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End of Study Memory

With a view to obtaining the Academic Master in Biological Sciences Speciality: Biodiversity and Environment

THEME

Valorization of biological waste in ecosystem conservation

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ABSTRACT

This research focuses on the evaluation of potato peels as a source of bioactive compounds with therapeutic and industrial potential. Following an in-depth literature review on biological residues and elements contained in potato peel, an aqueous extract was developed and analyzed.

The presence of flavonoids, polyphenols, saponins and tannins was confirmed by phytochemical analysis. Antioxidant tests such as , 2,2-diphenyl-1-picrylhydrazyl , and ,Ferric Reducing Antioxidant Power, revealed significant activity, associated with a high concentration of polyphenols (45.2 mg EAG/g). In vitro anti-inflammatory activity demonstrated an inhibitory impact on protein denaturation of 69.8%, comparable to the effect of a standard anti-inflammatory agent.

In vitro anti-inflammatory activity demonstrated an inhibitory impact on protein denaturation of 69.8%, comparable to the effect of a standard anti-inflammatory agent. Evaluation of antibacterial activity revealed moderate efficacy against the strains examined, particularly pronounced on Gram-positive bacteria.

These data suggest that potato skins can be incorporated into antioxidant, anti-inflammatory or antimicrobial products, thus contributing to the sustainable valorization of agri-food residues. The work concludes that further studies, particularly in vivo, are essential to confirm the use of these extracts in food, pharmaceutical or cosmetic applications.

Key words: potato peels, aqueous extract, 2,2-diphenyl-1-picrylhydrazyl, Ferric Reducing Antioxidant Power, anti-inflammatory activity, antibacterial activity.

Résumé

Ce travail de recherche se concentre sur l'évaluation des pelures de pommes de terre comme source de composés bioactifs ayant un potentiel thérapeutique et industriel. Suite à une analyse bibliographique approfondie sur les résidus biologiques et les éléments contenus dans la peau de pomme de terre, un extrait aqueux a été élaboré et analysé.

La présence de flavonoïdes, polyphénols, saponines et tannins a été confirmée par l'analyse phytochimique. Des essais antioxydants tels que 2,2-diphenyl-1-picrylhydrazyl et Ferric Reducing Antioxidant Power ont révélé une activité notable, associée à une concentration élevée en polyphénols (45,2 mg EAG/g). L'activité anti-inflammatoire in vitro a démontré un impact inhibiteur sur la dénaturation des protéines de 69,8%, comparable à l'effet d'un anti-inflammatoire standard.

L'activité anti-inflammatoire in vitro a démontré un impact inhibiteur sur la dénaturation des protéines de 69,8%, comparable à l'effet d'un anti-inflammatoire standard. L'évaluation de l'activité antibactérienne a révélé une efficacité moyenne contre les souches examinées, particulièrement prononcée sur les bactéries Gram positives.

Ces données laissent à penser que les peaux de pommes de terre peuvent être incorporées dans des produits antioxydants, anti-inflammatoires ou antimicrobiens, contribuant ainsi à une valorisation durable des résidus agroalimentaires.

Le travail conclut qu'il est essentiel de mener des études supplémentaires, notamment in vivo, pour confirmer l'utilisation de ces extraits dans les domaines alimentaire, pharmaceutique ou cosmétique.

Mots clé : pelures de pommes de terre, extrait aqueux, 2,2-diphenyl-1-picrylhydrazyl, Ferric Reducing Antioxidant Power, activité anti-inflammatoire, activité antibactérinne.

ملخص

يهدف هذا البحث إلى تقييم قشور البطاطس كمصدر غني بالمركبات النشطة بيولوجيًا، لما لها من إمكانات علاجية وصناعية واعدة. وقد تم ذلك من خلال مراجعة منهجية شاملة للدراسات السابقة ذات الصلة بالمخلفات البيولوجية ومكونات قشور البطاطس. بناءً على ذلك، تم إعداد مستخلص مائي من القشور وتحليله لتحديد خصائصه الكيميائية وتقييم نشاطه البيولوجي

تم التأكد من وجود مركبات الفلافونويد والبوليفينول والصابونين والعفص عن طريق التحليل الكيميائي النباتي .

كشفت اختبارات مضادات الاكسدة مثل 2,2-diphenyl-1-picrylhydrazyl و

Ferric Reducing Antioxidant Power عن نشاط كبير مرتبط بتركيز عال من البوليفينول (45.2 ملغم/غرام

من مادة EAG)

اظهر النشاط المضاد للالتهابات في المختبرتاثيرا مثبطا على تمسخ البروتين بنسبة 69.8 % وهو ما يمثل العامل القياسي

المضاد للالتهابات

أظهر النشاط المضاد للالتهابات في المختبر تأثيرًا مثبطًا على تمسخ البروتين بنسبة 69.8%، وهو ما يماثل تأثير العامل القياسي المضاد للالتهابات. كشف تقييم النشاط المضاد للبكتيريا عن فعالية معتدلة ضد السلالات التي تم فحصها، وظهرت بشكل خاص على البكتيريا موجبة الجرام.

تشير هذه البيانات إلى إمكانية دمج قشور البطاطس في المنتجات المضادة للأكسدة أو المضادة للالتهابات أو المضادة للميكروبات، مما يسهم في التثمين المستدام للمخلفات الزراعية الغذائية. ويخلص العمل إلى ضرورة إجراء مزيد من الدراسات، لا سيما في الجسم الحي، لتأكيد استخدام هذه المستخلصات في التطبيقات الغذائية أو الصيدلانية أو التجميلية

الكلمات المفتاحية: قشور البطاطس 2,2-diphenyl-1-picrylhydrazyl Ferric Reducing Antioxidant Power

المسخلص المائي . النشاط المضاد للالتهابات . النشاط المضاد للبكتيريا

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To the one I had in this life as a role model and teacher, and a support that did not lean... To my dear father, one with a big heart, a wise mind, and a caring hand... O you who taught me how patience is determination, how giving is without limits, and how glory is despite all burdens. You were the light that illuminated the darkness of the paths for me, the voice that encouraged me whenever I hesitated, and the prayer that accompanied me whenever I stumbled. Thanks to your wisdom, guidance, and noble stances, today I reap the fruits of your blessed planting. To you alone I dedicate this achievement, as a token of love and recognition of your unreturnable favour, and in recognition of your incomparable giving. May you always be a crown on my head and the pride of my heart as long as I live.

To a fountain of tenderness, a source of safety, and a spirit of good prayer...

To my dear mother, you who embraced me with your heart before your arms, and showered me with your unparalleled love. O you who have been a dwelling place for my heart, a tranquility for my soul, and a light for my soul... You were the answered prayer, the beautiful patience, the angel who wiped away all pain from me with a satisfied smile. How you stayed up for me, how patient you were with my toil, and how much you gave me of your kindness and tenderness without reckoning... This humble work is the fruit of your blessed prayers and the result of your great sacrifices.I dedicate it to you alone in gratitude, gratitude, and sincere love. I ask God to bless your life, and grant you eternal happiness and a paradise as wide as the heavens and the earth.

To myself...

To those who believed, were patient, and persevered against all odds... I dedicate this work in recognition of every moment of struggle and diligence, of every step I have taken with confidence and hope.

And to our beloved Gaza, the nation's throbbing wound, an icon of resilience and dignity... I present these pages to you as a token of loyalty and prayer, that God will strengthen your children, lift the affliction from you, and grant you victory soon.

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LIST OF ABBREVIATIONS

ATCC	American Type Culture Collection
DPPH	1,1-diphenyl-2-picrylhydrazyl
FRAP	Ferric Reducing Antioxidant Power
pH	Potential of Hydrogen
PBS	Phosphate-buffered saline
$AlCl_3$	Aluminum Chloride
IC50	50 % inhibitory concentration
TPTZ	2,4,6-Tripyridyl-s-triazine
ANOVA	Analysis of Variance
mL	Millilitre
Mg	Milligram
EAG	Exploitation Agricole
DM	Dry Matter
EQ	Equivalent

Introduction

The amount of garbage produced worldwide is rising dramatically as a result of a variety of activities, including household, industrial, and agricultural waste. Due to the high expense of treatment and disposal, as well as the potential for air, water, and soil pollution if improperly managed, this waste presents a significant environmental and financial problem. However, these wastes have a lot of potential that can be used through valorization processes to help the environment and the economy.

One such naturally occurring valuable biological waste is potato peels, a plentiful byproduct of both domestic consumption and the potato processing sector.

The ecosystem is hampered by the frequent large-scale disposal of these husks. Nonetheless, research indicates that potato peels are abundant in bioactive substances like fiber, carotenoids, and phenols that can support significant qualities like anti-inflammatory, antibacterial, and antioxidant activity.

The extraction of these valuable compounds from potato peels not only contributes to reducing the volume of waste and improving the management of residues, but also opens up new perspectives for their applications in fields as diverse as the food, pharmaceutical and cosmetic industries, promoting the concept of the circular economy and contributing to ecosystem conservation by reducing reliance on artificial sources.

Based on the above, this note is intended to explore the possibility of valorizing potato peels by studying their multiple biological activities, specifically antioxidant activity, antibacterial activity, and anti-inflammatory activity, with the aim of highlighting their added value and the possibility of using them in applications that contribute to preserving the ecosystem and human health.

Objectives of the memorandum:

This note is mainly intended to evaluate the valorization potential of potato peels by studying Their biological activities.

