Study of Stem Growth in Bean (*Phaseolus vulgaris*) and Chickpea (*Cicer arietinum*) Plants with RDF Biochar Treatment. (a): Bean Plants, (b): Chickpea Plants.

The data (Fig.22) indicate that bean plants treated with RDF AqE biochar exhibited the highest leg length growth over a 35-day period, followed by those treated with RDB AqE, RDO AqE, and RDB MeE biochars, respectively. Similarly, for chickpea plants, the RDF AqE biochar treatment resulted in the greatest growth, with RDB AqE and RDB MeE showing comparable results, and RDO AqE providing moderate growth enhancement compared to untreated controls. The order of effectiveness for the biochar treatments, from most to least effective, is: RDF AqE > RDB AqE > RDB MeE > RDO AqE > untreated soil.

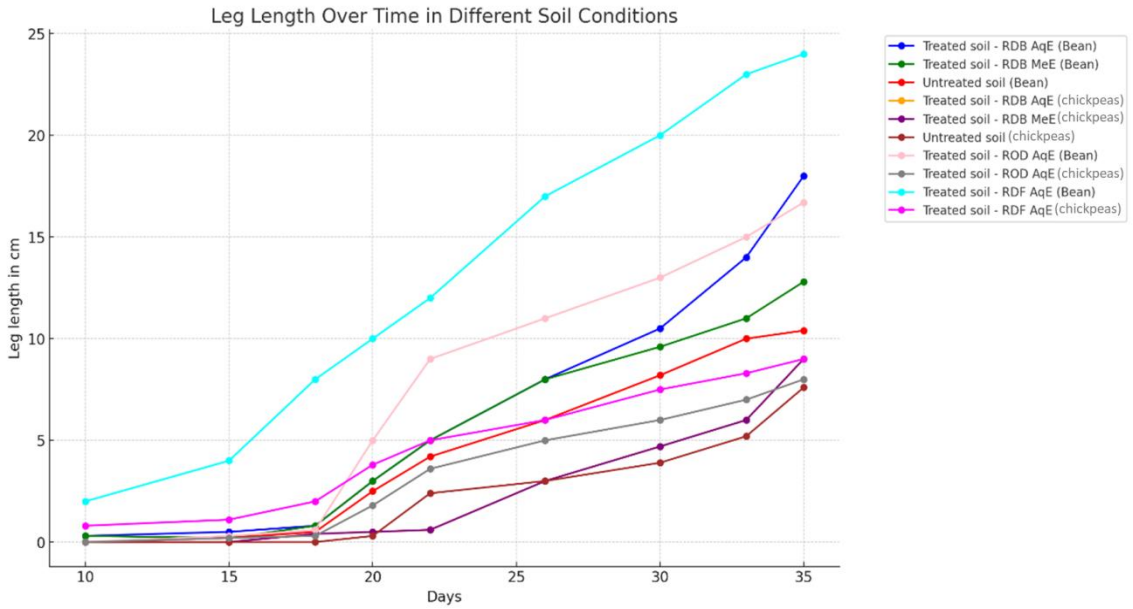


Figure 22: Comparative study of stem growth in bean (*Phaseolus vulgaris*) and Chickpea (*Cicer arietinum*) plants with RDF, RDO, and RDB biochar treatment, over a 35-day period.

DISCUSSION

The research aims to evaluate the impact of biochar derived from kitchen and market waste on the growth of *Phaseolus vulgaris* (bean) and *Cicer arietinum* (chickpea) plants, enhancing agricultural productivity. It seeks to identify **cost-effective**, **eco-friendly** biochar recycling methods that improve crop yields and family profitability.

I. Chemical screening Study

The results of the phytochemical and polyphenol analyses, it is evident that the extraction method significantly affects the concentration of various metabolites (Swallah, Sun et al. 2020). The findings align with previous studies indicating that methanolic extracts generally yield higher concentrations of phenolic compounds and flavonoids compared to aqueous extracts (Tab.10). For instance, Harborne and Baxter (2013) (Harborne and Mabry 2013), documented that methanol, as an organic solvent, effectively extracts a broader range of phenolic compounds due to its polar nature, which matches our observation that ROD MeE exhibits the highest concentrations of phenols (45.2 ± 0.114 mg GAEq/g) and flavonoids (20.3 ± 0.144 mg QEq/g) (Tab.11).

The higher yield of RDB AqE (18.2 ± 0.6%) compared to RDB MeE (14.9 ± 0.3%) suggests that aqueous extraction might be more effective for certain biomasses in terms of quantity, though it may yield lower concentrations of specific phytochemicals. This observation is consistent with previous findings that water extraction could produce higher overall yields but lower concentrations of targeted secondary metabolites like flavonoids and terpenoids (Yang, Wen et al. 2018).

In terms of specific metabolites, the absence of flavonoids in RDB extracts contrasts with their presence in ROD extracts, particularly ROD MeE, where intense red coloration indicated significant flavonoid content. This difference could be due to the inherent chemical composition of the raw materials used, as noted by previous studies emphasizing that the source material heavily influences the profile of extracted phytochemicals (Sadighara, Gharibi et al. 2012).

The high concentration of reducing sugars in RDB AqE (++++ in Tab. 10) is another point of interest, as it suggests a potential application for biochar derived from banana peels in bioenergy production, corroborated by studies highlighting the importance of high

sugar content in biomass for efficient biofuel conversion (Adamu, Bello et al. 2023, Giwa, Sheng et al. 2023).

