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Assessment of biological activities and polyphenolic composition of medicinal plants

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Dedication

To my mother,
For your prayers and unconditional love that lit my path.

To my father,
For your silent strength and the look in your eyes that always said, “I’m proud of you.”

To my brothers and sisters,
For your faith in me when I doubted myself.

To my teachers,
For every word of knowledge and guidance that opened doors for me.

To my dear friends,
For the laughter that eased the struggle, and your presence that made the journey lighter.

And to myself,
For standing tall through it all, and believing that I deserve to reach the finish line.

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Abstract

Medicinal plants are a rich source of bioactive compounds with multiple health benefits. In this context, we carried out a phytochemical and biological study on two medicinal plants common in Algeria, *Zygophyllum* and *Solanum*. The active compounds of these two plants were extracted using a 70/30 ethanol/water solvent by Macération and Soxhlet extraction methods. The antimicrobial and antioxidant activities were studied, and an ointment based on *Zygophyllum* extract was prepared, and its anti-inflammatory activity was evaluated in an experimental model of formaldehyde-induced inflammation in rats. The results showed a clear efficacy of the ointment, demonstrating its anti-inflammatory properties.

Keywords: Medicinal Plants, Antimicrobial Activity, Antioxidant Activity, Ointment, Anti-inflammatory Activity.

الملخص

تُعد النباتات الطبية مصدرًا غنيًا للمركبات الحيوية النشطة ذات الفوائد الصحية المتعددة. في هذا السياق، قمنا بإجراء دراسة فيتوكيميائية وبيولوجية على نباتين طبيين منتشرين في الجزائر*Zygophyllum* و . *Solanum*تم استخراج المركبات الفعالة لهذين النباتين باستخدام مذيب إيثانول/ماء بنسبة (30/70) بطريقتي النقع (Macération) والاستخلاص بالسوكسلي.(Soxhlet) ثم قمنا بدراسة النشاطية المضادة للميكروبات و النشاطية المضادة للأكسدة كما تم تحضير مرهم اعتمادًا على مستخلص *Zygophyllum* ، وتم تقييم النشاط المضاد للالتهاب له في نموذج تجريبي للالتهاب المحرَّض بالفورمالدهيد عند الجرذان. أظهرت النتائج فعالية واضحة للمرهم ، مما يدل على خصائصه المضادة للالتهاب .

الكلمات المفتاحية: النباتات الطبية،النشاطية المضادة للميكروبات،النشاطية المضادة للأكسدة،المرهم،النشاط المضاد للاتهاب.

Résumé

Les plantes médicinales sont une source riche en composés bioactifs aux multiples bienfaits pour la santé. Dans ce contexte, nous avons réalisé une étude phytochimique et biologique sur deux plantes médicinales communes en Algérie, *Zygophyllum* et *Solanum*. Les composés actifs de ces deux plantes ont été extraits à l'aide d'un solvant éthanol/eau 70/30 par des méthodes d'extraction par macération et Soxhlet. Les activités antimicrobiennes et antioxydantes ont été étudiées et une pommade à base d'extrait de *Zygophyllum* a été préparée et son activité anti-inflammatoire a été évaluée dans un modèle expérimental d'inflammation induite par le formaldéhyde chez les rats. Les résultats ont montré une efficacité évidente de la pommade, démontrant ses propriétés anti-inflammatoires.

Mots-clés : Plantes médicinales, Activité antimicrobienne, Activité antioxydante, Pommade, Activité anti-inflammatoire

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General Introduction

General Introduction

Since *Zygophyllum* and *Solanum* are rich in secondary compounds and are used in traditional medicine to treat many diseases *(Zygophyllum* Traditionally used as a remedy against hyperglycemia, gastrointestinal pain and inflammation, as well as for infant body care and as an external therapeutic agent Solanum has been used as an antiseptic for toothaches, digestive issues, and sore throats. It has been used to treat snake bites, ear infections, stomachaches, and angina

This study aimed to evaluate the biological activity of two local medicinal plants. The focus was on extracting and analysing their chemical compounds, followed by evaluating their antibacterial and antioxidant efficacy.

The first plant belongs to the *Zygophyllaceae* family, *Zygophyllum*, and the second belongs to the *Solanaceae* family, *Solanum*, although studies on these two species are still limited.

This work is divided into two main parts:

The theoretical part includes two chapters:

Chapter I: Provides an overview of medicinal plants and their properties, in addition to a detailed botanical study of the two studied species based on scientific references.

The second chapter highlights the various biological activities.

Applied part:

Dedicated to analysing the chemical structure and studying the antioxidant and antibacterial activity, through two sections:

Presentation of the materials and methods used.

Discussion of the results obtained.

This work concludes with a conclusion summarising the results achieved, followed by appendices and a list of approved references.

Chapter I

Bibliographic Synthesis

Chapter I: Bibliographic Synthesis

I.1. General information on medicinal plants

Medicinal plants are one of the oldest therapeutic methods used by humans throughout the ages and continue to be an important source of active substances used in the pharmaceutical industry. (They represent one of the main pillars of traditional medicine, with more than 80 per cent of the world's population, especially in developing countries, relying on herbal remedies in primary health care.

In the context of scientific advances, it has become necessary to integrate traditional knowledge with modern research to enhance the efficacy and safety of plant products. In this context, the role of modern genomics in uncovering active compounds and optimising their extraction methods, contributing to the development of safer and more effective plant medicines [1].

The authors also point out the importance of scientific documentation of ethnobotanical knowledge, given its promising potential in the discovery of new medicines, especially those targeting chronic diseases that are resistant to known chemical treatments. [1]

I.2. Plants and medicine

I.2.1. Definition of Phytotherapy

Phytotherapy is one of the oldest treatment methods that utilises the therapeutic properties of plants to combat the causes and symptoms of various diseases. This approach is characterised by its focus on treating the root cause of the disease rather than simply palliating the symptoms, making it an effective preventive and therapeutic option.[2] .

I.2.2. Forms of use of medicinal plants

Fresh plant: Used in beverages or poultices, but it is rarely available and may retain some toxicity in rare cases, such as boxwood.

Dry plant: More concentrated in active ingredients and used in drinks or therapeutic baths

Poudre totale: Prepared by deep freezing and consumed with liquids or foods for easy absorption.

Capsules: A practical option for transport and use, but the packaging may cause issues for some people.

Preparing herbal drinks

Infusion: Used for flowers and leaves of delicate plants such as chamomile, pour boiling water over the plant and leave for 10 minutes.

Décoction: Preferred for tough roots and leaves such as ginger, which are boiled with water to extract the active ingredients[2] .

Safety and interactions

Caution should be exercised when using medicinal plants during pregnancy or with certain medications, such as St John's wort (Hypericum perforatum), which interferes with antidepressants and contraceptive pills.[2]

I.2.3. Aromatherapy

Aromatherapy derives its name from aroma, which means fragrance or odour, and therapy, which means treatment. Aromatherapy is a natural way to heal the human mind, body, and spirit. It has been used by many ancient civilisations such as Egypt, China, and India as a popular complementary and alternative therapy for at least 6000 years. Aromatherapy has established itself in the treatment of many different complications and conditions. The literature survey reveals that this therapy gained a lot of attention in the late 20th century and is gaining popularity in the 21st century as well, and due to its importance, popularity, and widespread use, it has been recognised as an aromatherapy. Essential oils have gained importance in therapeutic, cosmetic, aromatherapeutic, and spiritual uses. Aromatherapy uses essential oils as the main therapeutic agents.[3]

I.2.4. Herbalism

Herbalism is an ancient medical practice based on traditional knowledge passed down from generation to generation. In Quebec, a recent study revealed that 64% of the population uses medicinal plants, whether for pleasure (56%), to treat diseases (48%), or for prevention (38%). The study showed that women (95% of practitioners) and indigenous or black communities show a notable interest in this field. [4].

This tradition dates back to ancient times, as evidenced by archaeological finds such as the Ötzi man, who was found with birch fungi with therapeutic properties. In the historical context, herbalism went through periods of tension, especially with the Attars (ancestors of pharmacists), before it was officially abolished in some countries.[5]

In modern times, the practice continues through family transmission, as evidenced by the natural remedies used by grandmothers.[5]. In Quebec, knowledge continues through vocational training (39% of healers), self-learning (73%), or the apprenticeship system.[4]. Specialized schools play a pivotal role in this knowledge transfer. [4]. But challenges remain: lack of professional recognition, misinformation, and protection of natural resources.[4]. Solutions such as the inclusion of herbal medicine in school curricula

or formal recognition by institutions are proposed to address these challenges. [4]. This renewed interest in naturopathic medicine revives a discipline that has long been marginalized.[5].

I.2.5. Pharmaceutical phytotherapy

'Pharmaceutical phytotherapy' refers to the use of medicinal herbal preparations containing active plant ingredients used to treat specific diseases, known as Herbal Medicinal Products (HMPs). HMPs are characterised by a complex composition of natural compounds that are often extracted from plants without undergoing extensive chemical purification processes, which distinguishes them from monocompound chemical drugs.[6]

HMPs are subject to strict regulatory requirements to ensure their safety and quality, including Good Agricultural Practice (GACP), Good Manufacturing Practice (GMP), and extraction controls for active botanical substances, as outlined in the European Union's Standards for the Regulation of Herbal Medicinal Products (THMPD)[6]

These products should be treated as active medicines by health professionals, as they have proven pharmacological effects and sometimes potential interactions with other medicines. Their use requires a clear understanding of their chemical composition and the impact of environmental and agricultural conditions on their active ingredient content. [6]

These products are registered either through traditional licences (THR) in cases based on longstanding popular use, or through licences based on clinical data where available, as is the case with fully licensed medicines.[6].