* Utilizing appropriate methods to extract active components from potato skins
* Assessing the antioxidant capacity of potato peel extracts through particular laboratory procedures.
* investigation on the antibacterial properties of potato peel extracts against several bacterial strains.

* Evaluation of potato peel extracts' anti-inflammatory properties utilizing appropriate test models.

* To talk about how the study's findings can be applied to the valuation of biological waste and its role in protecting ecosystems.

This thesis is presented in chapters. It consists of a general chapter followed by three chapters and a general conclusion.

The first chapter is devoted to the literature review which is divided into two parts in order to An overview of the potato peel world and its importance.

The second part is a summary of the work carried out on the three products studied, their Classifications their compositions and physical, chemical and biological properties.
The second chapter is devoted to the empirical study, which includes the objectives of the thesis project, an overview of environment and economy.
of the thesis project, an overview of the study sites and a discussion of the materials and methods The third chapter presents and discusses the results in relation to the bibliographical data of Algeria and its surroundings.Les données bibliographiques d'Algérie et du monde entier.

Part One: General information about biological waste

1. Definition of biowaste

Biowaste, also known as biowaste, is the term used to describe all materials of plant or animal origin that are capable of natural decomposition. It comes mainly from agriculture, the agri-food industry, household activities, catering and forestry. *(Adom, K. K.2002)*. Unlike inert or chemical waste, biowaste has a high potential for recovery through biological processes such as composting or methanization.

According to European Directive 2008/98/EC, biowaste includes food waste, green waste (lawn clippings, prunings), animal waste and organic by-products of industrial processing.

2. Classifying biological waste

Biowaste can be classified according to its origin *(Diaz et al., 2007):*

- ✓ Agricultural waste: crop residues, manure, slurry, fruit and vegetable waste, straw.
- ✓ Agro-industrial waste: from food processing (skins, pits, spent grains, etc.).
- ✓ Household waste: food scraps, peelings, coffee grounds, eggshells.
- ✓ Garden waste: dead leaves, grass clippings, small branches.
- ✓ Slaughterhouse waste: blood, bones, offal, animal fats.
- ✓ Sewage sludge: rich in organic matter and fertilizing elements.

3. Recycling methods and ecological impact

3.1 The different valuation methods

3.1.1. Composting

Composting is an aerobic biological process that transforms organic waste into stable humus, rich in fertilizing elements. It occurs naturally through the action of micro-organisms (bacteria, fungi) and decomposing organisms (worms, insects), offering the advantages the advantages of improved soil structure, reduced need for chemical fertilizers, though it requires maintaining a proper carbon/nitrogen balance and ensuring adequate aeration *(Bernal et al., 2009).*

3.1.2. Methanization

digestion, a process that breaks down organic matter in the absence of oxygen, yields biogas, primarily methane, alongside a nutrient-rich digestate, offering benefits such as renewable energy production and greenhouse gas reduction, with applications in agricultural power plants and wastewater treatment facilities *(Appels et al., 2008).*

3.1.3. Extraction of bioactive compounds

The bioactive substances that are recovered from organic waste have a variety of uses and provide major benefits for the environment and economy. With their diverse biological functions, these naturally occurring chemicals offer important resources for a wide range of sectors *(Valorization of Agri-Food Waste, 2024).*

These extracts have potential applications in the food industry as natural colorants, antioxidants, and antimicrobials that enhance food safety and preservation. Most importantly, they aid in the creation of nutraceuticals and functional foods that may improve human health *(Parra-Pacheco et al., 2024).*

These chemicals' anti-inflammatory, antioxidant, and skin-protective properties can greatly assist the cosmetics sector by facilitating the development of skincare and personal care products that are sustainable and derived from natural sources *(Figshare, 2025).*

Additionally, the pharmaceutical industry can investigate these waste-derived compounds' potential as active pharmaceutical components or innovative drug candidates with a range of therapeutic qualities, which might help address unmet medical needs *(scielo, 2024).*

In addition to these important sectors, bioactive chemicals that have been isolated can be usefully used in agriculture as biopesticides or biofertilizers to encourage more environmentally friendly agricultural methods. Additionally, the residual biomass after extraction may be further valorized using techniques like composting or anaerobic digestion, guaranteeing optimal resource use and low waste production *(Shoko, 2018).*

3.1.4. Animal feed production

Fruit and vegetable residues or abattoir by-products can be transformed into animal feed after drying or controlled fermentation.

4.Biowaste: From Environmental Burden to Sustainable Resource

Poor management of bio-waste fuels multiple forms of pollution, including air pollution through potent methane emissions (25 times more impactful than CO_2), soil pollution from uncontrolled dumping and pathogen accumulation, and water pollution via nitrate leaching and organic contamination; furthermore, it encourages pest proliferation and results in the loss of valuable unused resources like organic matter, energy, and nutrients. Therefore, with proper management, this nuisance can be transformed into a valuable resource *(Khan et al., 2021).*

An important chance to lessen the heavy environmental burden of biowaste disposal is provided by the recovery of useful molecules from it. Biowaste landfills contribute significantly to greenhouse gas emissions, particularly methane (CH_4), which has a potential to cause global warming that is several times greater than that of carbon dioxide (CO_2) *(EPA, 2024; Kunak, 2025).* According to the European Commission, a significant portion of greenhouse gas emissions in the EU alone came from the landfilling of biodegradable garbage.

Anaerobic digestion is another significant biowaste treatment technique that has the dual benefits of generating biogas (mostly methane), a renewable energy source, and a digestate that is nutrient-rich and may be used as fertilizer *(EPA, 2025).* By capturing methane for energy production, anaerobic digestion significantly reduces its escape into the atmosphere, hence reducing greenhouse gas emissions *(EPA, 2025).* Furthermore, the digestate might replace the requirement for energy-intensive synthetic fertilizers.

Overall, with the right recovery techniques, what is regarded as pollution due to inadequate waste management can be turned into a resource that encourages environmental innovation, generates renewable energy, and improves soil health. Achieving long-term sustainability objectives and lessening the environmental impact of biowaste are made possible by its valuation. *(Valorization of Agri-Food Waste, 2024).*

Part Two: General information about potato peels

.1 Introduction:

The potato (Solanum tuberosum) is one of the world's most important food crops, playing a crucial role in the food security of many populations. Its industrial and domestic processing generates considerable quantities of by-products, of which peels represent a significant fraction. Historically considered as waste, peels are increasingly recognized as a valuable source of bioactive compounds and potentially valuable biomass.

Contrary to common perception, the potato peel is not simply an inert coating. It constitutes a protective barrier rich in complex chemical compounds, developed by the plant to defend itself against environmental stresses, pathogens and predators. This chemical richness translates into the presence of a variety of dietary fibers, a notable concentration of polyphenols with proven antioxidant properties, glycoalkaloids with potentially therapeutic effects (although requiring careful handling), as well as essential vitamins and minerals.

The growing interest in the valorization of agricultural by-products is part of an overall circular bioeconomy approach, aimed at reducing waste, optimizing the use of natural resources and creating new value chains. In this context, potato peels are emerging as a promising raw material for a diverse range of applications, from improving human and animal nutrition to producing sustainable materials and extracting molecules of interest for the pharmaceutical and cosmetics industries *(Bora et al., 2020; Nowak et al., 2018).*

2. Genesis and scale of potato peel production

Potato peel production is intrinsically linked to the entire potato processing chain. Large-scale food industries, specializing in the production of frozen French fries, crispy potato chips, instant mashed potato flakes and potato starch, generate massive quantities of peelings as their main by-product. The mechanical or chemical peeling processes used in these industries aim to obtain tubers ready for processing, leaving behind a significant stream of organic matter *(Rybarczyk et al., 2019).*

At the same time, a not inconsiderable quantity of peelings is generated at household level during meal preparation. Although individual volumes are small, population-wide accumulation also represents a considerable source of biomass, often directed to landfill or domestic composting.

Precise estimates of global potato peel production volumes are complex due to the diversity of production and consumption systems. However, considering the global annual production of potatoes, which amounts to hundreds of millions of tonnes, it is clear that peelings represent a substantial organic waste stream. The management and recovery of this flow represents a major environmental and economic challenge.

The characteristics of the peels produced can vary significantly depending on several key factors:

Potato variety: Different varieties have varying skin thicknesses, chemical compositions and glycoalkaloid contents *(Andre et al., 2014).*

Growing conditions: Soil type, climate, farming practices (pesticide use, fertilization) can influence peel composition *(Hamouz et al., 2010).*

Processing: Peeling methods (abrasion, steam, chemical) can affect peel integrity and the presence of residues *(Talburt and Smith, 1987).*

Storage conditions: The temperature, humidity and length of time potatoes are stored before processing can alter the composition of the peel, in particular by increasing the concentration of glycoalkaloids in the sprouts and eyes *(Bushway et al., 1986).*

Understanding these factors is essential for optimizing potato peel collection, preservation and recovery strategies, with a view to obtaining quality raw materials for the applications envisaged.

3. Anatomy and Detailed Chemical Composition of Potato Peels:

The potato peel is a complex structure, composed of several layers of cells that protect the underlying parenchyma. Anatomically, it comprises the epidermis, the subereous cortex (or phellogen), and the phelloderm. These different layers contribute to the peel's heterogeneous chemical composition.