II. Biological Activity in vitro

The antioxidant potency of ROD and RDB extracts, as measured by DPPH and FRAP assays, shows significant variations. ROD MeE has the lowest IC50 value (0.045 ± 0.01 mg/ml) in the DPPH activity test (Tab. 12), indicating higher antioxidant activity compared to ROD AqE, RDB AqE, and RDB MeE, with IC50 values of 0.08 ± 0.01, 0.09 ± 0.01, and 0.05 ± 0.01 mg/ml, respectively. In the FRAP activity test, ROD MeE also demonstrates a lower EC50 value (0.09 ± 0.01 mg/ml) compared to ROD AqE (0.15 ± 0.01 mg/ml), RDB AqE (0.18 ± 0.01 mg/ml), and RDB MeE (0.10 ± 0.01 mg/ml). The reference compound (AAs) shows the highest antioxidant activity with the lowest IC50 (0.0145 ± 0.005 mg/ml) and EC50 (0.068 ± 0.001 mg/ml) values. These results are consistent with previous studies that found methanolic extracts to have higher antioxidant activities due to their ability to dissolve a broader spectrum of antioxidant compounds (Fagbemi, Aina et al. 2022, Dolma, Shahar et al. 2024).

The measured SPF values indicate that ROD MeE exhibits the highest SPF value among the biochar extracts (18 ± 3), followed by RDB MeE (15 ± 2), ROD AqE (12 ± 2), and RDB AqE (8 ± 1). The commercial sunscreen Avene® demonstrates significantly higher SPF protection (41 ± 4) compared to all the tested extracts (Tab. 13). The variability in SPF values suggests that methanolic extracts generally provide higher sun protection than aqueous extracts, which is in line with studies showing that methanol is more effective at extracting UV-absorbing compounds (Salian, Dutta et al. 2021, Ameri, Khazaeli et al. 2024).

III. Evaluation of biochar effectiveness (RDB, RDO, RDF) on growth of bean and chickpea plants in desert sandy soil

The photos in (Fig. 18) demonstrate that both bean and chickpea plants grown in soil treated with RDB AqE biochar exhibited superior stem and leaf growth compared to those in untreated soil at all observed time points (18, 22, 33, and 35 days post-planting). This trend, consistently observed across the experiment, indicates a positive effect of RDB AqE biochar on plant growth. Similar observations were made with RDO and RDF biochar

treatments (Fig. 19, 20, and 21), further supporting the enhanced growth performance of biochar-treated plants. The data in (Fig. 22) illustrate that bean plants treated with RDF AqE biochar reached the highest leg length growth (24 cm by day 35), followed by those treated with RDB AqE, RDO AqE, and RDB MeE biochars. Chickpea plants showed a similar trend, with RDF AqE treatment resulting in the greatest growth (9 cm), followed by RDB AqE and RDB MeE. The order of effectiveness for the biochar treatments, from most to least effective, is: RDF AqE > RDB AqE > RDB MeE > RDO AqE > untreated soil.

These findings align with Lehmann et *al.* (2006), who reported that biochar enhances soil fertility and plant growth by improving nutrient retention and water-holding capacity (Lehmann, Gaunt et al. 2006). Rondon et *al.* (2007) found that biochar-treated soils supported better root development and higher biomass production (Rondon, Ramirez Orozco et al. 2007). Chan et al. (2007) highlighted that biochar can vary in effectiveness depending on its feedstock and production conditions, with green waste biochar showing significant benefits for soil amendment (Chan, Van Zwieten et al. 2007). Sohi et *al.* (2010) further confirmed that biochar's agronomic benefits are influenced by its physical and chemical properties (Sohi, Lopez-Capel et al. 2010).

Additionally, Glaser et *al.* (2002) demonstrated that biochar amendments could significantly increase crop yields by enhancing microbial activity and soil structure, particularly in nutrient-poor soils (Glaser, Lehmann et al. 2002). Another study by Karhu, Kristiina, et *al.* (2021) indicated that biochar combined with organic fertilizers improved maize yields by up to 150%, underscoring the synergistic effects of biochar and nutrient amendments (Karhu, Kalu et al. 2021, Ning, Liu et al. 2022). These examples from the literature support the observed positive impacts of RDB, RDO, and RDF biochar treatments on the growth of bean and chickpea plants in this study.

CONCLUSION

CONCLUSION

The study demonstrates that biochar derived from kitchen and market waste significantly enhances the growth of bean (*Phaseolus vulgaris*) and chickpea (*Cicer arietinum*) plants. The application of RDF (Dried Bean Peels) AqE (Aqueous Extract) biochar exhibited the highest effectiveness in promoting plant growth, followed by RDB (Raw Dried Banana Peels) AqE, RDB MeE (Methanolic Extract), and RDO (Red Dried Onion Peels) AqE. These results indicate that biochar can improve soil fertility by increasing nutrient availability and water retention, enhancing the photosynthetic efficiency and overall biomass of the plants.

Biochar's role in enhancing plant growth is attributed to its ability to improve soil structure, increase microbial activity, and provide essential nutrients. The findings support the potential of utilizing waste-derived biochar as an eco-friendly and cost-effective method to boost agricultural productivity and profitability. This approach not only addresses waste disposal issues but also contributes to sustainable agricultural practices by enhancing soil health and crop yields. The increased water use efficiency and reduced oxidative stress in plants treated with biochar further underline its beneficial impact under various environmental conditions, making it a valuable addition to modern agricultural systems.