I.2.6. Definition of medicinal plants

Medicinal plants are plants that contain active substances that are used to treat diseases or alleviate their symptoms, and may also be used for preventive purposes or to improve overall health. These plants are used in both traditional and modern medicine and include different parts of the plant, such as roots, leaves, flowers, or seeds. They are often prepared as extracts, powders, or herbal teas.[7]

Different parts of the plant are used: Roots, leaves, flowers, or seeds are used in botanical medicine, where the flowering aerial part is used.[7].

Medicinal plants are often prepared as extracts, powders, or herbal teas. This can be seen in the description of different dosage forms such as 'dry extract', 'tincture', "infusion", etc., under the 'Dosage forms' section for most plants such as Trifolium pratense (Flos Trifolii) [7].

I.2.7. Classification des plantes médicinales

There are different ways to classify medicinal plants so that these classifications help in various purposes, including assisting pharmacologists in research, and the most important of these classifications are

- Alphabetically, this is based on the Latin name or common name.
- Taxonomic. Based on the botanical
- methodology, morphological. Here, remedies are grouped according to a common anatomical characteristic
- Therapeutic. There are several different ways to categorize plants according to their pharmacological effects.

Potency-based. Since the effect-based ranking provides some indication of the plant's effect on the human body, this method of categorization provides valuable information for the holistic practitioner. Body system or organ affinity.

- Medical system
- biochemical. This type of classification categorizes plants according to their content of biochemical constituents. This approach classifies plants according to genetic classification and evolutionary relationships between plant biochemicals. Non-academic

- geographic. This type of classification is based on ethnobotanical uses, or how people in different parts of the world use plants. [8]

I.2.8. Harvesting and drying medicinal plants

Collecting and Drying Medicinal Plants: Sustainable Techniques and Quality Controls

1. Sustainable Collection Techniques

Careful controls must be followed when collecting medicinal plants to ensure that their potency and active ingredients are preserved:

Collection time: Leaves are best collected in the morning or evening when concentrations of active ingredients are at their peak

Roots: Collect in the dry season (not during rainfall) to avoid diluting the active ingredients with water[9]

Peels (e.g., baobab): Taken from trees that are neither too old nor too young, and in limited quantities to ensure regeneration.

Tools: Clean and sharp tools should be used to avoid contaminating the plants or transmitting diseases[9].

2. Drying and preservation

Drying: done at room temperature, avoiding direct exposure to sunlight, which destroys the active ingredients.

Storage: Plants should be stored in dry, clean containers, separated from each other to prevent harmful chemical reactions.

Packaging: Use paper or glass bags instead of plastic to avoid moisture and damage.

3. Challenges and solutions

Species extinction: Such as Fagara xanthoxyloides, due to overharvesting of its roots. The solution lies in organised farming rather than relying on the wild.

Contamination of samples: Plants should not be collected near sources of contamination (e.g., urine or waste) to ensure their purity [9].

I.2.9. Herbal medicine

Herbal medicine is common to all peoples and cultures of the world is the shared experience of treating or relieving pain using plant medicines so that there is a close relationship between each culture and its botanical environment so that the herbalist plays a pivotal role according to his acquisition of experience and wisdom that links humanity and plants There are many diverse medical systems in the world, including Indian Ayurveda, Traditional Chinese Medicine, and Greco-Islamic medicine, which uses aromatherapy, flowers and vapors of herbs.[8]

I.2.10. History of the use of traditional herbal medicines

The traditional use of herbal medicines has a great historical use, and many products are considered traditional herbal medicines, as a large percentage of the population of developed countries rely on experts in the field of traditional medicine and their knowledge of medicinal plants to maintain their health, as these uses are passed down from generation to generation for historical and cultural reasons so that their uses expand at present, such as the use of ephedra for slimming.

1.1 The role of herbal medicines in traditional healing. Since ancient times, herbs have been used for the medicinal treatment of various diseases, and this is called folk medicine and is common around the world as part of traditions. The following are examples of civilizations that use it

1.1.1 Traditional Chinese medicine has been known since ancient times, despite the use of animal and mineral substances, but the main source was plants. Plants are used after being processed by rapid boiling or soaking in vinegar or wine, and this treatment is still popular

in China, where 5000 traditional remedies are available, which is one-fifth of the Chinese pharmaceutical market.

1.1.2 Japanese traditional medicine, so that the first codex of traditional medicines in the ninth century contained herbs, with many Chinese herbal remedies being transplanted

1.1. Ayurvedic traditional Indian medicine is a 5,000-year-old system based on herbal remedies with a focus on the mind, body, and spirit to prevent and treat disease. [10]

I.3. The *Zygophyllaceae* family

I.3.1. Definition

Zygophyllaceae is a plant family with 25 genera and 240 species.[11] Trees, shrubs, subshrubs, or annual or perennial herbs often with jointed branches and swollen at the nodes; axillary or stipular thorns are sometimes present. Leaves stipulate, opposite or less frequently alternate, bi- or trifoliolate or pinnately multifoliolate, rarely simple; usually petiolate, rarely with glandular dots, sometimes unequal; leaf(let)lamina entire, often asymmetric, flattened, fleshy or terete. Flowers solitary, paired or in few-flowered cymes, axillary or terminal, bisexual, actinomorphic or rarely slightly zygomorphic; sepals 4–6, ± free, rarely connate at base, usually imbricate, valvate in Seetzenia; petals free, often clawed, mostly as many as sepals, rarely 0; disc frequently present; stamens (5)8-12 as many as or twice the number of petals and then obdiplostemonous; filaments sometimes with basal scales or appendages; anthers introrse, dorsifixed, 4-sporangiate, with longitudinal dehiscence; ovary syncarpous, superior, sessile or shortly stipitate, angular, ribbed or winged, (2-)4-5(-12)-locular; style filiform or subulate; stigma capitate, clavate or slightly lobed or ridged; ovules 1 to many per locule, bitegmic, pendulous, usually with axile placentation. Fruit a loculicidal or septicidal capsule, or splitting into mericarps which may be winged, lobed or angled, spiny or tuberculate; rarely a 1-seeded drupe (Balanites). Seeds with or without endosperm; embryo straight or slightly curved. [12]

I.3.2. Interest in *Zygophyllaceae*

Economic interest of *Zygophyllaceae*

The *Zygophyllaceae* family has several important economic benefits. On the one hand, the family includes species that produce valuable hardwoods, such as Guaiacum officinale (guaiac tree), whose wood is used to make linings for ship nails and carpentry tools, including hammers. Other species, such as Guaiacum sanctum, Bulnesia arborea, and B. sarmientoi, produce wood suitable for small tools that require high strength and density. The wood of B. sarmientoi is extracted from guaiac oil, which is used in soaps and perfumes for

its distinctive floral odour. In terms of food and agricultural use, some species produce edible fruits, their seeds are used to extract oils for cooking or soap making, and the buds of some species, such *as Zygophyllum fabago,* are consumed as a pickle in North Africa. The family also shows remarkable ecological adaptations, with Kallstroemia utilising self-pollination to ensure seed formation in arid environments where pollinators are scarce.[13]

Therapeutic value of *Zygophyllaceae*

Plants in the family are traditionally used to treat: Fever, inflammation, liver problems, high blood pressure, and skin conditions.[11]

Geographical distribution of *Zygophyllaceae*

Zygophyllaceae are found all over the world, especially in warm tropical, subtropical, and cool temperate regions, with a high concentration in hot, dry environments with alkaline soils. Geographical areas where species of this family are found include: Africa, South Asia, India, Australia, and Parts of the United States.[14][15]

I.4. Presentation of the genus *Zygophyllum*

I.4.1. Definition

Species belonging to the genus *Zygophyllum* represent a group of drought-resistant and salt-tolerant succulent plants, living in harsh and arid climatic conditions. The abundance of species related to this genus can be attributed to their high tolerance to environmental stresses. The growth and distribution of *Zygophyllum* species are due to their dependence on the chemical nature of the soil. The genus *Zygophyllum* consists of 100 species. Most plants in the genus *Zygophyllum* are small perennial herbs with fleshy leaves and flowers, as in *Z. simplex, Z. coccineum, Z. album, Z. fabago,* and *Z. dumosum*.[11]

I.4.2. Use in traditional medicine

It has been used in traditional medicine for various ailments, such as rheumatism, gout, diabetes, asthma, hypertension, dysmenorrhoea, as well as fungal infections.[11]

I.4.3. Previous phytochemical and biological studies on the genus

Biological studies on *zygophyllum* species have indicated significant antioxidant, antidiabetic, antitumour, antimicrobial, and anti-inflammatory activities in their phytochemical constituents. Different classes of compounds, including triterpenes, flavonoids, saponins, sterols, phenols, essential oils, and esters, have been isolated from different species of *Zygophyllum*[11]

I.5. The *Solanaceae* family

I.5.1. Definition

The *solanacee* family represents about 85 genera of plants and includes more than 2800 species globally Physical description They are in the form of trees, shrubs and herbs Their leaves are highly lobed or simple and contain thorns, their flowers are pentagonal and contain a medium-sized, axillary sheath The fruits are berries, capsules or nuclei, and the seeds are small, round and flat The importance of the family includes a wide variety of secondary metabolites such as alkaloids, flavanoids and terpenes. [16]

I.5.2. Interest in *Solanaceae*

Economic interest of *Solanaceae*

The *Solanaceae* family is one of the most economically important plant families globally, due to its multiple uses in the agricultural, nutritional, and pharmaceutical sectors. They represent an important source of agricultural income and contribute directly to food security. Many of its species are characterised by the presence of high-value-added biocompounds, such as carotenoids, phenols, and alkaloids, which are used in the production of functional foods, dietary supplements, and pharmaceutical products, opening wide economic prospects in the fields of food and pharmaceutical industries. The processing of edible parts of these plants provides opportunities to extract bioactive compounds from agricultural residues, which enhances the overall economic value of the crop and supports the principles of the circular economy. Some species of this family are used as ornamental plants, adding economic dimension to the ornamental plant sector. Finally, the rich genetic diversity within the family represents a valuable resource for crop improvement and productivity within sustainable agriculture strategies.