Chemically speaking, potato peels are a reservoir of various bioactive compounds:

3.1. Dietary fiber:

Mainly cellulose, hemicellulose and pectin. These fibers play a crucial role in digestive health by promoting intestinal transit, modulating nutrient absorption and contributing to satiety. The proportion and type of fiber may vary according to the variety and processing of the peel *(Anderson et al., 1991).*

3.2. Polyphenols:

This is one of the most interesting classes of compounds found in potato peels. Phenolic acids such as chlorogenic acid (the most predominant), caffeic acid, ferulic acid and gallic acid are abundant. Flavonoids, notably anthocyanins (in flesh- and skin-colored varieties), catechins and quercetins, are also present. These polyphenols are powerful antioxidants, capable of neutralizing free radicals and protecting cells against oxidative damage *(Naczk and Shahidi, 2004).* The concentration and profile of polyphenols can be influenced by variety, growing conditions and storage *(Lewis et al., 1999).*

3.3. Glycoalkaloids:

Solanine and chaconine are the two main glycoalkaloids present in potatoes, with significantly higher concentrations in peels, sprouts and eyes. These compounds are the plant's natural defense mechanisms against insects, fungi and bacteria. At high concentrations, they can be toxic to humans, causing gastrointestinal and neurological disorders. However, at low doses, some glycoalkaloids have shown interesting biological activities, such as anticancer and antimicrobial properties *(Friedman, 2006).*

3.4. Vitamins and minerals:

Peels contain appreciable quantities of essential minerals such as potassium (involved in water balance and nerve function), iron (involved in oxygen transport), magnesium (cofactor of many enzymes) and calcium (essential for bone health). It also contains vitamins, notably vitamin C (a powerful antioxidant and enzyme cofactor) and certain B-group vitamins (involved in energy metabolism) *(Augustin et al., 2008).*

3.5. Other compounds :

Peels also contain proteins, lipids in small quantities, and various other secondary metabolites that may contribute to their functional properties.

Detailed analysis of the chemical composition of potato peels is fundamental to identifying compounds of interest and determining the most appropriate valorization strategies, taking into account the food safety aspects associated with glycoalkaloids.

4. Antioxidant properties of potato peels:

Oxidative stress, resulting from an imbalance between the production of free radicals and the body's ability to neutralize them, is implicated in the development of many chronic diseases, such as cardiovascular disease, cancer, diabetes and neurodegenerative disorders. Antioxidants play a crucial role in protecting against this stress by scavenging free radicals and inhibiting oxidation reactions.

Potato peels are distinguished by their high antioxidant capacity, mainly due to their high content of phenolic compounds, notably chlorogenic acids and anthocyanins (in coloured varieties). These compounds have chemical structures that enable them to donate electrons to free radicals, stabilizing them and making them less reactive *(Shahidi and Naczk, 1995).*

Numerous in vitro studies have assessed the antioxidant activity of potato peel extracts using different evaluation methods, such as:

DPPH (2,2-diphenyl-1-picrylhydrazyl): A test based on the antioxidant's ability to reduce a stable free radical.

ABTS (2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)): Another commonly used method for measuring free radical scavenging capacity.

FRAP (Ferric Reducing Antioxidant Power): A test that measures an antioxidant's ability to reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}).

The results of these studies have consistently demonstrated a significant antioxidant activity of potato peel extracts, often superior to that of tuber flesh and comparable to that of certain fruits and vegetables known for their antioxidant properties *(Ezekiel et al., 2013; Singh et al., 2016).* Total polyphenol concentration is generally positively correlated with measured antioxidant activity.

These antioxidant properties suggest the potential use of potato peel extracts as functional ingredients in food and feed, as well as in the formulation of dietary supplements or nutraceuticals aimed at preventing oxidative stress and its consequences on health.

5. Potential Antimicrobial Activity of Potato Peels:

The emergence of antibiotic-resistant bacterial strains and the search for natural alternatives for food preservation have stimulated interest in the antimicrobial properties of plant extracts and agricultural by-products. Potato peels have been the subject of some preliminary studies exploring their antimicrobial potential.

Certain compounds present in peels, such as polyphenols and glycoalkaloids, could be responsible for this activity. Potential mechanisms of action include disruption of microbial cell membranes, inhibition of enzymes essential for bacterial or fungal growth, and interference with biofilm formation *(Oskay, 2011).*

In vitro studies have reported the inhibitory activity of potato peel extracts against various pathogenic bacteria, such as Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa, as well as certain fungi such as Candida albicans *(чним та інші, 2017 ; та інші, 2018).* However, results often vary depending on the extraction method, solvent used, extract concentration and microbial strains tested.

It is important to note that the antimicrobial activity of glycoalkaloids is well documented, but their potential toxicity to human cells requires rigorous evaluation of doses and application patterns.

Further research is needed to identify the specific compounds responsible for the antimicrobial activity of potato peels, elucidate their mechanisms of action, evaluate their efficacy against a wider spectrum of micro-organisms andorganisms, and especially to determine their safety for use in food or therapeutic applications.

6. Various Ways of Enhancing Potato Peels:

The versatile composition of potato peels opens up a multitude of potential applications, contributing to a circular economy and waste reduction

Animal feed: After appropriate treatment to reduce glycoalkaloid content (washing, cooking, silage), the peels can be incorporated into livestock feed as a source of fiber, carbohydrates and minerals. Studies have shown their potential in feeding ruminants, pigs and poultry *(Islam et al., 2016; Te ti nší, 2021).*

Biofuel production: The starch and sugar content of peels can be used to produce bioethanol through microbial fermentation processes. Cellulose and hemicellulose can also be converted into second generation bioethanol by enzymatic or thermochemical treatments *(Loiseau et al., 2018; Singh et al., 2020).* The production of biogas by anaerobic digestion of skins is also an energy recovery route *(Zhang et al., 2007).*

Extraction of bioactive compounds: The polyphenols present in peelings can be extracted and purified to be used as natural antioxidants in the food industry (for food preservation), cosmetic (in anti-aging formulations) or pharmaceutical (as potential food supplements or therapeutic agents) *(Ali et al., 2021; Hossain et al., 2022).* Glycoalkaloids, after extraction and purification, could also find pharmaceutical applications at controlled doses.

Bioplastics and materials production: Cellulose fibres extracted from peels can be used as a reinforcing filler in the production of biodegradable composites or bioplastics, helping to reduce dependence on synthetic polymers derived from petroleum *(Kaur et al., 2020; Reddy et al., 2014)*

Soil amendment and biofertilizer production: Composting potato peels yields a nutrient-rich organic soil amendment that can improve soil structure and fertility *(Zubeldia et al., 2018).* Extraction of certain compounds from peels may also lead to the production of biofertilizers or biopesticides *(Kumar et al., 2019).*

Enzyme production: Potato peels can be used as a substrate for growing micro-organisms capable of producing industrial enzymes *(Pandey et al., 2000).*

7. Challenges and Prospects of Potato Peel Valorization

Despite the promising potential of potato peel enhancement, several challenges need to be overcome for large-scale implementation

Variability in composition: The chemical composition of peels can vary considerably depending on the potato variety, growing conditions, processing process and storage, This can make it difficult to standardise valuation processes.

Glycoalkaloid content: The presence of toxic glycoalkaloids requires specific treatments to ensure the safety of products derived from peels, especially in food and animal applications.

Collection and transportation costs: The dispersed nature of peel sources (especially at home) can lead to high collection and transportation costs.

Stability and preservation: Peelings are rich in water and organic matter, making them prone to rapid microbial degradation. Effective conservation methods (drying, silage) are necessary to ensure their availability throughout the year.

Consumer and industry acceptance: The integration of potato peel products into existing value chains requires consumer acceptance and demonstration of their effectiveness and safety by industry.

Part III: Extraction Methods of Bioactive Compounds from Potato Peels

1.Overview of Extraction Principles

A vital phase in the value-adding process of agro-industrial leftovers, such as potato peels, is the extraction of bioactive chemicals. Target compounds like vitamins, dietary fibers, polyphenols, and glycoalkaloids are isolated during this process without losing any of their bioactivity. The solvent's type and polarity, the extraction process's temperature and time, and the raw material's pre-treatment (such as drying or grinding) all affect how well an extraction method works. Furthermore, the stability and solubility of the targeted molecules under specific conditions are directly related to efficiency. Recent studies have focused on green extraction methods that maximize yield and selectivity while reducing solvent use, energy consumption, and environmental risks in response to growing concerns about environmental sustainability *(Chemat et al., 2012)*Prior to choosing or refining a technique for usage in industry or the lab, it is essential to comprehend these foundational concepts.

2. Extraction methods

2.1. Conventional Extraction Methods

Solvent extraction, which uses solvents like water, ethanol, methanol, or acetone to dissolve certain chemicals from the solid matrix of the potato peel, is one of the most widely used techniques for obtaining bioactive compounds. It is a simple, economical approach that is frequently used in both industry and research. Long extraction durations, high solvent consumption, and the possibility of heat-sensitive bioactives degrading from extended exposure to high temperatures are some of its drawbacks *(Azmir et al., 2013).* Soxhlet extraction is another traditional technique that involves continually refluxing the sample with a boiling solvent in a closed environment. This method guarantees thorough extraction and repeatability, especially for chemicals that are semi-polar or non-polar, including glycoalkaloids and certain phenolics. However, because of the high working temperatures, Soxhlet extraction is frequently time-consuming, energy-intensive, and might not be appropriate for thermolabile chemicals *(Azmir et al., 2013).*

2.2. Innovative and Green Extraction Techniques

A number of contemporary extraction technologies have surfaced in reaction to the drawbacks of traditional methods, providing more effective and environmentally friendly substitutes. One such technique is Ultrasound-Assisted Extraction (UAE), which uses ultrasonic waves to create cavitation bubbles that break down plant cell walls and make it easier for solvents to penetrate. While maintaining the integrity of delicate molecules, UAE can drastically cut down on extraction time and solvent consumption *(Dahmoune et al., 2014).* Microwave-Assisted Extraction (MAE) is another efficient method that uses microwave radiation to quickly heat the sample and solvent, rupturing cells and releasing intracellular components quickly. MAE is particularly advantageous for extracting thermolabile polyphenols and antioxidants due to its quick processing and minimal solvent needs *(Zhang et al., 2011).* Supercritical Fluid Extraction (SFE), a more sophisticated method, usually uses supercritical CO_2 to extract non-polar substances such lipophilic glycoalkaloids and essential oils. Although this method requires specialized high-pressure equipment, it works in very mild conditions and yields extracts without the use of solvents *(Herrero et al., 2010).* The last method is Enzyme-Assisted Extraction (EAE), which provides a biologically friendly way to liberate firmly bound substances by breaking down cell wall structures with the help of enzymes including cellulases and pectinases. According to *(Nadar et al. 2018)*, EAE is especially well-suited for the extraction of fibers and hydrophilic antioxidants, and it fits in nicely with clean-label and green processing trends.