REFERENCES

REFERENCES

- Abila, B. and J. Kantola (2019). "Waste management: relevance to environmental sustainability." International Journal of Environment and Waste Management **23**: 337.
- Aboody, M. S. A. and S. Mickymaray (2020). "Anti-Fungal Efficacy and Mechanisms of Flavonoids." Antibiotics (Basel) **9**(2).
- Adamu, H., U. Bello, A. U. Yuguda, U. I. Tafida, A. M. Jalam, A. Sabo and M. Qamar (2023). "Production processes, techno-economic and policy challenges of bioenergy production from fruit and vegetable wastes." Renewable and Sustainable Energy Reviews **186**: 113686.
- Agarwal, P. K., A. Singh, K. Gaurav, S. Goel, H. D. Khanna and R. K. Goel (2009). "Evaluation of wound healing activity of extracts of plantain banana (Musa sapientum var. paradisiaca) in rats." Indian J Exp Biol **47**(1): 32-40.
- Alan, A., A. Brants, E. Cobb, P. Goldschmied, M. Mutschler and E. Earle (2004). "Fecund gynogenic lines from onion (Allium cepa L.) breeding materials." Plant Science **167**: 1055-1066.
- Amalina, F., A. S. A. Razak, S. Krishnan, H. Sulaiman, A. W. Zularisam and M. Nasrullah (2022). "Biochar production techniques utilizing biomass waste-derived materials and environmental applications – A review." Journal of Hazardous Materials Advances **7**: 100134.
- Ameri, A., P. Khazaeli, B. Behnam, M. Mehrabani and H. Forootanfar (2024). "Formulation and optimization of phytosomes of ethanolic extract of Viola tricolor flowers using design of experiment (DOE) to evaluate in vitro photoprotective potential as sunscreen cream." Industrial Crops and Products **209**: 118057.
- Anhwange, B., J. Ugye and T. D. Nyiatagher (2009). "Chemical Composition of Musa sepientum (Banana) Peels." Electronic Journal of Environment, Agriculture and Food Chemistry **8**: 437-4442.
- Armi, A., H. Husainah, D. Sembiring, R. Roslina and E. Elvitriana (2023). "Processing of Your Banana Peel Waste (Mussa paradisiaca) into Organic Vinegar with the Addition of Acetobacter aceti bacteria." Jurnal Penelitian Pendidikan IPA **9**: 7606-7613.
- Artanti, G. D., C. Chayana and A. Fadiati (2023). "Analysis of Food Consumption Patterns as a Step for Mapping Future Food Needs Based on the Potential of Local Food."
- Atef, C., F. Anouar, A. El-Hadda and C. Azzedine (2015). "Phytochemicals study, antioxidant and antimicrobial activities of Helianthemum lippii (L.) pers. in different stages of growth (somatic, flowering and fruiting)." World J Pharm Pharm Sci **4**: 338-349.
- Balraj, G., P. Preethi, M. G and R. Selvaraj (2021). Banana**:** 43-114.

References

- Behiry, S. I., M. K. Okla, S. A. Alamri, M. EL-Hefny, M. Z. M. Salem, I. A. Alaraidh, H. M. Ali, S. M. Al-Ghtani, J. C. Monroy and A. Z. M. Salem (2019). "Antifungal and Antibacterial Activities of Musa paradisiaca L. Peel Extract: HPLC Analysis of Phenolic and Flavonoid Contents." Processes **7**(4): 215.
- Benítez, V., E. Mollá, M. A. Martín-Cabrejas, Y. Aguilera, F. J. López-Andréu, K. Cools, L. A. Terry and R. M. Esteban (2011). "Characterization of industrial onion wastes (Allium cepa L.): dietary fibre and bioactive compounds." Plant Foods Hum Nutr **66**(1): 48-57.
- Benny, N., R. Shams, K. K. Dash, V. K. Pandey and O. Bashir (2023). "Recent trends in utilization of citrus fruits in production of eco-enzyme." Journal of Agriculture and Food Research **13**: 100657.
- Benzie, I. F. and J. Strain (1999). [2] Ferric reducing/antioxidant power assay: direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. Methods in enzymology, Elsevier. **299:** 15-27.
- Berawi, K. and M. Bimandama (2018). "The Effect of Giving Extract Etanol of Kepok Banana Peel (Musa Acuminata) toward total Cholesterol Level on Male Mice (Mus Musculus L.) Strain Deutschland-denken-yoken (ddy) Obese." Biomedical and Pharmacology Journal **11**: 769-774.
- Bhavani, M., S. Morya, D. Saxena and C. Awuchi (2023). "Bioactive, antioxidant, industrial, and nutraceutical applications of banana peel." International Journal of Food Properties **26**.
- Bitocchi, E., D. Rau, E. Bellucci, M. Rodriguez, M. L. Murgia, T. Gioia, D. Santo, L. Nanni, G. Attene and R. Papa (2017). "Beans (Phaseolus ssp.) as a model for understanding crop evolution." Frontiers in plant science **8**: 251783.
- Boizot, N. and J.-P. Charpentier (2006). "Méthode rapide d'évaluation du contenu en composés phénoliques des organes d'un arbre forestier." Le Cahier des Techniques de l'INRA, In: Numéro spécial: 79-82.
- Brekke, J. E. and L. Allen (1966). "Banana dehydration."
- Britannica, T. (2020). "Editors of encyclopaedia." Argon. Encyclopedia Britannica.
- Chan, K. Y., L. Van Zwieten, I. Meszaros, A. Downie and S. Joseph (2007). "Agronomic values of greenwaste biochar as a soil amendment." Soil Research **45**(8): 629-634.
- Choudhary, D. R. (2018). Scientific Cultivation of Onion (Allium cepa L.)**:** 239-260.
- Chukwuka, K. S., A. O. Akanmu, O. Umukoro, M. D. Asemoloye and A. C. Odebode (2020). "Biochar: a vital source for sustainable agriculture." Biostimulants in Plant Science: 51-74.