Therapeutic value of *Solanaceae*

This family is known for producing a wide variety of secondary metabolites, for example, alkaloids, flavonoids, and terpenes. Recently, the ecological importance of Solanum alkaloids as antifungal agents has been reported. While many members are pharmacologically important, such as Atropa and Datura, others serve as major food crops.[16]

Geographical distribution of *Solanaceae*

The Solanaceae family is widely distributed in tropical, subtropical, and temperate regions around the world, with a high concentration in South and Central America, especially in the Andes, where these regions are considered the centre of diversity for this plant family.

Many species of this family are also found in other areas such as Africa, South Asia, and the Mediterranean, but with less diversity compared to South America. Some species are also found in dry or desert areas such as parts of North Africa, reflecting their ability to adapt to different environments.[17]

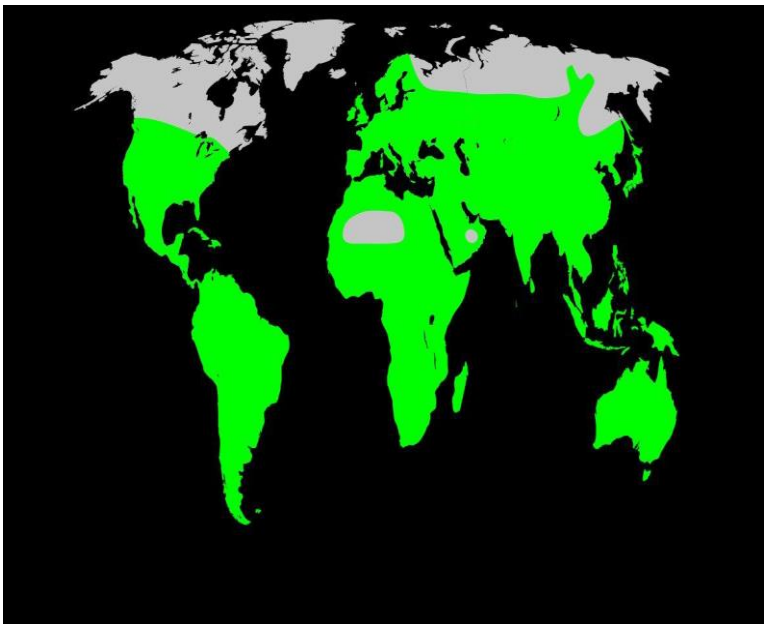


Figure I.2: Global geographical distribution map of the *Solanaceae* family[18]

I.6. Presentation of the genus *Solanum*

I.6.1. Definition

Solanum is the largest angiosperm genus, with approximately 1500 species distributed worldwide. It belongs to the kingdom Plantae, Order Solanales, Family Solanaceae. The genus includes important economic plants such as the tomato, potato, and brinjal, as well as several lesser-known cultivated species, such as the pepino (S. muricatum), naranjilla (S. quitoenseLam.), cocona (S. sessiliflorum Dunal.), and tree tomato (S. Betaceum Cav.)[19]

I..6.2. Use in traditional medicine

The genus *Solanum* has been widely used in traditional medicine in various regions. For example, *Solanum* aculeastrum is used to treat toothache and ringworm. Solanum aethiopicum is used for its anti-ulcer and anti-cancer properties. *Solanum* americanum is used for antiviral, antimicrobial, and anti-diabetic purposes, as well as to treat bladder spasms, joint pain, and stomach ulcers. *Solanum Angustifolium* is used for cough, dysuria, asthma, and diabetes. *Solanum incanum* is used for conjunctivitis and inflammation,

Solanum nigrum is used for mouth ulcers, peptic ulcers, dysentery, and skin disorders, and *Solanum* torvum is used for antibacterial, anti-inflammatory, and anti-diabetic purposes.[20]

I.6.3. Previous phytochemical and biological studies on the genus

Previous phytochemical studies on the genus *Solanum* have identified a variety of compounds, including steroidal saponins, steroidal alkaloids, terpenes, flavonoids, and phenolic compounds. These compounds exhibit various biological activities, such as

- Cytotoxicity: Compounds such as solamargin and solasonein exhibit cytotoxic effects against cancer cell lines, including breast, colorectal, and prostate cancer.
- Antimicrobial activity: Steroidal saponins and alkaloids from *Solanum chrysotrichum* exhibit antifungal properties.
- Anti-inflammatory effects: The steroidal saponins from *Solanum torvum* show significant anti-inflammatory activity.
- Anti-diabetic properties: Flavonoids and alkaloids from *Solanum lycocarpum* and *Solanum americanum* have been studied for their hypoglycaemic effects.
- Antitoxic activity: Compounds from *Solanum nudum* show activity against Plasmodium species.[20]

I.7. Components of medicinal plants

I.7.1. Primary metabolites

I.7.1.1. Carbohydrates

Definition of carbohydrates

Carbohydrates are organic compounds, also known as sugars, and are essential primary metabolites that are widely found in all living organisms on Earth. Carbohydrates are the primary product of photosynthesis in plants and thus represent the starting point for the formation of all plant compounds (phytochemicals) and later all biochemical compounds in animal organisms.[8]Chemically, carbohydrates are defined as carbon-water compounds composed of carbon, hydrogen, and oxygen atoms with the general formula $(CH_2O)n$, where n represents the number of atoms and must be at least 3.[21]

• Types of carbohydrates

Structures

Monosaccharide: The most basic, fundamental unit of a carbohydrate. These are simple sugars with the general chemical structure of C6H12O6.

- Examples: glucose, galactose, fructose

Disaccharide: Compound sugars containing two monosaccharides, with the elimination of a water molecule, with the general chemical structure C12H22O11

- Examples: sucrose, lactose

Oligosaccharide: The polymer contains three to ten monosaccharides

- Examples: maltodextrins, raffinose

Polysaccharides: Polymers containing long chains of monosaccharides connected through glycosidic bonds

- Examples: amylose, cellulose

Types

Simple Carbohydrates: One or two sugars (monosaccharides or disaccharides) combined in a simple chemical structure. These are easily utilized for energy, causing a rapid rise in blood sugar and insulin secretion from the pancreas.

- Examples: fructose, lactose, maltose, sucrose, glucose, galactose, ribose
- Foods: candy, carbonated beverages, corn syrup, fruit juice, honey, table sugar

Complex Carbohydrates: Three or more sugars (oligosaccharides or polysaccharides) bonded together in a more complex chemical structure. These take longer to digest and therefore have a more gradual effect on the increase in blood sugar.

- Examples: cellobiose, rutinulose, amylose, cellulose, dextrin
- Foods: apples, broccoli, lentils, spinach, unrefined whole grains, brown rice

Starches: Complex carbohydrates contain a large number of glucose molecules. Plants produce these polysaccharides.

- Examples include potatoes, chickpeas, pasta, and wheat.

Fiber: Non-digestible complex carbohydrates that encourage healthy bacterial growth in the colon and act as a bulking agent, easing defecation. The main components include cellulose, hemicellulose, and pectin.

- Insoluble: Remains in the intestines, softening and bulking the stool. Benefits include regularity of bowel movements and a decreased risk of diverticulosis.
  - ✓ Examples: beans, seeds, vegetables, brown rice, and potato skins.
- Soluble: Helps decrease blood cholesterol and LDL levels, reduces straining with defecation, and blunts postprandial blood glucose levels.
  - ✓ Examples are fleshy fruit, oats, broccoli, and dried beans.[22]

Carbohydrates in Therapeutics:

Play a role in cellular recognition, Such as cell-to-cell or cell-to-extracellular matrix adhesion, as well as cellular recognition of intruders (such as bacteria and viruses).

They are used as differentiation markers and antigenic determinants, making them important elements in pharmacological and immunological targeting.