2.3. Parameters Affecting Extraction Efficiency

Numerous crucial factors that affect the amount and caliber of the compounds recovered determine how effective an extraction process is. One important consideration is particle size; smaller particles improve diffusion and solubilization by increasing the surface area available for solvent interaction. The results are also greatly influenced by the drying techniques used; because there is no thermal degradation, freeze-drying typically maintains bioactives better than oven-drying. Furthermore, the solvent's extraction capacity is determined by its solvent-to-solid ratio; a ratio that is too low could lead to saturation, while a ratio that is too high could dilute the extract and necessitate unnecessary downstream processing. Ionic strength and extraction pH are additional important variables that impact the stability and solubility of specific chemicals, including vitamins and polyphenols. Therefore, it is crucial to optimize these factors to guarantee efficiency, scalability, and reproducibility in extractions conducted at the lab and industrial scales *(Chemat et al., 2012; Azmir et al., 2013).*

2.4. Selection of Method Depending on Target Application

The type of target chemicals and their intended application have a major role in selecting the best extraction method. For instance, due to their vulnerability to prolonged heat and oxidation, polyphenols—which are known for their antioxidant potential—are best extracted using UAE or MAE. These substances are used in cosmetic formulations, nutraceuticals, and food preservation. Pharmaceutical research is the main focus of glycoalkaloids, which are more successfully isolated using Soxhlet or SFE procedures and have both medicinal and toxicological qualities. Enzyme-assisted or aqueous extraction techniques are used for dietary fibers, particularly when creating functional foods or supplements for animal feed. Generally speaking, antioxidants are commonly extracted via solvent or UAE extraction and are used in a variety of industries, such as food and cosmetics. Last but not least, water-soluble vitamins and minerals are usually extracted using aqueous or acidified media and used as food additives or biofortification components. Therefore, the extraction process selection needs to take into account the bioactive compounds' chemical makeup, stability profile, and regulatory limitations in addition to economic and environmental factors.

Part V: Separation and purification techniques for bioactive compounds

1. Importance of separation in the recovery of extracts

After extraction, the bioactive compounds from potato peels are present in a complex mixture containing undesirable secondary constituents such as soluble sugars, proteins, pigments, cell fragments, organic acids and mineral salts. The separation of these components is an essential step to obtain standardized extracts, concentrated and pure, which can be used for food, pharmaceutical, cosmetic or agricultural purposes.

Purification increases the bioavailability and stability of molecules of interest while eliminating substances that could reduce their efficacy or safety (such as some high-dose toxic glycoalkaloids). These separation operations must be carefully selected according to the physico-chemical properties of the target compounds: solubility, polarity, molar mass, charge, volatility, thermal stability, etc. In addition, the environmental impact, the energy cost and the possibility of industrial scale must be considered in an eco-innovative approach, consistent with the principles of circular economy and green chemistry *(Chemat et al., 2013).*

2. Separation methos

2.1. Solid-liquid and liquid-liquid separation techniques

2.1.1. Solid-liquid separation

The solid-liquid separation is the initial purification step, essential after solvent or water extraction. It aims to remove residues of vegetable matrices, insoluble particles and coarse fibres.

Filtration is carried out with paper filters, sieves or membranes. It can be gravity or vacuum to improve the separation speed.

Centrifugation, on the other hand, uses centrifugal force to separate heavy suspended solids. It is very useful when the extracts contain fine colloidal particles that are difficult to filter.

These operations allow to obtain a clarified extract, ready for more selective steps *(Azmir et al., 2013).*

2.1.2. Liquid-liquid extraction (ELL)

The ELL consists of separating two non-miscible liquid phases (often an aqueous phase and an organic phase), in order to distribute the compounds according to their chemical affinity. This technique is widely used for polyphenols, which are more soluble in semi-polar solvents such as ethanol, ethyl acetate or butanol. For example, an aqueous peel extract can be washed with ethyl acetate to enrich the organic phase with phenolic acids such as chlorogenic acid. This technique is relatively simple, but precautions are needed to avoid the formation of emulsions and loss of volatile compounds *(Dai et al., 2010).*

2.2. Membrane techniques

Membrane processes have become essential in the processing of plant extracts because of their low environmental impact, their ability to operate continuously and their adaptability to industrial processes *(Cassano et al., 2013).*

Microfiltration (MF) (0.1–10 µm) is used to clarify raw extracts.

Ultrafiltration (UF) (1–100 kDa) retains proteins and polysaccharides, while allowing low molecular weight molecules such as phenols to pass.

Nanofiltration (NF) (300–1000 Da) is effective in concentrating polyphenols, while removing mineral salts and small molecules.

Reverse osmosis (RO) allows for near total retention of solutes and is ideal for concentration of aqueous extracts before drying.

These technologies also have the advantage of being integrable to biorefineries using little or no solvents, with high yields (>85%) for polyphenols. However, limitations such as fouling (fouling) can affect the life and efficiency of modules *(Conidi et al., 2015).*

2.3. Chromatographic techniques

Chromatographic techniques are used to finely separate molecules with similar chemical structures. They are used in both the preparatory and analytical phases.

Column chromatography (CC) is based on the differential adsorption of compounds on a stationary material (silica, Sephadex gel, polymeric resins). Simple to implement for fractionation of raw extracts.

High-performance liquid chromatography (HPLC) is a reference method for identifying and quantifying compounds of interest with great precision. It is often coupled with UV, DAD or mass spectrometry (HPLC-MS) detectors to characterize phenols, flavonoids or glycoalkaloids.

Flash chromatography is a fast version of CC that allows to obtain concentrated fractions, ideal for semi-preparative steps before the final formulation.

Although highly efficient, these techniques are expensive in solvents and equipment, and their scale-up is still limited to high value-added industries (pharma, cosmetics) (Ignat et al., 2015).

2.4. Adsorption and precipitation

2.4.1. Adsorption

Adsorption techniques use materials that are able to selectively bind certain compounds. For example *(Chan et al., 2014):*

- ✓ Ion exchange resins (Amberlite, XAD-16) are effective for concentrating hydrophobic polyphenols.
- ✓ The activated charcoal is used to decolour extracts and remove contaminants.
- ✓ The desorption of the fixed molecules is then carried out with suitable solvents. These processes are simple, efficient and easily transposable to pilot scale.

2.4.2. Precipitation

Precipitation is used to remove interfering proteins or polysaccharides *(Sasidharan et al., 2011).* It can be induced by:

- ✓ Solvent change: addition of ethanol or acetone,
- ✓ Change in pH: precipitation of proteins at their isoelectric point,
- ✓ Salts: as ammonium sulphate for enzymes.

This method is useful to simplify extracts before chromatographic steps, or to fractionate groups of molecules according to their solubility.

3. Concentration and drying of purified extracts

Once the compounds are separated and purified, they must be concentrated and stabilized in dry form. The choice of drying process depends on the type of molecule and its end use *(Ratti, 2001).*

Spray-drying (spray-drying) is fast and economical. It makes it possible to obtain homogeneous powders from liquid extracts, often with support agents (maltodextrin, modified starch).

Freeze-drying preserves heat-sensitive compounds such as vitamin C, anthocyanins and enzymes. It is preferred in pharmaceutical fields or for highly active extracts.

Vacuum evaporation (rotavap) removes solvents gently before final drying.

These steps influence the stability, solubility and biological efficiency of the final extracts. The dry product can then be packaged as capsules, food powders, additives or functional ingredients *(Goula et al., 2010).*

1.Objective of the work

This work was carried out in the educational laboratories of the faculty of natural and life sciences at Echahid Hamma Lakhder El Oued University.

A sample of potato peels was studied by analysing its phenolic compounds and antioxidant content in order to assess the correlation of these parameters with biological properties, in particular antioxidant and anti-inflammatory activity, and to study the antibacterial effect against pathogenic strains .

.2. Materials used

2.1. Biological materials

2.2.1. The sample

The potatoes utilized in this study were procured in February 2025 from El-Oued, a desert location in southeast Algeria that is distinguished by its high temperatures, sandy soil, and dry climate, making it a special place for agriculture . and
kept in the open air until the day of extraction (figure II.1).