References

- Clemente-Suárez, V. J., A. I. Beltrán-Velasco, L. Redondo-Flórez, A. Martín-Rodríguez and J. F. Tornero-Aguilera (2023). "Global Impacts of Western Diet and Its Effects on Metabolism and Health: A Narrative Review." Nutrients **15**(12).
- Cuendet, M., K. Hostettmann, O. Potterat and W. Dyatmiko (1997). "Iridoid glucosides with free radical scavenging properties from Fagraea blumei." Helvetica Chimica Acta **80**(4): 1144-1152.
- Czerwińska, K., M. Śliz and M. Wilk (2022). "Hydrothermal carbonization process: Fundamentals, main parameter characteristics and possible applications including an effective method of SARS-CoV-2 mitigation in sewage sludge. A review." Renewable and Sustainable Energy Reviews **154**: 111873.
- Debnath, S., A. Khan, A. Das, I. Murmu, A. Khan and K. Mandal (2019). Genetic Diversity in Banana**:** 217-241.
- Dehpour, A. A., M. A. Ebrahimzadeh, N. S. Fazel and N. S. Mohammad (2009). "Antioxidant activity of the methanol extract of Ferula assafoetida and its essential oil composition." Grasas y aceites **60**(4): 405-412.
- Deveoglu, O. (2022). "A Review on Onion Skin, a Natural Dye Source." Journal of Textiles Coloration and Polymer Science **19**: 307-319.
- Dias, J. S. (2012). "Major classes of phytonutriceuticals in vegetables and health benefits: A review." Journal of Nutritional Therapeutics **1**(1): 31-62.
- Dictionary, M.-W. (2019). "Merriam-Webster (2016)." Inc.: New York, NY, USA.
- Dolma, N., B. Shahar and N. Chongtham (2024). "Determination of Mineral elements, Antioxidant activity and Bio-active compounds of Allium prezewalskianum Regel, an Underutilized plant of Ladakh, India using ICP-AES, AAS and GC-MS." Measurement: Food: 100144.
- Duangkham, S. and P. Thuadaij (2023). "Characterization of charcoal briquettes produced from blending rice straw and banana peel." Heliyon **9**: e16305.
- Escalante, J., W.-H. Chen, M. Tabatabaei, A. T. Hoang, E. E. Kwon, K.-Y. Andrew Lin and A. Saravanakumar (2022). "Pyrolysis of lignocellulosic, algal, plastic, and other biomass wastes for biofuel production and circular bioeconomy: A review of thermogravimetric analysis (TGA) approach." Renewable and Sustainable Energy Reviews **169**: 112914.
- Evans, W. C. (2009). Trease and Evans' pharmacognosy, Elsevier Health Sciences.
- Fagbemi, K. O., D. A. Aina, M. O. Adeoye-Isijola, K. K. Naidoo, R. M. Coopoosamy and O. O. Olajuyigbe (2022). "Bioactive compounds, antibacterial and antioxidant activities of methanol extract of Tamarindus indica Linn." Scientific Reports **12**(1): 9432.

References

- Fatemeh, S., R. Saifullah, F. Abbas and M. Azhar (2012). "Total phenolics, flavonoids and antioxidant activity of banana pulp and peel flours: influence of variety and stage of ripeness." International food research journal **19**(3).
- Freitas, L. C., J. R. Barbosa, A. L. C. da Costa, F. W. F. Bezerra, R. H. H. Pinto and R. N. de Carvalho Junior (2021). "From waste to sustainable industry: How can agro-industrial wastes help in the development of new products?" Resources, Conservation and Recycling **169**: 105466.
- Fritsch, R. and N. Friesen (2002). "1 Evolution, Domestication and Taxonomy." Allium Crop Science: Recent Advances.
- Giwa, A. S., M. Sheng, N. J. Maurice, X. Liu, Z. Wang, F. Chang, B. Huang and K. Wang (2023). "Biofuel Recovery from Plantain and Banana Plant Wastes: Integration of Biochemical and Thermochemical Approach." Journal of Renewable Materials **11**(6).
- Glaser, B., J. Lehmann and W. Zech (2002). "Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal – a review." Biology and Fertility of Soils **35**(4): 219-230.
- Gogoi, N., B. Sarma, S. C. Mondal, R. Kataki and A. Garg (2019). "Use of biochar in sustainable agriculture." Innovations in sustainable agriculture: 501-528.
- Gowe, C. (2015). "Review on potential use of fruit and vegetables by-products as a valuable source of natural food additives." Food Sci. Qual. Manag **45**(1): 47-61.
- Griffiths, G., L. Trueman, T. Crowther, B. Thomas and B. Smith (2002). "Onions—a global benefit to health." Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives **16**(7): 603-615.
- Happi Emaga, T., R. H. Andrianaivo, B. Wathelet, J. T. Tchango and M. Paquot (2007). "Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels." Food Chemistry **103**(2): 590-600.
- Harborne, A. (1998). Phytochemical methods a guide to modern techniques of plant analysis, springer science & business media.
- Harborne, J. B. and T. J. Mabry (2013). "The flavonoids: advances in research."
- Hardin, C. F., C. Fu, H. Hisano, X. Xiao, H. Shen, C. N. Stewart, W. Parrott, R. A. Dixon and Z.-Y. Wang (2013). "Standardization of Switchgrass Sample Collection for Cell Wall and Biomass Trait Analysis." BioEnergy Research **6**(2): 755-762.
- Hikal, W. M., H. A. H. Said-Al Ahl, A. Bratovcic, K. G. Tkachenko, J. Sharifi-Rad, M. Kačániová, M. Elhourri and M. Atanassova (2022). "Banana Peels: A Waste Treasure for Human Being." Evid Based Complement Alternat Med **2022**: 7616452.