A basis for the design of new drugs: Thanks to their vital role, carbohydrates are strong candidates for the development of new targeted drugs for the treatment of complex diseases, including genetic diseases related to glycosylation defects.[23]

Used in cardiovascular and haematological therapies, Such as anti-inflammatory, anticoagulant, and antithrombotic therapies, both from natural and synthetic sources.

have multifunctional effects: Some carbohydrates exhibit anti-cell adhesion, anti-HIV, and anti-arthritic properties.

Contribute to cardioprotection and anti-inflammation: The effect of monosaccharides and their derivatives on cardioprotection and anti-inflammatory activities has been verified in animal experiments.

Glycosylation improves the properties of drugs: This process improves the plasma half-life of the drug and increases its biological potency.[24]

I.7.1.2. Lipids

1. Definition of lipid

Lipids are a large and diverse class of organic molecules found in living organisms, characterised by being insoluble in water, but soluble in non-polar organic solvents such as alcohol, ether, chloroform, and benzene. Physiologically, lipids are essential compounds in both plant and human functions, with vital roles in structure, energy, and the regulation of biological processes.[8]Chemically, a lipid is defined as a fatty acid, a fatty acid derivative, or an ester of a fatty acid, i.e., the reaction product of a fatty acid with an alcohol or a compound containing a hydroxyl group (-OH) such as sterols. In general, lipids share the property of being hydrophobic to varying degrees, but they are soluble in non-polar organic solvents and are usually less dense than water [25]

2. Classification of lipids

1. Simple lipids: Fatty acyls, Glycerol lipids, Sterol lipids, Prenol lipids
2. Complex lipids: Glycerophospholipids, Sphingolipids, Saccharolipids, Polyketides[26]

3. Health and therapeutic benefits of fats (lipids)

Fats and heart disease:

- ✓ Omega-3s reduce inflammation and improve cholesterol levels.
- ✓ Plant sterols reduce cholesterol absorption by up to 12% when taken daily.

Nervous System Support:

- ✓ DHA is crucial for brain development and cognitive function, particularly during childhood.
- ✓ Phospholipids help improve memory, stress resistance, and anti-aging.

Improve digestive health:

- ✓ Short fatty acids improve the gut environment and reduce inflammation.
- ✓ Fats help with mineral absorption and support the body during periods of malnutrition.

Metabolism and fighting obesity:

- ✓ Medium-chain fats are rapidly metabolised and may reduce obesity.
- ✓ Reduces insulin resistance and improves fatty liver conditions.

Fats and anti-inflammation:

- ✓ Omega-3 reduces inflammatory substances such as TNF-α and IL-6.
- ✓ Marine fats have an anti-inflammatory effect.

Fats and cancer:

- ✓ Achieving a balance between omega-3 and omega-6 may contribute to a lower risk of cancer.

Clinical nutrition:

- ✓ Lipids are used in parenteral nutrition to minimise dependence on glucose.
- ✓ ESPEN recommends the use of specific formulations depending on the health condition.

Anti-aging:

- ✓ Some lipids act as cellular signals that regulate ageing and biological lifespan.

Support the immune system:

- ✓ Short fatty acids stimulate immunity and improve the gut environment[27].

I.7.1.3. Proteins

1. Definition of proteins

Proteins are polymers of some 21 different amino acids joined together by peptide bonds. Because of the variety of side chains that occur when these amino acids are linked

together, the different proteins may have different chemical properties and widely different secondary and tertiary structures.[28]

2. Protein structure

The overall three-dimensional structure of a protein, its tertiary structure, is determined by the arrangement of its primary and secondary structural elements (Figure 2). The sequence of amino acids that make up the polypeptide chain of a protein is called the primary structure. Secondary structure is the formation of regular, repeating structural elements (alpha helices and beta sheets) through interactions between the atoms of the peptide's primary structure - the peptide chain, excluding the variable side chains. Both beta sheets and alpha helices are maintained by a hydrogen bond between carbonyl oxygen atoms and amino hydrogen atoms in the primary structure. The overall structure of the entire protein is called the tertiary structure, and depends mainly on interactions between the side chains of the amino acids. These interactions include hydrogen bonds, ionic interactions, van der Waals interactions, disulfide bonds, and hydrophobic interactions that catalyse protein folding. Finally, the quaternary structure of proteins is the structural arrangement that occurs when more than one polypeptide chain is linked to form a single functional unit. In this case, the individual chains in the complex are called subunits. Most proteins are made up of smaller units called ‘domains’.[29]

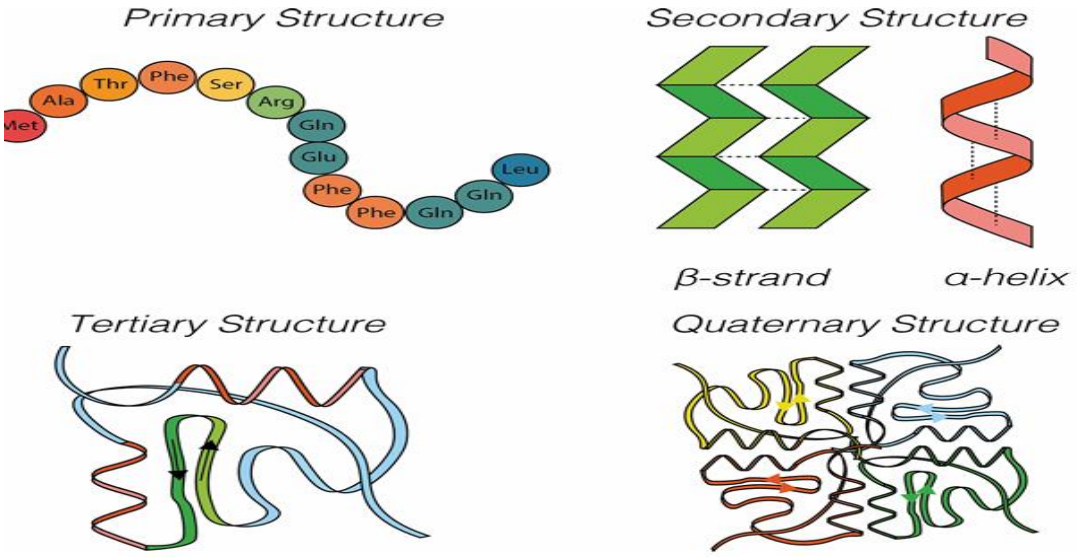


Figure I.4. Primary, secondary, tertiary, and quaternary protein structure[29]

3. Role in health and medicine

Proteins play a pivotal role in the management and prevention of chronic diseases, offering a natural and therapeutic alternative to synthetic drugs. Proteins contain bioactive peptides that contribute to cardiovascular health, blood sugar control, weight management,

and muscle maintenance. For example, plant proteins have been shown to lower cholesterol levels, reduce inflammation, and improve heart health. Additionally, proteins support immune function and bone health, making them particularly valuable for the elderly. Their anti-inflammatory and antioxidant properties help alleviate conditions such as diabetes, obesity, and neurodegenerative diseases [30].

I.7.2. Secondary metabolites

Plants are one of the most important sources of life on Earth, not only for their role in balancing the environment, but also for their health, nutritional, and medical benefits. Plants rely on photosynthesis to produce organic compounds from simple inorganic materials. These compounds are categorised into primary metabolites (PPMs), which are essential for plant growth and development, and secondary metabolites (PSMs), which were previously considered metabolic waste but are now recognised for their biological and medical importance. PSMs play a pivotal role in protecting the plant from UV radiation, pests, and diseases, as well as attracting pollinators. In addition, these compounds are effective in the prevention and treatment of many human diseases such as cancer, inflammation, and neurological diseases, making them a focus of interest for researchers to develop natural and synthetic drugs. These compounds are divided into four main groups: Phenols, polyphenols, terpenes, nitrogen-containing compounds (such as alkaloids), and sulfur-containing compounds, each of which has distinctive structural and chemical properties that explain its biological activity.[31]

I.7.2.1. Alkaloids

1. Definition Alkaloids:

They are cyclic organic compounds that contain a nitrogen atom (nitrogen) in their structure, often in a heterocyclic ring, and are characterised by basic properties, bitter taste, and weak solubility in water but dissolve in organic solvents such as ethanol, benzene, and ether. They are mostly derived from plant sources and may also be found in some animals, and are used in medical applications due to their pharmacological and toxicological effects.[32]

2. Classification of Alkaloids

Types of alkaloids by biological origin:

True alkaloids

This class of alkaloids, also known as heterocyclic alkaloids, is derived from amino acids and contains a nitrogen atom in a heterocyclic ring. They also consist of one or more heterocyclic rings with monocyclic or polycyclic compounds as well as with either oxygen, sulfur, or more than one nitrogen atom, for example, pyridine alkaloids pyrrolidine alkaloids, piperidine alkaloids, tropane alkaloids, quinoline alkaloids, isoquinoline alkaloids, quinolizidine alkaloids, indole alkaloids, pyrrolizidine alkaloids, and imidazole alkaloids**.**

Proto alkaloids

Proto alkaloids are also known as heterocyclic alkaloids, which also originated from amino acids, while the nitrogen atom is not part of the heterocyclic ring but is in the outer ring system, meaning it is part of a side chain.

Pseudoalkaloids

Pseudoalkaloids are primary carbon skeleton compounds derived from precursors or post-precursors of amino acids, as well as non-amino precursors. Terpenoid alkaloids (sterol alkaloids), phenanthrene alkaloids. Tropolone alkaloids. They are subclasses of semi-alkaloids.