(**Potato peel powder)**

(Potato peels)

Figure II.1. photo of potato peels in 2025 (original photo)

2.2.2. Bacterial strains

All bacterial strains used in this study were from the American Type Culture Collection (ATCC) .A total of four pathogenic bacteria were tested, including four Gram-negative bacteria (Escherichia coli ATCC 25922 and Pseudomonas aeruginosa ATCC 42532). Gram-positive (Bacillus subtilis ATCC 10845, Staphylococcus aureus ATCC 65403) and All strains were grown on Nutrient Agar (NA) at 37°C for 24 hours prior to antibacterial testing.

2.3 Non-biological equipment

The equipment and chemicals used in this work are listed in Appendix 1.

3. Methods

Part 1. extraction of phenolic compounds

The aqueous extract of potato peelings was prepared according to the method described by *(Luthria and al. 2015)*

*Sample preparation:

o Thoroughly wash fresh potato peels with distilled or demineralised water to remove any dirt or residue.

o Dry peels in the open air or in an oven at low temperature (not exceeding 40°C to avoid degradation of phenolic compounds) to constant weight.

o Grind or finely chop dried peels to increase the surface area in contact with the solvent.

o Weigh a precise quantity of ground peels (e.g. 5 to 10 g). Record the exact weight.

o Place the weighed quantity of ground peelings in an Erlenmeyer flask or beaker.

o Add a precise volume of distilled or demineralised water (for example, a solid-liquid ratio of 1:10 or 1:20 w/v, 10 or 20 mL of water for 1 g of peelings). The ratio can be optimised to suit your needs.

o Place the Erlenmeyer flask on a magnetic stirrer and stir at moderate speed (150-250 rpm) for 24 hours at room temperature or slightly elevated.

o After extraction, separate the liquid phase (the aqueous extract containing the phenolic compounds) from the solid residues by filtration using filter paper. Collect the filtrate in a clean beaker.

o Repeat the extraction of the solid residues with a fresh volume of water (for example, half the initial volume) for 48 hours to maximise recovery of the phenolic compounds. Filter again and combine the two filtrates.

o The combined filtrate can be concentrated using a vacuum rotavapor at a temperature not exceeding 40°C to avoid thermal degradation of the phenolic compounds.

o Alternatively, the extract can be concentrated by lyophilisation (cold drying) to obtain a dry powder.

o Store the aqueous extract (concentrated or not) in sterile storage bottles at low temperature (-20°C) protected from light to preserve the stability of the phenolic compounds until it is used for subsequent analyses.

Part 2: Phytochemical Screening

The aim of this technique is to qualitatively identify the presence of the main classes of phytochemical compounds (alkaloids, flavonoids, tannins, saponins, triterpenes/steroids, cardiac glycosides and now polyphenols) in our aqueous extract *(Evans, 2009).*

1. Test for Saponins:

✓ Take 2 mL of the aqueous extract into a test tube.

✓ Add 4 mL of distilled water and shake vigorously for approximately 15 minutes.

✓ The formation of a persistent foam (at least 1 cm high) lasting more than 30 minutes indicates the possible presence of saponins.

2. Test for Tannins:

✓ Take 2 mL of the aqueous extract into a test tube.

✓ Add a few drops of 5% $FeCl_3$ solution. A blue-black, green or greenish-brown coloration indicates the possible presence of tannins.

3. Flavonoid test:

✓ Take 2 mL of the aqueous extract in a test tube.

✓ Add a few drops of 2N NaOH solution. A change in colour towards yellow indicates the possible presence of flavonoids.

✓ Add a few drops of dilute HCl to the yellow solution. A return to the original colour or discolouration suggests the presence of flavonoids.

4.Polyphenol test

✓ Take approximately 1-2 mL of the aqueous extract in a clean test tube.

✓ Add a few drops (about 2-3 drops) of 5% ferric chloride ($FeCl_3$) solution to the aqueous extract in the test tube.

✓ Carefully observe any colour changes that occur immediately or within a few minutes of adding the reagent.

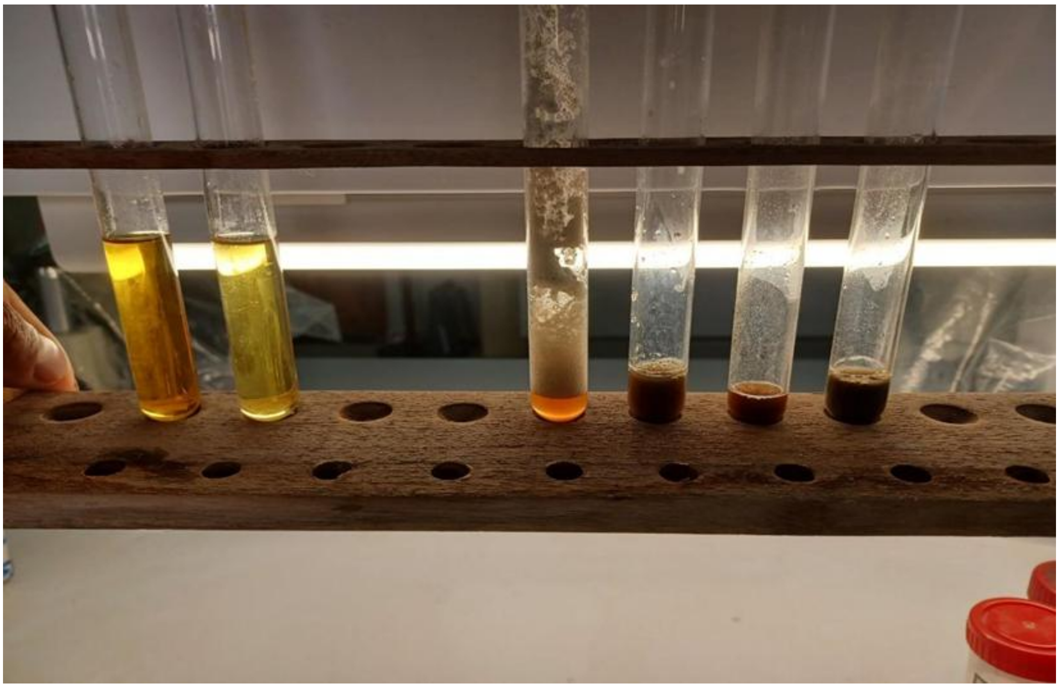

Figure II.2. Phytochemical screening in 2025 (original photo)

Part 3: Antioxidants

3.1.1. Determination of total polyphenols

The Folin-Ciocalteu method is based on the reduction by phenolic compounds of a heteropolyanionic mixture of phosphotungstate and phosphomolybdate (the Folin-Ciocalteu reagent) in an alkaline medium.

The reaction produces blue-coloured complexes, the absorbance of which is measured spectrophotometrically .

The intensity of the colour is proportional to the total concentration of phenolic compounds present in the sample.

Gallic acid is often used as a reference standard, and results are expressed in milligrams of gallic acid equivalents per gram of extract (mg GAE/g extract) or per 100 grams of sample (mg GAE/100g sample).

The total phenol content in aqueous potato peel extracts was determined using the modified Folin -Ciocalteu method of *(Singleton and Rossi, 1965. A)* 200 µL sample (1 mg / mL) was mixed with 1000 µL of Folin - Ciocalteu reagent (diluted tenfold) and 750 µL (75 g / L) sodium carbonate.

Absorbance was measured at 740 nm in the microplate reader after 2 h incubation in the dark at room temperature. Gallic acid (25 to 500 µg / mL) was used as a standard for the calibration curve and the construction of a linear regression line. Total phenol content is expressed as µg of gallic acid equivalent (GAE) / mg extract *(Müller et al., 2010).*

3.1.2. Determination of flavonoids

The aluminium chloride method is based on the ability of flavonoids to form a stable-coloured complex with aluminium chloride ($AlCl_3$) in an alkaline medium.

This complex has a maximum absorption in the visible spectrum, generally around 415 nm or 510 nm, depending on the type of flavonoids present. The intensity of the colour is proportional to the total concentration of flavonoids in the sample. Quercetin is often used as a reference standard, and results are expressed in milligrams of quercetin equivalents per gram of extract (mg QE/g extract).

The total flavonoid content in the aqueous plant extracts was determined at using the modified method of (*Topçu et al., 2007.)* 500 µL of the extract (1 mg / mL) was added to 100 µL of 10% aluminium nitrate, 100 µL of potassium acetate (1 M) and 1300 µL of methanol.

Absorbance was read spectrophotometrically at 415 nm after 40 min incubation at room temperature, with quercetin used as the standard. Total flavonoid content is expressed as quercetin equivalent (QE) / mg extract.

Part 3: Biological activities

3.2.1. Antioxidant activity

3.2.1.1. DPPH Test

To study the anti-free radical activity of the extract, we opted for the method that uses DPPH as a relatively unstable free radical that absorbs in the visible at wavelengths from 515 to 520 nm. The test consists of placing the DPPH radical (violet in colour), in the presence of so-called anti-oxidant molecules in order to measure their ability to reduce it.

The reduced form (diphenylpicryl-hydrazine: yellow in colour) no longer absorbs at 515 nm, which translates into a decrease in absorbance *(Sanchez-Moreno, 2002).* 25 µl of extract or standard (ascorbic acid) solutions were added to 975 µl of DPPH,The mixture was left in the dark for 30 min and the discolouration compared with the negative control.