References

- Holm, L., J. Doll, E. Holm, J. V. Pancho and J. P. Herberger (1997). World weeds: natural histories and distribution, John Wiley & Sons.
- Igliński, B., W. Kujawski and U. Kiełkowska (2023). "Pyrolysis of Waste Biomass: Technical and Process Achievements, and Future Development-A Review." Energies **16**: 1829.
- Iwuozor, K. O., E. C. Emenike, E. O. Omonayin, J. O. Bamigbola, H. T. Ojo, A. A. Awoyale, O. A. A. Eletta and A. G. Adeniyi (2023). "Unlocking the hidden value of pods: A review of thermochemical conversion processes for biochar production." Bioresource Technology Reports **22**: 101488.
- Jaganath, I. B. and A. Crozier (2010). "Dietary flavonoids and phenolic compounds." Plant phenolics and human health: biochemistry, nutrition, and pharmacology **1**: 1-50.
- Jaiswal, A. K. (2020). Nutritional composition and antioxidant properties of fruits and vegetables, Academic Press.
- Jideani, A. I. and T. A. Anyasi (2020). Banana Nutrition: Function and Processing Kinetics, BoD–Books on Demand.
- Jing, X.-R., Y.-Y. Wang, W.-J. Liu, Y.-K. Wang and H. Jiang (2014). "Enhanced adsorption performance of tetracycline in aqueous solutions by methanol-modified biochar." Chemical Engineering Journal **248**: 168-174.
- Johnston, A., P. Poulton and K. Coleman (2008). "Chapter 1 Soil Organic Matter: Its Importance in Sustainable Agriculture and Carbon Dioxide Fluxes." Advances in Agronomy **101**: 1-57.
- Joković, N., J. Matejić, J. Zvezdanović, Z. Stojanović-Radić, N. Stanković, T. Mihajilov-Krstev and N. Bernstein (2024). "Onion Peel as a Potential Source of Antioxidants and Antimicrobial Agents." Agronomy **14**(3): 453.
- Júnior, J., Â. Santiago, P. Galdino, N. Santos, S. Barros, R. Almeida, I. Alves, P. Galdino, W. Marsiglia, C. Muniz and M. Mota (2020). "Osmotic Dehydration Process Study With Complementary Banana Peel Drying." Journal of Agricultural Studies **8**: 217.
- Kapadia, S. P., P. S. Pudakalkatti and S. Shivanaikar (2015). "Detection of antimicrobial activity of banana peel (Musa paradisiaca L.) on Porphyromonas gingivalis and Aggregatibacter actinomycetemcomitans: An in vitro study." Contemp Clin Dent **6**(4): 496-499.
- Karhu, K., S. Kalu, A. Seppänen, B. Kitzler and E. Virtanen (2021). "Potential of biochar soil amendments to reduce N leaching in boreal field conditions estimated using the resin bag method." Agriculture, Ecosystems & Environment **316**: 107452.

References

- Kibria, A., Kamrunnessa, M. Rahman and A. Kar (2020). "Extraction and Evaluation of Phytochemicals from Banana Peels (Musa sapientum) and Banana Plants (Musa paradisiaca)." Malaysian Journal of Halal Research **2**: 2616-1923.
- Knapp, F. and H. Nicholas (2006). "The Sterols and Triterpenes of Banana Pulp." Journal of Food Science **34**: 584-586.
- Kumar, M., M. Barbhai, M. Hasan, S. Dhumal, S. Singh, R. Pandiselvam, N. Rais, S. Natta, S. Marisennayya, N. Sinha, R. Amarowicz and B. Mrunal (2022). "Onion (Allium cepa L.) peel: A review on the extraction of bioactive compounds, its antioxidant potential, and its application as a functional food ingredient." Journal of Food Science **2022**: 1-23.
- Lehmann, J., J. Gaunt and M. Rondon (2006). "Bio-char Sequestration in Terrestrial Ecosystems – A Review." Mitigation and Adaptation Strategies for Global Change **11**.
- Leng, L. and H. Huang (2018). "An overview of the effect of pyrolysis process parameters on biochar stability." Bioresource Technology **270**: 627-642.
- Lihong, W., G. Jianing, W. Jian, A. Mahmood, A. Rasheed, M. U. Hassan, J. Al-Khayri, M. Aldaej, M. Sattar, A. Rezk, M. Al Maghaslah and W. Shehata (2023). "Biochar a promising amendment to mitigate the drought stress in plants: review and future prospective." Notulae Botanicae Horti Agrobotanici Cluj-Napoca **51**: 13447.
- Mansur, J. d. S., M. N. R. Breder, M. C. d. A. Mansur and R. D. Azulay (1986). "Determinaçäo do fator de proteçäo solar por espectrofotometria." An. Bras. Dermatol: 121-124.
- Maseko, K. H., T. Regnier, B. Meiring, O. C. Wokadala and T. A. Anyasi (2024). "Musa species variation, production, and the application of its processed flour: A review." Scientia Horticulturae **325**: 112688.
- Modak, M., P. Dixit, J. Londhe, S. Ghaskadbi and T. P. Devasagayam (2007). "Indian herbs and herbal drugs used for the treatment of diabetes." J Clin Biochem Nutr **40**(3): 163-173.
- Mohd Zaini, H., J. Roslan, S. Saallah, E. Munsu, N. S. Sulaiman and W. Pindi (2022). "Banana peels as a bioactive ingredient and its potential application in the food industry." Journal of Functional Foods **92**: 105054.
- Mondal, N. K. and A. Roy (2018). "Potentiality of a fruit peel (banana peel) toward abatement of fluoride from synthetic and underground water samples collected from fluoride affected villages of Birbhum district." Applied Water Science **8**(3): 90.
- Niazi, P., Z. Hekmatullah, M. Mohammad, A. Monib, M. Hassand, H. Ozturk, A. Azizi, M. Mansoor, M. Akhundzada and O. Alimyar (2023). "Biochar as a Fertilizer Replacement for Sustainable Agriculture." Journal for Research in Applied Sciences and Biotechnology **2**: 8-18.