Polyamine alkaloids

Polyamine alkaloids are polyamine derivatives that consist of two or more amino groups as part of an aliphatic chain, and three or four bonds separate these amino groups to methylene group units as a characteristic feature. These alkaloids mainly consist of three basic structures of polyamines, such as putrescine (PA4), spermidine (PA34), and spermine (PA343).

Peptide and cyclopeptide alkaloids

Peptide and cyclopeptide alkaloids contain two or more amino acids linked by peptide bonds. They are derived from amino acids attached to a peptide and then a cyclopeptide. Cyclic peptides generally have a 13-, 14-, and 15-membered cycle containing an aromatic ring. These macrocyclic cycles consist of a peptide unit that is linked either through 1,4 or 1,3 orientation with a benzene ring. Linear peptide alkaloids that are formally obtained from cyclic peptide alkaloids through re-removal by bridge cleavage.[31]

3. Health and therapeutic benefits of alkaloids:

Antioxidant Properties (Antioxidant):

Alkaloids help reduce the levels of free radicals (ROS), which contributes to the prevention of cell damage and oxidative stress.

Anti-inflammatory Properties (Anti-inflammatory):

They are effective in reducing systemic inflammation, which makes them useful in the treatment of chronic diseases such as obesity and heart disease.

Ecological Defence Role:

Alkaloids play an important role in protecting plants from insects, bacteria, fungi, and viruses.

Useful in Cardiovascular Diseases (Cardioprotective):

helps prevent cardiovascular diseases caused by inflammation and blockages.[33]

Anti-cancer properties (Anticancer):

Compounds such as solamargine and solasonine in Solanum lycocarpum have an anti-growth effect on cancer cells.

Antigenotoxic:

Alkaloids show the ability to minimise genetic damage associated with exposure to toxic substances.

Antidiabetic properties (Antidiabetic):

Alkaloid-rich extracts are used to reduce blood sugar levels.

Antinociceptive:

Some alkaloids reduce the sensation of pain, making them effective as natural analgesics.

Antiparasitic (Antiparasitic):

Alkaloids are effective against certain pathogenic parasites.[34]

I.7.2.2. Terpenes

Definition Terpenes

Terpenes are a broad and diverse class of natural organic compounds, among the largest and most complex families of plant compounds, with around 15,000 known molecular structures. These compounds are typically derived from a basic five-carbon unit known as isoprene and are characterised by their lipophilic nature. The diversity of terpenes reflects their ability to assemble into chains of different lengths, form ring structures, and bind to other molecules such as sugars or oxygen-containing groups, giving them great structural diversity. All terpenes and their derivatives originate from a common biological pathway known as the Mevalonic Acid Pathway[35]

Table I.1: Classification and examples of terpenoids.[36]

Classification	Isoprene units	Carbon atoms	Example
Monoterpene	2	C10	Linalool, limonene
Sesquiterpene	3	C15	Farnesol
Diterpene	4	C20	Phytol, retinol
Sesterpene	5	C25	Geranyl farnesol
Triterpene	6	C30	Amyrin
Tetraterpene	8	C40	β-Carotene

General therapeutic properties of turpentine:

Trypan is used in the treatment of cancer, infections, viruses, and bacteria. It also has anti-diabetic and anti-depressant properties.

Protects plants from environmental stress and harmful organisms[37]

I.7.2.3. Phenolic compounds

Phenolic compounds represent a large group of molecules with diverse functions in plant growth, development, and defence. Phenolic compounds include signalling molecules, pigments, and flavours that can repel or attract pests, as well as compounds that can protect plants from parasites, fungi, bacteria, and viruses. Most phenolic compounds are esters or glycosides rather than free compounds. Tannins and lignin are enolic polymers. Tannins are used commercially as pigments and astringents, while lignin contributes to the rigidity of cells and skeletal tissues and is essential for the growth of blood vessels. From this brief overview, it is clear that phenolic compounds form a large and interesting family, demonstrating their diversity and forming a basis for ongoing research.[38]

The phenolic compounds are substances that have at least one benzene ring in which at least one hydrogen of its structure is replaced by a hydroxyl group capable of donating electrons or hydrogen atoms, neutralizing free radicals and other reactive oxygen species; Souza. They can be obtained from two main metabolic routes: shikimic acid and mevalonic acid.

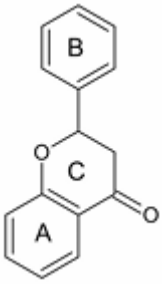
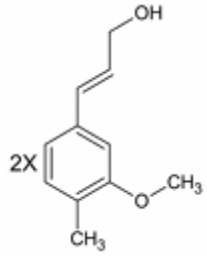
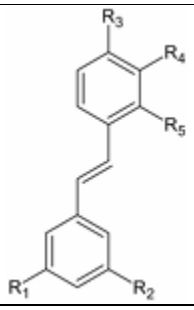
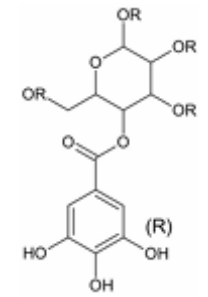
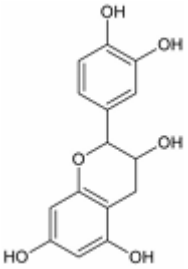
Phenolic compounds may have a single-chain molecule with a well-modified variant and well-modified chains. In the group that is poorly distributed in nature, we have simple phenols, such as the isomers pyrocatechol (ortho), hydroquinone (para), and resorcinol (meta), with molecular formula $C_6H_4(OH)_2$. This group also includes aldehydes from reactions of

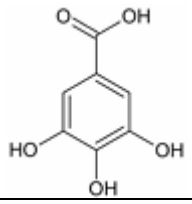
benzoic acids, present in essential oils. The group of polymers comprises tannins and lignins. Finally, the family of those widely distributed in nature includes flavonoids, phenolic acids, and coumarins.

In plants, in addition to acting as a defense against microorganisms and insects, they also contribute to some characteristics, such as color, flavor, and texture. Additionally, they can act as antioxidants, where their intermediate radicals prevent the oxidation of substances in foods, especially lipids, which can result in the formation of tumors, neurogenerative diseases, diabetes, and proteins that affect enzyme activity, receptors, and membrane transport. Most

Phenolics occur in nature as bonded forms combined with sugars, organic acids, and esters, although some phenolics occur as aglycones. Phenolic acids are found in plant tissues primarily as hydroxyl derivatives of benzoic and cinnamic acids. In plants, these compounds are involved in processes such as bitterness and sour taste, and astringent properties.

Table I.2. Classification of natural phenolic compounds.[39]

Polyphenols	General Structure	Representative Compounds	Antibacterial Activity
Flavonoid		• Flavones • Flavonols • Isoflavones • Flavanones • Anthocyanidins (flavylium salt) • Flavanols	Flavonoids act against bacteria such as S. aureus and P. aeruginosa with a very low minimum inhibitory concentration (MIC) value (0.062 µg/mL
Lignans		•Dibenzylbutanes •Dibenzylbutyrolactones, arylnaphthalenes • Terahydrofurans Furofurans •Dibenzocyclo-octadienes	Due to structural Properties, the antibacterial activity of lignans is influenced by the stereochemistry of the molecules
Stilbenes		• R1R2R3=OH, R4R5=H: Resveratrol. • R1R2=OCH3, R3=OH, R4, R5=H: Pterostilbene. • R1R2R3R4=OH, R5=H: Piceatannol. • R1R2R3R5=OH, R4=H: Oxyresveratrol.	In combination with antibiotics, some stilbenes can be useful in treating infections caused by multidrug-resistant bacteria
Tannins		•Gallotannins •Ellagitannins •Complex tannins (Acutissimin A and Eugenigrandin A) •Condensed tannins (ProcyanidinB2Proanthocyanidin A1, Proanthocyanidin A2) • Low molecular mass phenolics (gallic acid).	Tannin compounds act against bacteria, causing the disintegration of bacterial colonies by interfering with the bacterial cell wall and inhibiting fatty acid biosynthesis pathways
a. Hydrolysable tannins			
b.Nonhydrolysable tannins (Condensed tannins)			

c. Pseudo tannins			

I.7.2.3.1. Phenolic Acids

1. Definition of Phenolic Acids

Phenolic acids are aromatic acids composed of a phenyl and a carboxylic acid group. The aromatic ring is substituted either by hydroxyl, alkoxy, or alkyl groups.[31]

2. Classification of Phenolic Acids

1-Hydroxybenzoic acids

Hydroxybenzoic acids are benzoic acids substituted with a hydroxyl group. Alternatively, they can be viewed as phenols that are replaced by a functional group of a carboxylic acid directly attached to the phenolic ring, and the hydroxyl group in hydroxybenzoic acids can be ortho (o) (salicylic acid), meta (m), or para (p) Dihydroxybenzoic acids are benzoic acids that are replaced by two hydroxyl groups. The two hydroxyl groups can be in positions 2,3,2,4,4,2,5,2,6,3,4,3,5, relatively speaking. Trihydroxybenzoic acids are benzoic acids that are substituted with three hydroxyl groups. Examples include 2,4,6-trihydroxybenzoic acid and 3,4,5-trihydroxybenzoic acid (gallic acid)

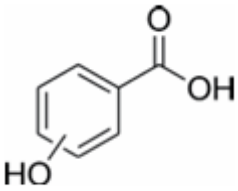


Figure I.5. General structures of Hydroxybenzoic acids

2-Hydroxycinnamic Acids

When the carboxylic acid functional group is separated from the phenolic ring by a C=C bond, phenolic acids are described as hydroxycinnamic acids

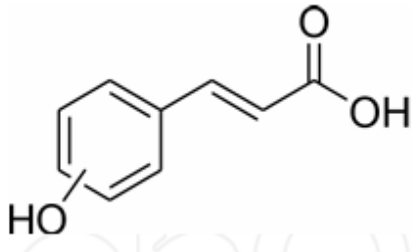


Figure I.6. General structures of Hydroxycinnamic Acids[40]

3. Therapeutic benefits of phenolic acids:

Cardiovascular benefits:

Improved blood vessel function and reduced blood pressure, especially when taking chlorogenic acid.