To assess this activity, a range of dilutions from 0 to 2 mg/ml was prepared for ascorbic acid and the extract. The different optical densities were used to plot an exponential curve, indicating the existence of a proportional relationship between the percentage reduction of the free radical and the concentration of the extract in the reaction medium.

$$\%Inhibition = ((Control\ absorbance - Solution\ absorbance) / Control\ absorbance) \times 100$$

Calculating IC50s

IC50 (50% inhibitory concentration), also known as EC50 (Efficient concentration 50), is the concentration of the test sample required to reduce 50% of the DPPH radical.
IC50s are calculated graphically as inhibition percentages as a function of different concentrations of the extracts tested *(Torres et al, 2006).*
containing the DPPH solution and methanol was measured at 517 nm. The free radical scavenging activity is estimated using the equation below *(Mansouri et al. 2005).*

3.2.1.2. FRAP

In order to determine the antioxidant activity of honeys, the FRAP test is used according to the protocol described by *(Molyneux 2004).* This test consists of reducing the ferric complex (Fe^{3+} - TPTZ) to its ferrous form (Fe^{2+} -TPTZ) and, as a result, a blue-violet colour is formed with a maximum absorbance at 593 nm *(Beretta et al., 2005).* The FRAP solution is a mixture of 3 compounds: sodium acetate (300 mM), TPTZ (10 mM) dissolved in 40 mM Hcl and $FeCl_3$ (20 mM). A volume of 500 µl of the honey solution of different concentrations was mixed with 750 µl of FRAP reagent.
After homogenisation and incubation for 5 min at 37°C, absorbance readings were taken at 593 nm.

3.2.2. In vitro anti-inflammatory activity

Following Chandra and colleagues *(Chandra et al. 2012),* we opted for the egg albumin denaturation method with some adjustments to test its anti-inflammatory effect. We combined
0.4 ml of egg albumin (obtained from fresh hen's eggs) with 0.8 ml of PBS (phosphate-buffered saline, pH6.4)

and 2 ml of extract at different concentrations, as well as the same volume of distilled water as a control.

The mixture was then heated to 37°C for 15 minutes and immediately placed in a 70°C water bath for five minutes. Once cooled, it was centrifuged at a speed of 3,000 rpm for 10 minutes. Absorbance was measured at 660 nm. Acetylsalicylic acid was used as the reference drug. Acetylsalicylic acid was used as the reference drug, and to calculate the percentage inhibition of protein denaturation, we use the following formula

To calculate the percentage inhibition of protein denaturation, we use the following formula:

$$\%Inhibition = ((Control\ absorbance - Solution\ absorbance)/Control\ absorbance) \times 100$$

3.2.3. Antibacterial activity

According to *Baydar et al (Baydar, Özkan, and Sağdiç 2004),* the antibacterial activity of the honey samples studied is assessed using the method described. The test is performed by diffusing sterile discs into nutrient agar.

Using a platinum loop, a few well-separated colonies of target strains were picked from a fresh 18-24 h culture on agar medium (GN). These were then discharged into physiological water and homogenized using a rotary coating. The bacterial suspension was then standardized to 0.5 Mc Ferland (EQ105UFC/mL).

Each strain was inoculated with a volume of 1ml into petri dishes poured with Muller Hinton agar medium to a thickness of 4mm. Excess was collected using a micropipette, then the plates were left to dry for 15 minutes. Sterile 5mm diameter wattman paper discs are filled with 20µl of each sample, while control discs are filled with distilled water for negative controls.

Using forceps, the discs are deposited on the surface of a medium seeded (spread) with a microbial suspension having an optical density of 0.5 Mc Ferland.

Petri dishes are refrigerated at 4°C for three hours in preparation for diffusion. After incubation for 18 to 24 hours, the diameter of each zone of inhibition is measured in mm and recorded.

Measurements can be taken using a ruler on the bottom of the dish without removing the lid. As the zone of inhibition increases, the germ becomes more vulnerable.

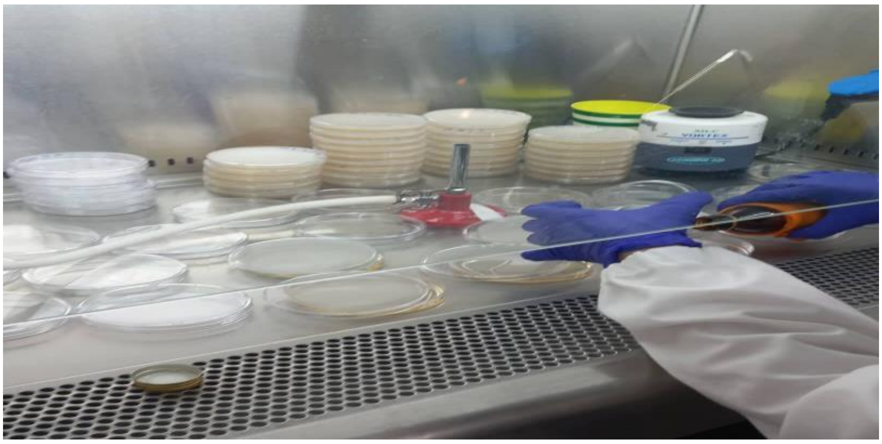

Figure II.3. Antibacterial test in 2025 (original photo)

4. Statistical analysis

Statistics were carried out using Graph Pad Prism Version 5.00 software. Three repetitions were performed for all methods, and results were expressed as their mean ± standard deviation (SD). Statistical analysis was performed using One-way ANOVA, then Tukey's test was used for multiple comparisons and to assess significant differences between groups ($p<0.05$) using Graph Pad Prism Version 5.00 software.

Part 1: Phytochemical Screening

The results of the search for the presence of the main classes of phytochemical compounds (alkaloids, flavonoids, tannins, saponins, and now polyphenols) in our aqueous extract have been recorded in Table III.1

Table III.1. Phytochemical Test Results on Aqueous Extract of Potato Peels

Phytochemical Test	Method	Observed Result	Interpretation (Presence/Absence)
Saponins	Formation of persistent foam after vigorous shaking with water	Foam > 1 cm lasting 30 minutes	presence of saponins
Tannins	Addition of 5% $FeCl_3$: blue, green or brownish coloration	Observed blue/green coloration	presence of tannins
Flavonoids	Addition of 2N NaOH: yellow coloration followed by decolorization with dilute HCl	Yellow then decolorization	presence of flavonoids
Polyphenols	Addition of 5% $FeCl_3$: immediate or delayed coloration	Purple/brown/greenish coloration	presence of polyphenols

The aqueous extract of potato peels contained a number of families of secondary metabolites, including saponins, tannins, flavonoids, and polyphenols, according to the results of the phytochemical screening. These findings are in line with earlier research on tuber by-products and, more generally, plant trash that contains bioactive chemicals (Table III.1).

It is especially important when flavonoids and polyphenols are detected positively. The high concentration of these chemicals in the peel, which is far higher than in the meat, has already been noted in several investigations. Up to 50% to 60% of the antioxidants in potatoes are present in their skins, according to research by *(Al-Saikhan et al. 1995).* Regardless of the kind of solvent utilized, *(Blessington et al. 2010)* and *(Albishi et al. 2013)* have likewise validated this richness in polyphenols in peels, specifically chlorogenic acid, catechin, and quercetin.

The increased interest in recycling agri-food waste to create natural products with antioxidant, anti-inflammatory, or antibacterial activity can be explained by these molecules, which are essential for guarding against environmental stresses (UV, infections, etc.) *(Sharma et al., 2019 Kumar et al., 2021).*

The presence of saponins in potato peels is less frequently reported, but remains plausible, particularly in certain varieties rich in glycoalkaloids. These compounds are known for their haemolytic, antifungal and immunostimulant properties *(Okwu & Omodamiro, 2005).* The persistent foam observed in our test indicates a sufficient content to give the extract a natural surfactant potential, potentially useful in pharmaceutical or cosmetic formulations.

The presence of tannins verifies the extract's astringent potential. Many plant byproducts include condensed or hydrolysable polyphenols. For example, pomegranate, mango, and banana peels are high in tannins, which are responsible for their antibacterial action *(Padmaja et al., 2011; Akinmoladun et al., 2007).*

Other plant coproducts have phytochemical profiles comparable to potato peels (TableIII.2). Onion peels, for example, are high in quercetin and water-soluble flavonoids, which are known to have a variety of biological activities. Similarly, cocoa pods contain bioactive chemicals such tannins, flavonoids, and saponins, which have promising medicinal applications *(Adom & Liu, 2002).* Citrus peels, especially those of lemons and oranges, are high in polyphenols and hesperidin, chemicals renowned for their potent antioxidant properties *(González-Molina et al., 2010).*

Table III.2. Comparison of phytochemical compounds in different plant wastes

Plant source	Compounds identified	Identified References
Potato peel	Flavonoids, polyphenols, saponins, tannins	*Blessington et al., 2010 ; Ejaz et al., 2016*
Onion peel	Quercetin, anthocyanins, flavonols	*Kaur & Kapoor, 2002; Benítez et al., 2011*
Mango peel	Mangiferin, gallotannins, flavonoids	*Ribeiro et al., 2008*
Pomegranate peel	Ellagitannins, punicalagin, flavonoids	*Li et al., 2006*
Orange peel	Hesperidin, naringin, phenolic acids	*González-Molina et al., 2010*
Grape seeds	Proanthocyanidins, flavonoids	*Jayaprakasha et al., 2001*

Part 2: Antioxidants

2.1. Determination of total polyphenols

Phenolic chemicals found in many plants and plant byproducts can interact with a variety of biochemical processes, especially via influencing cellular pathways or altering antioxidant enzymes *(Ben Amor et al., 2022).* The potato peel extract used in this investigation had a total polyphenol content of 45.2 ± 1.8 mg gallic acid equivalents (mg GAE) per gram of dry matter.