References

- Niftiyev, I. (2023). "The Onion Sector in Azerbaijan: A Descriptive Analysis and Links to the Policy Decisions in 2023." SSRN Electronic Journal.
- Ning, C., R. Liu, X. Kuang, H. Chen, J. Tian and K. Cai (2022). "Nitrogen Fertilizer Reduction Combined with Biochar Application Maintain the Yield and Nitrogen Supply of Rice but Improve the Nitrogen Use Efficiency." Agronomy **12**(12): 3039.
- Ochar, K. and S.-H. Kim (2023). "Conservation and Global Distribution of Onion (Allium cepa L.) Germplasm for Agricultural Sustainability." Plants **12**(18): 3294.
- Oso, A. A. and A. O. Ashafa (2021). "Nutritional composition of grain and seed proteins." Grain and seed proteins functionality: 31-47.
- Pandey, A. (2021). "Food wastage: Causes, impacts and solutions." Sci. Herit. J **5**: 17-20.
- Patel, M., K. Dave and P. Patel (2021). "A REVIEW ON DIFFERENT EXTRACTION METHOD OF PLANTS: INNOVATION FROM ANCIENT TO MODERN TECHNOLOGY." **10(12)**: 511-527.
- Pereira, A. and M. Maraschin (2015). "Banana (Musa spp) from peel to pulp: ethnopharmacology, source of bioactive compounds and its relevance for human health." Journal of ethnopharmacology **160**: 149-163.
- Rasheed, A., H. Li, M. M. Tahir, A. Mahmood, M. Nawaz, A. N. Shah, M. T. Aslam, S. Negm, M. Moustafa, M. U. Hassan and Z. Wu (2022). "The role of nanoparticles in plant biochemical, physiological, and molecular responses under drought stress: A review." Front Plant Sci **13**: 976179.
- Reay, D. and D. Reay (2019). "Climate-smart bananas." Climate-smart food: 81-91.
- Ren, F. and S. Zhou (2021). "Phenolic components and health beneficial properties of onions." Agriculture **11**(9): 872.
- Rondon, M., J. Ramirez Orozco, M. D. Hurtado and J. Lehmann (2007). "Biological nitrogen fixation by common beans (Phaseolus vulgaris L.) increases with bio-char additions." Biology and Fertility of Soils **43**: 699-708.
- Rudra, S. G., J. Nishad, N. Jakhar and C. Kaur (2015). "Food industry waste: mine of nutraceuticals." Int. J. Sci. Environ. Technol **4**(1): 205-229.
- Sadighara, P., S. Gharibi, A. M. Jafari, G. J. Khaniki and S. Salari (2012). "The antioxidant and Flavonoids contents of Althaea officinalis L. flowers based on their color." Avicenna journal of phytomedicine **2**(3): 113.
- Salian, A., S. Dutta and S. Mandal (2021). "A roadmap to UV-protective natural resources: Classification, characteristics, and applications." Materials Chemistry Frontiers **5**(21): 7696-7723.

References

- Samota, M. K., M. Sharma, K. Kaur, Sarita, D. K. Yadav, A. K. Pandey, Y. Tak, M. Rawat, J. Thakur and H. Rani (2022). "Onion anthocyanins: Extraction, stability, bioavailability, dietary effect, and health implications." Front Nutr **9**: 917617.
- Sayre, R. M., P. P. Agin, G. J. LeVee and E. Marlowe (1979). "A comparison of in vivo and in vitro testing of sunscreening formulas." Photochemistry and Photobiology **29**(3): 559-566.
- Sethi, G., E. Cassou, L. Bedregal and L. Constantino (2021). "Eliminating Food Waste." N. Batini, The Economics of Sustainable Food: Smart policies for health and the planet: 157.
- Shabir, I., V. K. Pandey, A. H. Dar, R. Pandiselvam, S. Manzoor, S. A. Mir, R. Shams, K. K. Dash, U. Fayaz, S. A. Khan, G. Jeevarathinam, Y. Zhang, A. V. Rusu and M. Trif (2022). "Nutritional Profile, Phytochemical Compounds, Biological Activities, and Utilisation of Onion Peel for Food Applications: A Review." Sustainability **14**(19): 11958.
- Sharma, K., N. Mahato, S. H. Nile, E. T. Lee and Y. R. Lee (2016). "Economical and environmentally-friendly approaches for usage of onion (Allium cepa L.) waste." Food & function **7**(8): 3354-3369.
- Sharma, R., H. Oberoi and G. Dhillon (2016). Fruit and Vegetable Processing Waste**:** 23-59.
- Sindhu, R. K., J. R. Koo, C. K. Roberts and N. D. Vaziri (2004). "Dysregulation of hepatic superoxide dismutase, catalase and glutathione peroxidase in diabetes: response to insulin and antioxidant therapies." Clinical and experimental hypertension **26**(1): 43-53.
- Singh, A., R. Bharati, N. Manibhushan and A. Pedapati (2013). "An assessment of faba bean (Vicia faba L.) current status and future prospect." African journal of agricultural research **8**: 6634-6641.
- Slimestad, R., T. Fossen and I. M. Vågen (2007). "Onions: a source of unique dietary flavonoids." Journal of agricultural and food chemistry **55**(25): 10067-10080.
- Sohi, S., E. Lopez-Capel and R. Bol (2010). "Chapter 2 - A Review of Biochar and Its Use and Function in Soil." Advances in Agronomy **105**: 47-82.
- Šovljanski, O., V. Travičić, A. Tomić, J. Vulić, V. T. Šaponjac, G. Ćetković and J. Čanadanović-Brunet (2023). "From Agricultural Waste to Functional Food Products: An Overview." Agricultural Waste: Environmental Impact, Useful Metabolites and Energy Production: 489-520.
- Stoddard, F. L. (2017). "Grain legumes: an overview." Legumes in cropping systems: 70-87.
- Stoica, F., R. N. Rațu, I. D. Velești, N. Stănciuc and G. Râpeanu (2023). "A comprehensive review on bioactive compounds, health benefits, and potential food

applications of onion (Allium cepa L.) skin waste." Trends in Food Science & Technology **141**: 104173.