Improved vasodilation (FMD) after certain doses of chlorogenic acid.

Manage obesity and metabolism:

Reduce body mass index (BMI) and body fat when consuming coffee rich in chlorogenic acid.

Stimulate fat utilisation after meals.

Control sugar and insulin levels:

Reduce glucose absorption and improve insulin response.

Increase glucagon-like peptide-1 (GLP-1) levels in individuals with a low metabolic index.

Antioxidant properties:

Reduce oxidative stress, as evidenced by reduced levels of isoprostane in urine.

Protects DNA from damage.

Neurological benefits:

Improved mood and cognitive function when consuming coffee rich in chlorogenic acid.

Chemopreventive benefits:

Reduce the risk of colorectal cancer.

Stimulation of detoxification enzymes via the Nrf_2/ARE pathway.

Anti-inflammatory effects:

Reduce signs of inflammation when consuming a polyphenol-rich diet.[41]

I.7.2.3.2. Coumarins

1. Definition of Coumarins

Coumarins are natural phenolic compounds belonging to the family of plant secondary compounds, characterised by a C_6-C_3 carbon structure with an oxygenated heterocyclic ring (oxy-heterocycle). Coumarins are known for their multiple biological roles, contributing to the resistance of plants to diseases and pests, in addition to their role in protecting against ultraviolet (UV) radiation. Among the most famous compounds in this family is Umbelliferone. There are also other derivatives known as Iso-coumarins, which differ from conventional coumarins in the position of the oxygen and carbonyl atoms within the ring. Examples include Bergenin (Bergenin).[38]

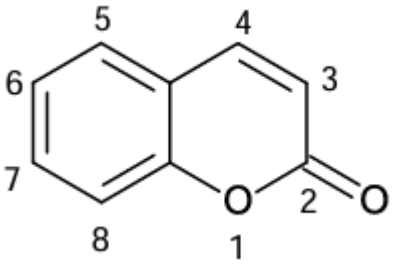


Figure I.7. Structural formula of coumarin

2. Biological and therapeutic benefits of coumarins:

Anticoagulant agents

Some coumarins are widely used in clinics as anticoagulant drugs, such as warfarin.

Antineurodegenerative agents

are effective in preventing or alleviating neurodegenerative diseases such as Alzheimer's.

Anti-tumour and anti-cancer agents (Anticancer agents)

play a role in inhibiting the growth of cancer cells.

Antidiabetics

are used in the design of drugs to control blood sugar levels.

Analgesic (Analgesic)

Some coumarin derivatives contribute to pain relief.[42]

Antioxidant

prevents free radical damage and protect cells.

Antibacterial & Antifungal

Effective in fighting disease-causing microbes

Antiviral

Coumarins have properties against multiple viruses.

Anti-inflammatory (Anti-inflammatory)

Used to reduce local and systemic inflammation.

Antigenotoxic & Anti-apoptotic

Protects cells from genetic damage and reduces abnormal cell death.

Antituberculosis (Antituberculosis)

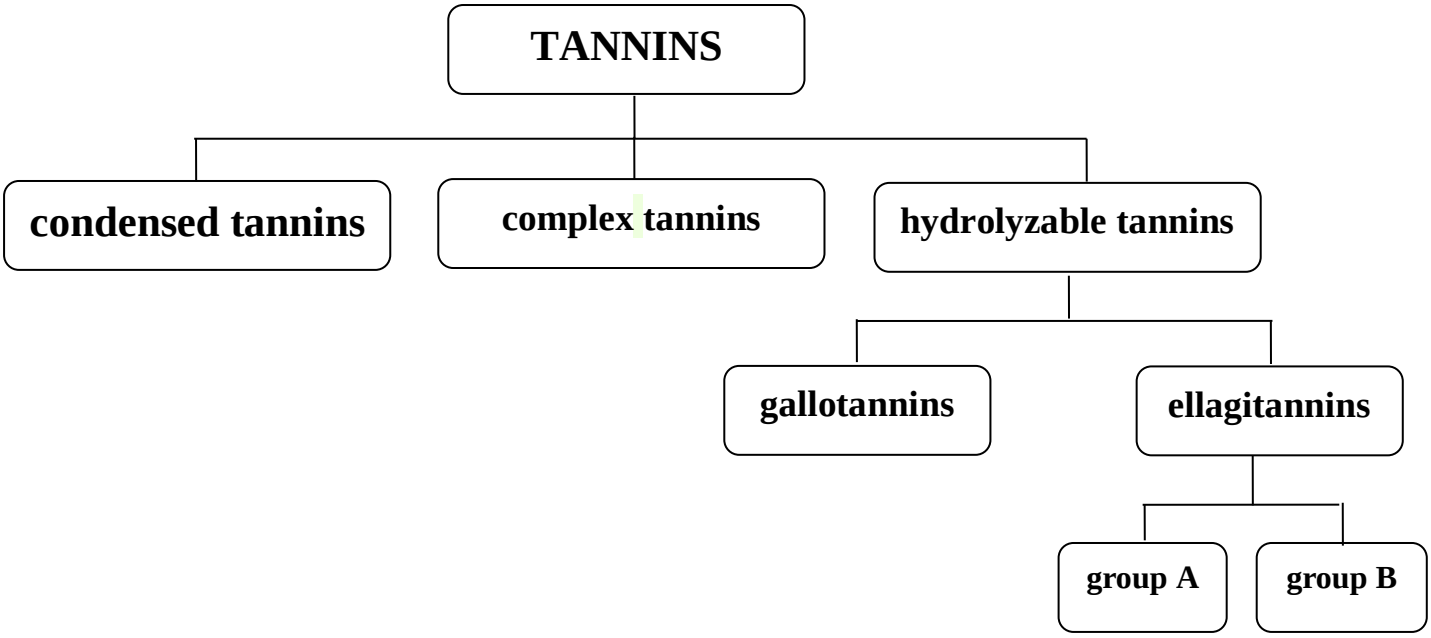
Some coumarins show activity against tuberculosis bacteria.[43]

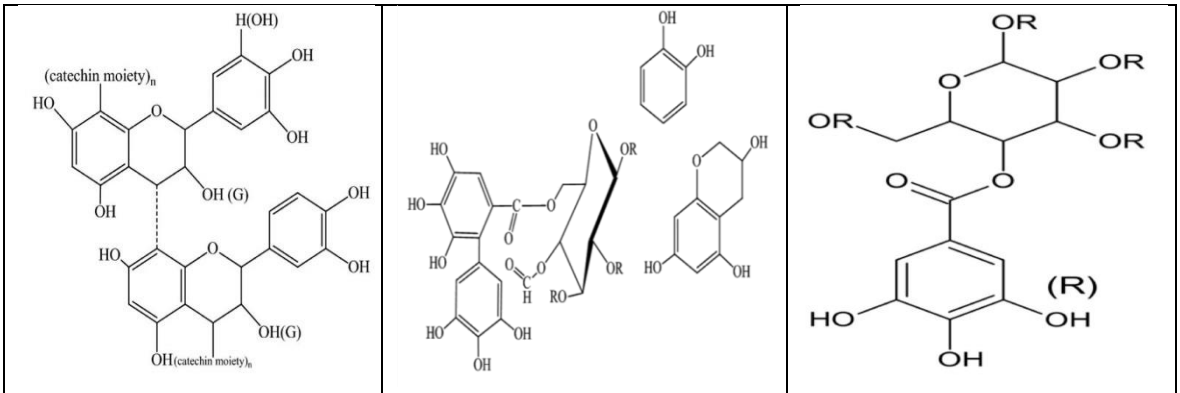
I.7.2.3.3. Tannins

1. Definition of Tannins

Tannins are a group of natural chemical compounds belonging to the polyphenol family, characterised by their unique ability to bind and precipitate proteins. The name "tannin" is derived from the word associated with the tanning process. These compounds have been used since ancient times to turn animal skins into leather by reacting with collagen fibres and cross-linking them, giving the skin its toughness and resistance. Tannins are found in many parts of plants, including leaves, scales, and fruits, and are thought to contribute to the plant's natural defence against herbivores and microbes[38]

2. Classification of Tannins[38]





condensed tannins	complex tannins[44]	hydrolyzable tannins[39]

Figure I.8. Representative chemical structures of three types of tannins

3. Therapeutic Benefits of Tannins

Anticarcinogenic Effects

- ✓ Inhibit the growth of tumours in the skin, lung, colon, and stomach.
- ✓ Block the effect of carcinogens such as benzopyrene.