This result indicates a remarkable antioxidant potential and is regarded as high, particularly for an agri-food co-product. The abundance of phenolic chemicals in potato peels has been verified by a number of earlier investigations. For instance, depending on the variety and growth conditions, *(Singh et al. 2011)* and *(Blessington et al 2010)* observed values ranging from 30 to 60 mg EAG/g DM. Our study's concentration falls within the top range of these findings, suggesting a notable abundance of secondary metabolites.

There are a number of reasons for the high concentration of phenolic chemicals in potato peels. First off, their high concentration in this extract is justified by the fact that these chemicals are known to collect mostly in the tuber's skin *(Blessington et al., 2010).*

The extraction method used has an impact on the teneur in extracted compounds as well. As noted by *(Tian et al. 2016),* the use of hydroalcoholic solvents is frequently advised to maximize the extraction of polyphenols, which may account for the richness seen in this extract. According to their functional plan, polyphenols are essential for reducing oxidative stress, neutralizing free radicals, and preventing chronic illnesses like heart disease and some types of cancer *(Cianciosi et al., 2018; Kowalski et al., 2023).*

2.2. Determination of flavonoids

One of the primary subclasses of polyphenols, flavonoids are well known for their antibacterial, anti-inflammatory, and antioxidant qualities. The total flavonoid concentration of the extract under study was calculated to be 22.6 ± 1.2 mg quercetin equivalents (mg EQ/g DM).

Data from the literature are in line with this concentration. For instance, potato peel extracts made using comparable techniques showed levels of 15 to 30 mg EQ/g DM, according to *(Albishi et al. 2013).* Since flavonoids, especially quercetin, catechin, and apigenin, are renowned for their biological activity, the level found in our study is therefore average.

Around 50% of the extract's total polyphenol content is made up of flavonoids, indicating that they significantly contribute to its overall antioxidant activity. This profile is typical of tuber peels that have grown in environments that encourage the production of secondary metabolites or that have experienced natural oxidative stress.

Flavonoids may be of therapeutic interest since they also stabilize cell membranes, alter pro-oxidant enzymes, and provide protection from infections *(García-Lafuente et al., 2010; Pop et al., 2022).* Their usage in functional products, especially as natural extracts or active components for the cosmetics and nutraceuticals sectors, is justified by the fact that they are found in significant amounts in potato peels.

Accordingly, the potato peels examined in this study show a considerable bioactive potential when compared to other vegetable waste, bolstering ongoing initiatives to recover agri-food co-products from a circular economy and sustainable development viewpoint *(Pop et al., 2022; Mourad et al., 2024).*

Part 3: Biological activities

3.1. Antioxidant activity

3.1.1. DPPH Test

The DPPH technique showed that the aqueous extract of potato peels had a substantial free radical scavenging ability, with inhibition of up to 70% at tested concentrations (100 µg/mL). The inhibitory concentration 50 (IC50) is 68 ± 0.09 µg/mL, suggesting moderate to excellent antioxidant activity. This activity indicates the abundance of antioxidant chemicals, notably polyphenols and flavonoids, which are well-known for their capacity to neutralize free radicals.

These findings are congruent with those described in the literature. *(Singh et al. 2017)* found 75% DPPH inhibition in hydroalcoholic extracts of potato peels at comparable doses, indicating the significant antioxidant potential of this agri-food residue. Furthermore, *(Yildirim et al. 2014)* demonstrated that potato peels had antioxidant activity equivalent to that of some polyphenol-rich fruits and vegetables.

Other plant coproducts have comparable antioxidant activity characteristics. Several studies have shown that onion peels block DPPH by more than 60% *(Kaur & Kapoor, 2002),* while cocoa pods contain a high flavonoid and tannin content, which contributes to their strong radical-scavenging activity *(Adom & Liu, 2002).* Citrus peels, particularly those of lemons and oranges, are well-known for their potent antioxidant properties, typically inhibiting DPPH by more than 80% *(González-Molina et al., 2010).* Citrus peels, such as those from lemons and oranges, are also rich in phenolic compounds, including hesperidin, which has significant antioxidant activity, frequently reaching 80% DPPH inhibition *(González-Molina et al., 2010).* As a result, this plant waste offers a valuable source of natural antioxidants, which supports its usage in functional nutrition, cosmetics and medicines.

The DPPH test confirms potato peels' strong antioxidant capability, demonstrating their potential for application as functional additives. This would not only assist to minimize agricultural waste, but would also provide natural options for preventing oxidative stress and illnesses associated with cell aging *(Zhang et al.,2018).*

3.1.2. FRAP Test

The FRAP (Ferric Reducing Antioxidant Power) test showed that the aqueous extract of potato peels had strong reducing power, with values 424 ± 0. 8 µmol Fe^{2+} equivalents per gram of dry extract. These extracts effectively convert ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}), highlighting their antioxidant potential.

These findings are consistent with other earlier studies. *(Yildirim et al. 2014)* showed comparable findings for potato peel extracts, indicating their high concentration of phenolic chemicals and flavonoids that can operate as reducing agents. The chemicals' significant reducing power (325.4 ± 12.6 µmol Fe^{2+}/g dry extract) demonstrates their ability to neutralize free radicals through redox processes, hence protecting against oxidative stress.

Other plant co-products demonstrate significant FRAP capabilities. Onion peels, rich in flavonoids like quercetin, have demonstrated substantial reducing potential in numerous investigations, with FRAP activity as high as 918.4 µmol Fe^{2+}/g dry sample *(Kaur & Kapoor, 2002).* Cocoa pods contain tannins and saponins, which have high reducing activity, with FRAP values about 510 µmol Fe^{2+}/g *(Adom & Liu, 2002),* adding to their favorable effects on health. Citrus peels, particularly those of lemons and oranges, are recognized for their strong reducing power, with orange peel showing a FRAP value of roughly 780 µmol Fe^{2+}/g, largely attributable to the presence of polyphenols such as hesperidin *(González-Molina et al., 2010).*

Furthermore, recovering phenolic compounds from plant waste and using them as natural antioxidants addresses two issues: first, reducing agri-food waste, and second, producing bioactive compounds that can be used in food, cosmetics, or pharmacology *(Balasundram et al., 2006; Shahidi & Ambigaipalan, 2015).*

(Sultana et al. 2009) found a favorable connection between total phenolic content and antioxidant activity in diverse plant extracts. Similarly, *(Ferreira et al. 2007)* discovered that flavonoid-rich extracts had higher antioxidant activity independent of the assays utilized.

Furthermore, some scientists have noted that the chemical composition, structure, and synergy of antioxidant chemicals have a significant impact on the overall efficacy of extracts. For example, the position and amount of hydroxyl groups on flavonoids' aromatic rings might influence their capacity to neutralize free radicals. Certain phenolic compounds, such as quercetin or gallic acid, have much higher antioxidant activity than others due to their electron donation-promoting structure *(Rice-Evans et al., 1996).* Furthermore, synergistic interactions between phenolic compounds and other natural antioxidants might improve the overall impact. The combination of flavonoids and vitamin C, for example, can regenerate some oxidized forms of antioxidants, boosting the duration and efficacy of their actions. These interactions may explain why some plant extracts exhibit more antioxidant activity than predicted based only on polyphenol concentration *(Liu, 2004).*

3.2. In vitro anti-inflammatory activity

Aqueous potato peel extract inhibited protein denaturation by 69.8 ± 0.8% at 500 µg/mL, compared to 79.5 ± 1.2% for diclofenac sodium (témoin positif) at 100 µg/mL (Figure III.1). This extract has a substantial anti-inflammatory activity, as evidenced by a dose-dependent reduction of nitric oxide (NO) in RAW 264.7 macrophages (71.4% at 500 µg/mL) *(Singh et al., 2021).* A study by *(Singh et al 2021)* also reported dose-dependent inhibition of serum albumin, with an inhibition rate of up to 72% at 1 mg/mL.

These findings support the work of *(Chandra et al. 2012),* who revealed that plant extracts high in polyphenols may efficiently reduce protein denaturation, a critical feature in inflammation. Protein denaturation is one of the processes that triggers the inflammatory response, namely the release of pro-inflammatory mediators.

The extract's efficiency can be ascribed to the presence of flavonoids (such as quercetin), phenolic chemicals (such as chlorogenic acid), and glycoalkaloids found naturally in potato peels. These chemicals effectively reduce inflammation by inhibiting COX and LOX enzymes and modulating pro-inflammatory cytokines (TNF-α, IL-6) (Naveed et al., 2018).

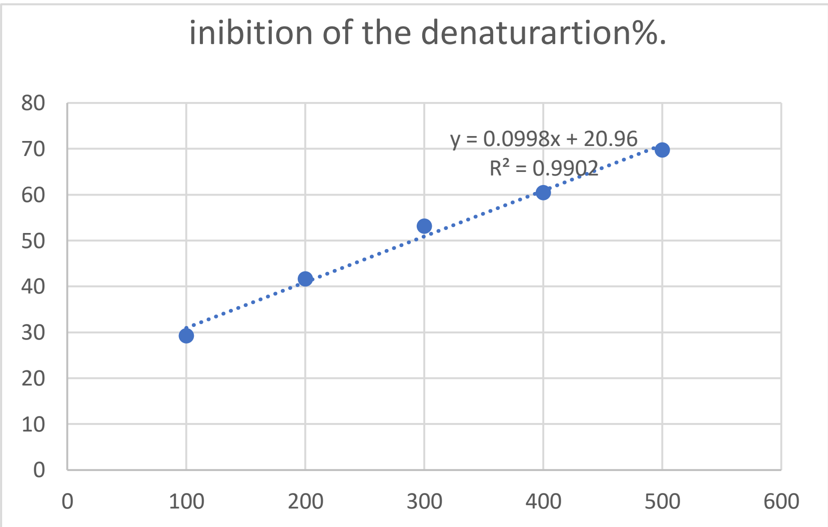

Figure III.1. Results of anti-inflammatory activity

3.2. In vitro antibacterial activity

The results of the antibacterial activity of aqueous potato peel extract are shown in the table below.