- Swallah, M. S., H. Sun, R. Affoh, H. Fu and H. Yu (2020). "Antioxidant potential overviews of secondary metabolites (polyphenols) in fruits." International journal of food science **2020**.
- Tayyab, M., F. Khalil, Z. Pang 庞孜钦, Z. Caifang, Y. Arafat, M. Rizwan, S. Waheed, M. Tarin, Z. Hua, K. Ahmad and W. Islam (2018). "Biochar: An efficient way to manage low water availability in plants." Applied Ecology and Environmental Research **16**.
- Tripathi, P., V. Sankar and K. E. Lawande (2017). "Microirrigation in onion (Allium cepa) and garlic (A. sativum) – a review." Current Horticulture **5**: 3-14.
- Uebersax, M., K. Cichy, F. Gomez, T. Porch, J. Heitholt, J. Osorno, K. Kamfwa, S. Snapp and S. Bales (2022). "Dry beans (Phaseolus vulgaris L.) as a vital component of sustainable agriculture and food security—A review." Legume Science **5**.
- V, B., L. K. S and R. K. S (2023). "Antioxidant and Anti-inflammatory Properties of the Two Varieties of Musa acuminata: An In Vitro Study." Cureus **15**(12): e51260.
- Varma, V. and D. P. Bebber (2019). "Climate change impacts on banana yields around the world." Nature Climate Change **9**(10): 752-757.
- Verheugen, G. (2006). "Commission recommendation of 22 September 2006 on the efficacy of sunscreen products and the claims made relating thereto." Official J Eur Union **265**: 39-43.
- Vithanage, M., V. Gunarathne and T. Bandara (2013). "Mini-review on influence of biochar for sustainable agriculture." J Food Agric. https://doi. org/10 **4038**.
- Vithanage, M., V. Gunarathne and T. Bandara (2013). "Mini-Review on Influence of Biochar for Sustainable Agriculture." Journal of Food and Agriculture **6**: 1.
- Wozniak, P., A. Bieńczak, S. Nosal, J. Piepiórka-Stepuk and M. Sterczyńska (2023). "Analysis and Modeling of the Onion Peeling Process in the Blowing Compressed Air Method." Processes **11**: 3138.
- Wu, Y., X. Wang, L. Zhang, Y. Zheng, X. Liu and Y. Zhang (2023). "The critical role of biochar to mitigate the adverse impacts of drought and salinity stress in plants." Front Plant Sci **14**: 1163451.
- Yadav, N. K., S. K. Singh, A. B. Patel, M. M. Meitei, D. K. Meena, M. K. Yadav, J. Lal and B. K. Choudhary (2023). Chapter 16 - Biochar production methods vis-a-vis aquaculture applications: a strategy for sustainable paradigm. Organic Farming (Second Edition). Sarathchandran, U. M.R, S. Thomas and D. K. Meena, Woodhead Publishing**:** 537-559.

References

- Yang, L., K.-S. Wen, X. Ruan, Y.-X. Zhao, F. Wei and Q. Wang (2018). "Response of plant secondary metabolites to environmental factors." Molecules **23**(4): 762.
- Zhao, X. X., F. J. Lin, H. Li, H. B. Li, D. T. Wu, F. Geng, W. Ma, Y. Wang, B. H. Miao and R. Y. Gan (2021). "Recent Advances in Bioactive Compounds, Health Functions, and Safety Concerns of Onion (Allium cepa L.)." Front Nutr **8**: 669805.
- Zubairu, A. and Y. Madu Mshelia (2015). "Effects of Selected Mordants on the Application of Natural Dye from Onion Skin (Allium cepa)." 26-32.

ANNEXE

ANNEXE

Table 1. DPPH Calibration Curve Data.

Concentration (mg/ml)	Absorbance (mean ± SD)
0.000	0.000 ± 0.022
0.005	0.078 ± 0.012
0.010	0.147 ± 0.110
0.015	0.215 ± 0.022
0.020	0.282 ± 0.043
0.025	0.338 ± 0.005

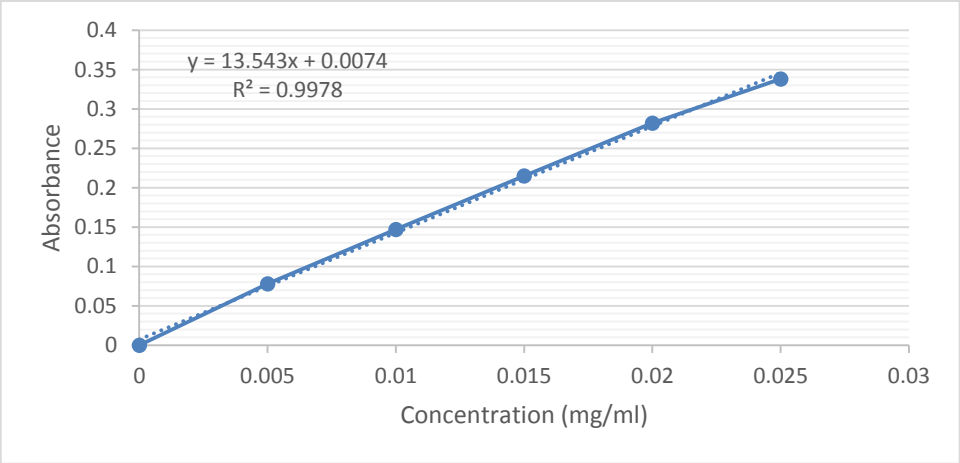


Figure 1. DPPH Calibration Curve.