- ✓ Promote detoxification enzymes in the body.

Antimutagenic Effects

- ✓ Neutralise harmful free radicals.
- ✓ Prevent the binding of carcinogens to DNA.

Antimicrobial Effects

- ✓ Bacteria: Inhibit the growth of *Staphylococcus aureus*, *E. coli* and *Salmonella*.
- ✓ Fungi: Resistance to *Aspergillus niger* and *Botrytis cinerea*.
- ✓ - Viruses: Inactivation of viruses such as herpes and HIV.

Cardiovascular Benefits

- ✓ Lower blood pressure.
- ✓ Improve cholesterol levels (lower LDL and increase HDL).

boost immunity

- ✓ Activate natural killer cells (NK cells).
- ✓ Stimulate immune response against infection. [45]

I.7.2.3.4. Flavonoids

1. Definition of Flavonoids

Flavonoids are C15 compounds, all of which have the structure C6-C3-C6. Flavonoids may be grouped into three big classes based on their gener structure. In each case, two benzene rings are linked together by a group of three carbons. It is the arrangement of the C group that determines how the compounds are classified.[38]

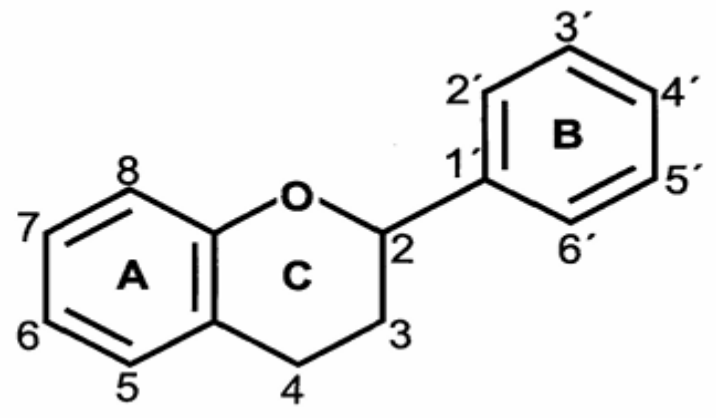


Figure I.9. Basic structure and numbering system of flavonoids.[46]

2. Classification of Flavonoids

Flavones, Isoflavones, Neoflavonoids, Chalcones, Flavonols, Anthocyanidins [31]

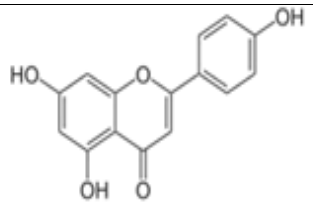
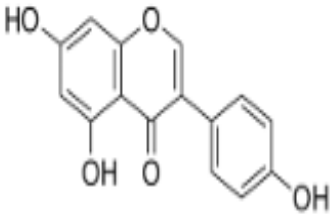
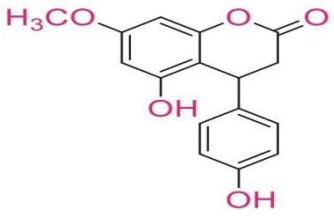
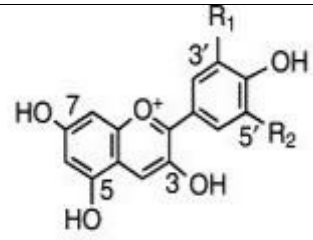
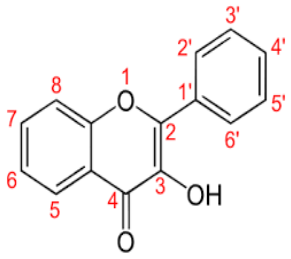
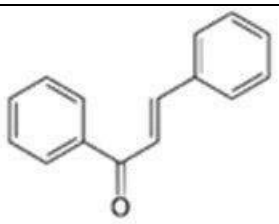
		
isoflavone	Neoflavan[31]	Flavon
		
Anthocyanidins [47]	Flavonols[48]	Chalcones [49]

Figure I.10. Representative chemical structures of flavonoids

3. Therapeutic Benefits of Flavonoids

Antioxidant Activity

- ✓ Flavonoids have an antioxidant capacity that protects the body from free radicals and reactive oxygen species (ROS).
- ✓ This activity is related to the number of hydroxyl groups in the flavonoid structure, with an increase in these groups increasing their effectiveness.
- ✓ Flavonoids can inhibit multiple types of oxidation, such as superoxide anion (O2-) and hydroxyl radicals.

Anti-Ageing Properties

- ✓ Flavonoids help minimise the oxidative damage that accumulates with age, such as damage to DNA, proteins, and lipids.

Anti-inflammatory activity

- ✓ Flavonoids inhibit enzymes such as cyclooxygenase (COX-2) and lipoxygenase, reducing inflammation.
- ✓ Compounds such as cyanidin and quercetin have anti-inflammatory effects by inhibiting the production of inflammatory interleukins.

Immunological effect

- ✓ Flavonoids are inhibitors or stimulators of the immune system, affecting immune cells such as lymphocytes and macrophages.

Cardioprotective effects

- ✓ Flavonoids protect against atherosclerosis by reducing the oxidation of low-density lipoprotein (LDL).
- ✓ Resveratrol has anti-clotting effects and reduces arterial damage.

Antimicrobial Activity

- ✓ Flavonoids inhibit the growth of bacteria and fungi by interfering with cell wall structure or microbial enzymes.

Antiviral activity

- ✓ Flavonoids prevent viruses from entering cells and inhibit their replication.

Antiparasitic activity

- ✓ Flavonoids such as quercetin have shown efficacy against Trypanosoma and Leishmania parasites.

Antifungal activity

- ✓ Compounds such as baicalin inhibit the growth of Candida fungi.[50]

I.7.2.4. Essential oils

General definition

Essential oils are a mixture of volatile organic compounds derived from a single plant source and are responsible for the characteristic odour and taste of aromatic plants. They are also called 'volatile oils' because they are volatile at low temperatures. The term 'essential' refers to the 'essence of the plant', while 'oil' is used to refer to their liquid nature, which is immiscible with water, but soluble in non-polar fatty solvents such as chloroform and benzene.[51]

Rôles dans la plantes

Essential oils play an important defence role in plants; they are used to protect against bacteria and fungi, help regulate plant temperature by forming a warm halo around the plant, and act as chemical messengers to other plants of the same genus[51],[3]

3. Principaux constituents:

Essential oils are made up of various organic compounds, including saturated and unsaturated hydrocarbons. alcohols, aldehydes, esters, ethers, ketones, ketone oxides, phenols, and terpenes[3][51]

4. Activités biologiques:

Essential oils have proven properties such as:

Antibacterial, Antiviral, Anti-inflammatory. They are used to relieve stress, improve sleep, relieve pain, and stimulate mental and physical balance.

They are also used for conditions such as cancer, Alzheimer's[3]

Chapter II

Biological activity

Chapter II: Biological activity

II.1. Biological activity

II.1.1. Antibacterial activity

General information on bacteria

Bacteria are single-celled microorganisms that lack a nuclear membrane, are metabolically active, and divide by binary fission. They are a major cause of disease in medical terms. On the surface, bacteria appear to be relatively simple forms of life; however, they are highly adaptable and sophisticated. Many bacteria reproduce rapidly, and different species can utilise a huge range of hydrocarbon substrates, including phenol, rubber, and petroleum. These organisms are widely found in both parasitic and free-living forms. They are ubiquitous and can remarkably adapt to changing environments by selecting for spontaneous mutations.[52]

Classification of bacteria of medical interest

- ✓ Morphologic characteristics (e.g., cocci, bacilli, spirochetes)
- ✓ Differential staining (e.g., Gram stain, acid-fast stain)
- ✓ Oxygen requirements (aerobic, anaerobic)
- ✓ Biochemical characteristics and metabolic pathways (e.g., fermentation of specific sugars, production of specific enzymes)
- ✓ Antigenic structure, Genetic makeup (DNA analysis, particularly ribosomal RNA sequencing)
- ✓ Ecological characteristics (e.g., natural habitat, relationship to host)[53]

Culture of bacteria

Complex media based on meat extracts or enzymatic hydrolysates are usually used to culture bacteria. or enzymatic hydrolysates of meat. These media can be liquid (broths) or solid. The media are solidified by the addition of agar, a seaweed extract that melts on boiling and solidifies at temperatures below 40°C. In a liquid medium, the bacteria disperse freely, and their multiplication results in a cloudy, usually homogeneous, liquid. usually homogeneous. In a solid medium, when the quantity of bacteria is low, each bacterium will be able to multiply. each bacterium will be able to multiply on the spot until it forms a clump of bacteria visible to the naked eye. visible to the naked eye, known as a colony. If the bacterial density is too high in the inoculated sample, the colonies become confluent and form a mat. The use of solid media allows the viable bacteria in a sample to be counted. [54]