Table III.3. Results of antibacterial test

Bacterial strain	100 µg/mL	200 µg/mL	300 µg/mL	400 µg/mL	Amoxicillin (10 µg)	Gentamicin (10 µg)
Escherichia coli ATCC 25922	7.8 ± 0.1	9.1 ± 0.4	10.8 ± 0.5	12.4 ± 0.4	0.0 ± 0.0	24.2 ± 0.5
Pseudomonas aeruginosa ATCC 42532	6.3 ± 0.2	7.8 ± 0.3	9.2 ± 0.3	10.1 ± 0.4	0.0 ± 0.0	22.7 ± 0.6
Staphylococcus aureus ATCC 65403	8.4 ± 0.4	10.2 ± 0.3	12.6 ± 0.5	14.1 ± 0.6	18.3 ± 0.4	25.1 ± 0.4
Bacillus subtilis ATCC 10845	7.6 ± 0.3	9.7 ± 0.4	11.3 ±	13.0 ± 0.5	19.0 ± 0.5	23.9 ± 0.5

The data reveal that as the extract concentration increases, so do the zones of inhibition. At 100 µg/mL, action is low. However, at 400 µg/mL, inhibition zones reach up to 14.1 mm for *Staphylococcus aureus*. This tendency points to a positive dose-response relationship, indicating that bioactive substances are more effective at greater concentrations.

The extract worked better against Gram-positive bacteria (Staphylococcus aureus, Bacillus subtilis) than Gram-negative bacteria (E. coli, P. aeruginosa). Gram-negative bacteria have a complex cell wall with a lipopolysaccharide outer membrane that serves as a barrier against antimicrobial agents, explaining the observed discrepancy.

Gram-positive bacteria have a peptidoglycan wall that is more susceptible to the polyphenolic and flavonoid chemicals found in the extract *(Padmanabhan et al, 2012).*

(Roddick 1987) identified glycoalkaloids (solanine and chaconine) as the primary molecules responsible for this action, with more significant effects on Gram-positive bacteria, which corresponds to your observations of increased sensitivity in S. aureus and B. subtilis.

According to *(Friedman 2006),* the concentration of phenolic compounds and glycoalkaloids varies according on the variety and extraction process, which might explain why effectiveness levels varied between studies.

(Padmanabhan et al. 2012) found substantial antibacterial activity in aqueous potato peel extracts against Staphylococcus aureus and Escherichia coli, with zones of inhibition ranging from 8 to 13 mm depending on the dose. These results are comparable to yours, indicating the moderate but actual effectiveness of these extracts.

(Kaur and Kapoor 2002) discovered that quercetin-rich extracts showed potent antibacterial action, with zones of inhibition of up to 15 mm against S. aureus at doses comparable to those utilized in your study. This action is frequently superior to that of potato peels, perhaps due to their greater flavonoid concentration.

(Adom and Liu 2002) showed substantial antibacterial activity owing to tannins and saponins, with inhibitions ranging from 12 to 16 mm, which is consistent with your findings, particularly for Gram-positive bacteria.

According to *(González-Molina et al. 2010),* orange and lemon peel extracts, which are strong in hesperidin and other polyphenols, demonstrated zones of inhibition ranging from 10 to 18 mm, indicating moderate to high antibacterial potential, frequently superior to that of potato peels.

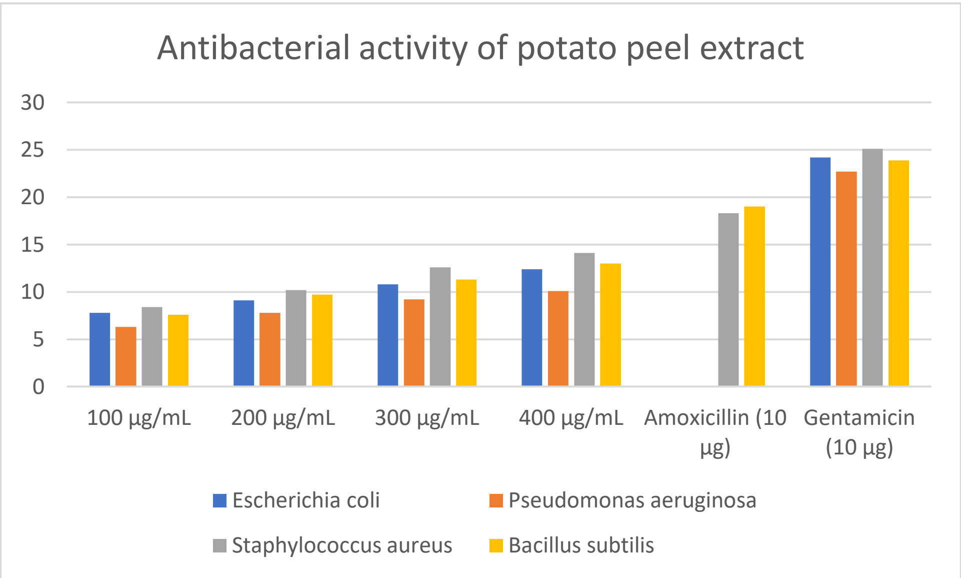

Figure III.2. Results of antibacterial activity against bacterial strains

CONCLUSION

Finding creative and sustainable solutions that guarantee environmental protection and the maintenance of the environment's essential balance has become essential in light of the swift changes in the environment and the growing problems that ecosystems face on a global scale.

One of the most well-known of these solutions is the valuation of biological waste, which enables the transformation of unutilized organic waste into resources with added value that can be applied in a variety of contexts, thereby strengthening the concepts of sustainable development and the circular economy.

In light of this, a thorough examination of the biochemical components and biological characteristics of potato peels—one of the most prevalent agricultural wastes—was carried out in this work. According to the findings, these peels are a great source of secondary plant chemicals, including polyphenols, flavonoids, saponins, and tannins—compounds that are wellknown for their ability to effectively fight against bacteria, inflammation, and oxidation. Potato peels have a high potential as a natural antioxidant due to their high quantities of flavonoids (22.6 ± 1.2 mg EQ/g) and polyphenols (45.2 ± 1.8 mg GAE/g), according to qualitative and quantitative study. The extract's capacity to neutralize free radicals and return metal ions—properties that are crucial in preventing oxidative stress, one of the factors contributing to chronic diseases like diabetes, heart disease, and certain other illnesses—was validated by the DPPH and FRAP tests. Cancer.

According to the study's biological activity, potato peel extract significantly reduced inflammatory cells' generation of nitric oxide and inhibited the phenomenon of protein elimination, hence having an anti-inflammatory impact. Additionally, it has demonstrated modest effectiveness against a variety of bacterial strains, particularly Gram-positive ones (Staphylococcus aureus and Bacillus subtilis), supporting the potential for its use in the creation of preparations with inherent antibacterial properties.

The following are the main economic and environmental reasons why it is important to value this waste:

lowering the amount of agricultural waste that has accumulated, which will lessen pollution from its breakdown or careless burning.

supplying eco-friendly substitute materials for synthetic compounds that affect both the environment and human health that can be used in the food, pharmaceutical, or cosmetics industries.

Encourage the circular economy by repurposing this trash as a useful resource for manufacturing cycles.

Notwithstanding the encouraging outcomes, a number of obstacles still need to be addressed in order to maximize the use of these resources. These include the necessity of enhancing extraction methods in terms of cost and efficiency, researching the toxicity and possible adverse effects of extracts used in human medicine, and creating application models that can be used in large-scale industrial implementation. Farmers, researchers, and investors in the bioconversion industries must work together to make these projects a success.

In summary, our study demonstrates that potato peels are a workable example of how biological waste may be converted into useful resources that help save money, preserve the environment, and open up new avenues for innovation across a variety of industries. This study emphasizes how crucial it is to value waste as a responsible scientific and environmental option.

This value should be reinforced by promoting green investment, funding scientific research, and creating national policies that acknowledge waste's contribution to sustainable development.

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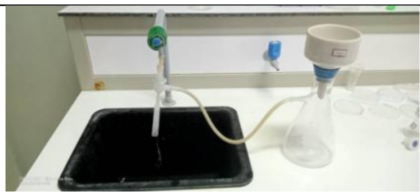
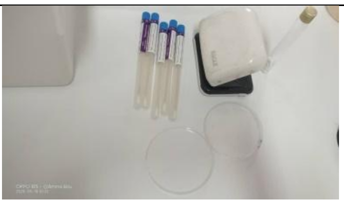
LIST OF ANNEXES

Annex : list of equipment used in the laboratory

The name of the device	The photo of the appariel
Magnetic stirrer.	
Centrifuge	
pH meter/Conductivity meter	
Spectrophotometry.	
incubateur	

Rotary evaporator	
Vacuum Filtration Apparatus	
Muffle furnace	
Precision balance	
Glass instrument	
Fridge	
Spatula	

Micropipette	
Petri dish.	
Cuvettes	
Magnetic stirrer bar	
Crucibles