Table 2. FRAP Calibration Curve Data.

Concentration (mg/ml)	Absorbance (mean ± SD)
0.000	0.000 ± 0.015
0.005	0.068 ± 0.036
0.010	0.128 ± 0.077
0.015	0.188 ± 0.126
0.020	0.236 ± 0.028
0.025	0.276 ± 0.001

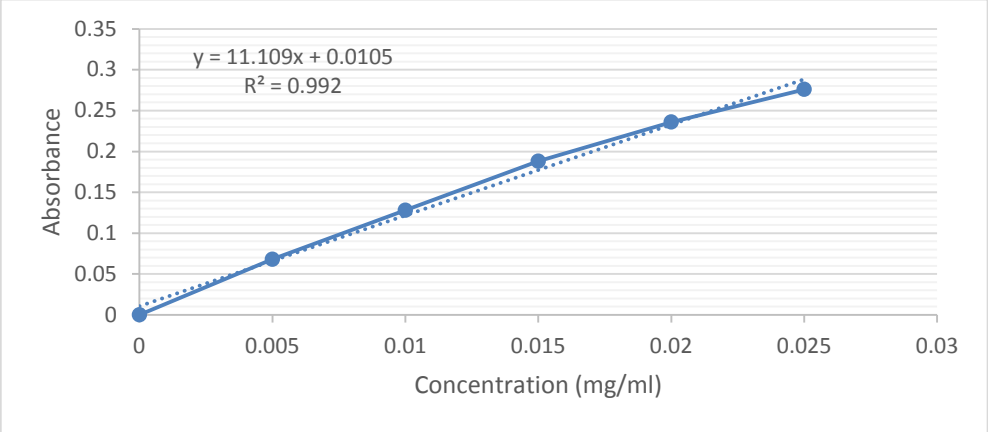


Figure 2. FRAP Calibration Curve.

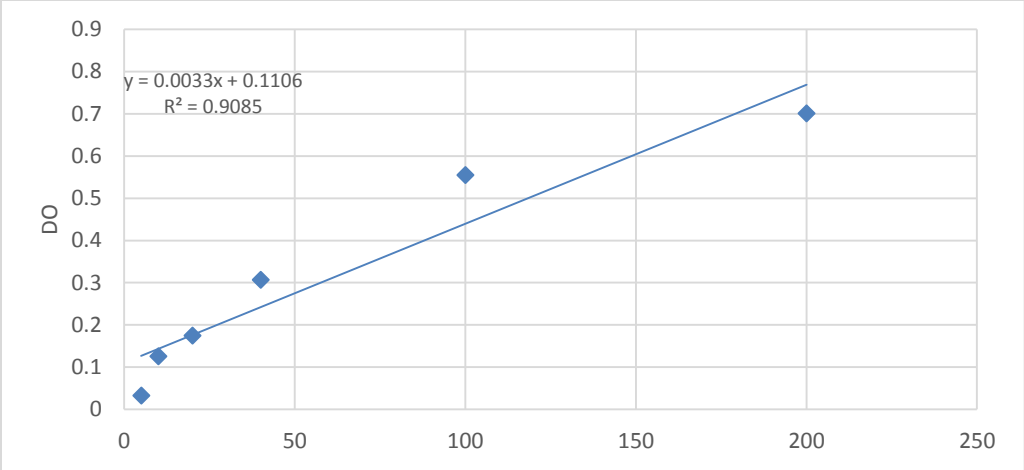


Figure 3. Quercetin Calibration Curve.

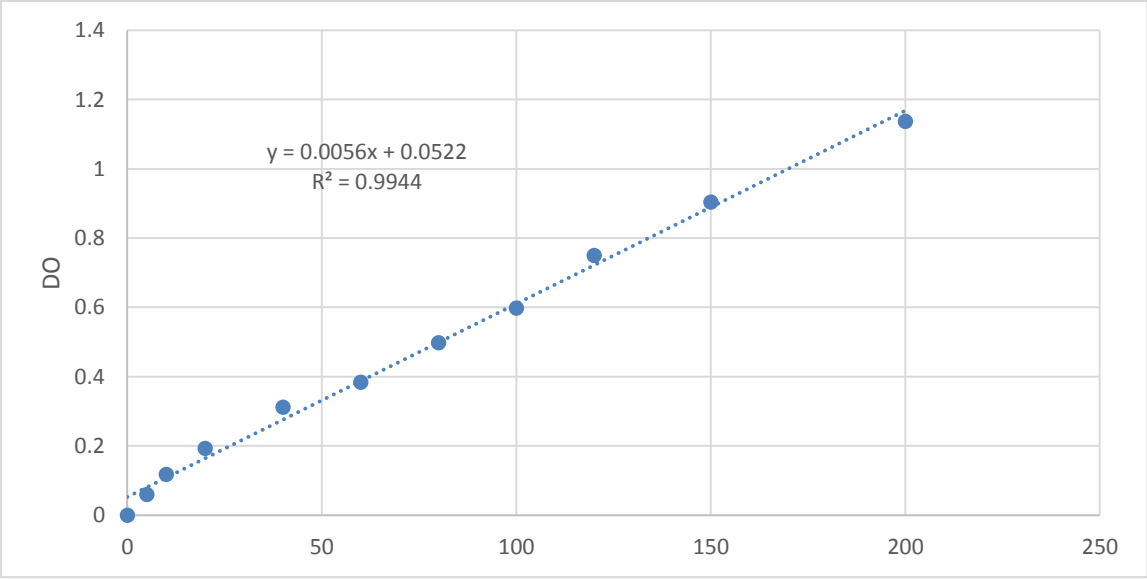


Figure 4. Gallic acid Calibration Curve.