Description of the bacteria studied

Staphylococcus aureus is a Gram-positive bacterium that causes a wide range of clinical diseases. Infections caused by this pathogen are common in both community-acquired and hospital-acquired infections. Treatment remains a challenge due to the emergence of multidrug-resistant strains such as methicillin-resistant Staphylococcus aureus (MRSA). Staphylococcus aureus does not usually cause infection on intact skin; however, if allowed to enter internal tissues or the bloodstream, this bacterium can cause a variety of potentially serious infections.[55]

Pseudomonas aeruginosa is the most common gram-negative bacterium found in nosocomial infections. Responsible for pneumonia, septicaemia, and burn diseases[56]

Escherichia coli (Escherichia coli) is a Gram-negative bacillus known to be part of the normal intestinal flora, but can also be the cause of intestinal and extra-intestinal disease in humans. There are hundreds of E. coli strains that have been identified, leading to a spectrum of diseases.[57]

II.1.2. Antioxidant activity

1. Methods for determining antioxidant activity

Several methods have been developed to measure the overall antioxidant activity of compounds. These methods include spectrophotometric measurements such as the DPPH test, Folin-Ciocalteu test, and others. In addition, electrochemical techniques such as amperometric and cyclic voltammetry can be used to assess bioactive compounds' oxidative-reductive behaviour and antioxidant capacity.[58]

2. Free radicals and oxidative stress

Free radicals are atoms or molecules that carry an unpaired electron (unpaired electrons). This property makes them highly reactive due to the electrons' tendency to recombine, destabilising other molecules. Molecules turn into other free molecules, starting a series of chain reactions. This is what typically happens during lipid peroxidation. Free radicals, which are by-products of metabolism, are produced in all cells, although some cells produce larger amounts (such as macrophages during phagocytosis). The main free radicals found in aerobic cells, especially human cells, are oxygen, superoxide ions, hydroxyl radicals, hydrogen peroxide, and transition metals. Free radicals present in a cell oxidize its molecules (molecules inside cells, especially lipids), leading to cell death. However, the human body has defense mechanisms against the effects of free radicals. These are enzymes that break down peroxides and transition metals, and proteins or other molecules that trap free radicals.[54]

3. Antioxidants: definitions and biological roles

The antioxidant activity of a compound corresponds to its ability to resist oxidation. The best-known antioxidants are beta-carotene (provitamin A), ascorbic acid (vitamin C), tocopherols (vitamin E), and phenolic compounds. Most antioxidants, whether synthetic or of natural origin, contain hydroxyphenolic groups in their structure, and their antioxidant properties are partly due to the ability of these natural compounds to trap free radicals such as hydroxyl radicals (OH-) and superoxide. Several methods are used to assess antioxidant activity in vitro and in vivo[59]

4. The DPPH test: principle and application

A fast and easy method to investigate the total antioxidant scavenging activity of a compound is the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. The experimental procedure can be easily and fast adjusted and customized to the analysis experiments. Blois first developed it to determine the total antioxidant activity of compounds. DPPH is a dark colored powder of stable free-radical molecules, which is soluble in methanol or ethanol. It has a strong absorption maximum at a wavelength around 515 nm due to the presence of an unpaired electron. As this electron becomes paired off in the presence of an antioxidant compound (hydrogen donor), the absorption strength decreases. A color change from violet to yellow can be observed (see Figure 4.5). The change of color, and more precisely, the change of the absorbance maximum, can be used to determine the antioxidant activity of compounds.

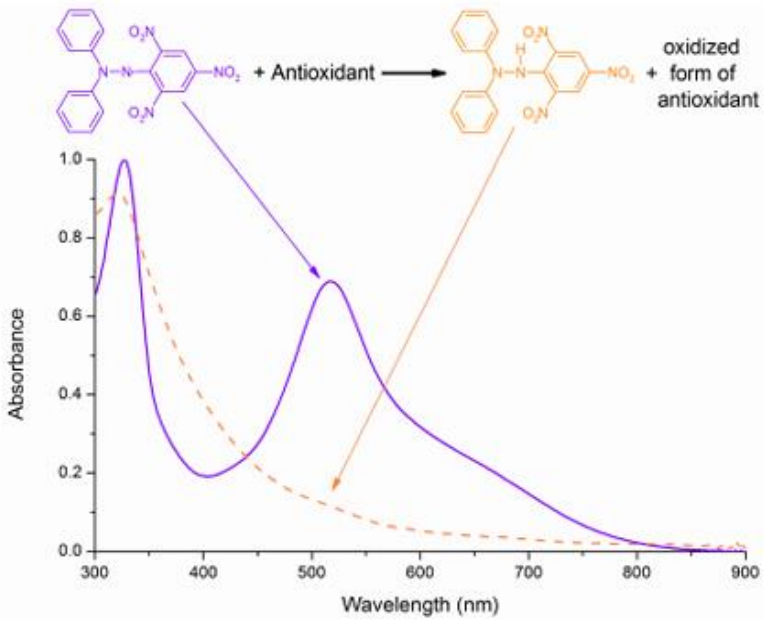


Figure II.1: Reaction between the DPPH radical (violet) and an antioxidant yielding the neutralized DPPH molecule (orange). [58]

Chapter III

Materials and Methods

Chapter III: Materials and Methods

III.1. Vegetable material.

III.1.1. Harvesting of plant materials

After harvesting, the collected plant material was dried at room temperature and stored in a dark location. The resulting dry matter was reduced to powder using an electric grinder. The latter were kept in closed glass jars and stored away from light.

III.2. Extraction

III.2.1. Maceration method

The pulverized plant is macerated in a mixture of solvents EtOH/ H2O: 70/30 (v/v) for 24 hours; this process is repeated 3 times. The various fractions recovered are combined and evaporated under reduced pressure at a temperature of 40°C.

Figure III 1: Filtration of the extract obtained by maceration

Figure III .2:Rota-viber device.

III.2.2. Soxhlet Extraction :

III.2.2.1. Extraction Principle

The Soxhlet device is a highly efficient device for performing solid-liquid extraction. The sample is placed inside a cartridge and then transferred to the extractor. The solvent is then placed in the flask and placed under a heating mantle. The solvent is evaporated, condensed, and collected in the extractor. Once the solvent level charged with the extract molecules reaches the line, they automatically fall back into the flask from the siphon and evaporate again.

The extract solution was allowed to cool to room temperature and then subjected to low-pressure evaporation at 40°C in a rotary evaporator.

Figure III 3: Soxhlet Extraction

III.3. Biological study:

III.3.1. Evaluation of antioxidant activity in vitro:

Preparation of the DPPH solution

Extract solution:

Solanum extract:

20 mg of the dry extract was dissolved in 1 ml of methanol, with good mixing using a Vortex apparatus to ensure complete solubility. After obtaining the parent concentration, a series of dilute concentrations was prepared as follows:20, 10, 5, 2.5, 1.25, 0.625, and 0.3125 mg/ml.

Zygophyllum extract:

160 mg of the dry extract was dissolved in 1 ml of methanol, with good mixing using a Vortex apparatus. Subsequently, diluted concentrations were prepared as follows: 160, 80 40, 40, 20, 10, and 5 mg/ml.

III.3.2. Evaluation of antibacterial activity in vitro:

The antibacterial activity of *Zygophyllum* and *Solanum* extracts was evaluated using the disc diffusion method on agar medium (Müller-Hinton Agar).

1. Prepare the planting medium:

The ready-made müller -hinton agar medium was used in the form of a powder packed in vials, where we dissolved the content of the vials in an appropriate amount of hot distilled water with stirring until complete dissolution, then allowed the medium to cool slightly and then poured directly into sterile petri dishes where the thickness was about 4 mm and placed in a sterile place to cool and harden the medium.

2. Prepare the bacteria:

We used three reference bacterial strains:

Staphylococcus aureus

Pseudomonas aeruginosa

Escherichia coli

Newly grown colonies were scraped off with a sterile stick and suspended in a tube containing a sterile physiological solution so that the turbidity of the bacterial suspension was adjusted to match the standard

Figure III.4: Bacterial colonies stored in the laboratory

Figure III .5: Preparation of bacterial suspension from pre-existing colonies

3. Prepare the extract:

20 mg of the dry extract was dissolved in 1 ml of DMSO (diméthylsulfoxyde), with good mixing using a Vortex apparatus to ensure complete solubility.

4. Impregnate the dishes:

We then inoculated the Müller-Hinton plates by wiping the surface with three swabs, rotating the Petri dish at a 60° angle in each swab to ensure a homogeneous distribution of bacteria on the surface, using a sterile squeegee

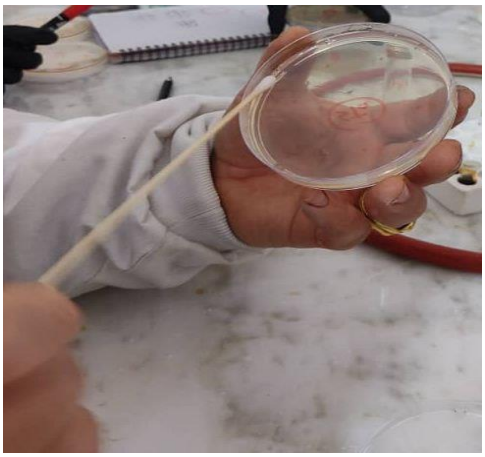


Figure III .6: Surface inoculation of Muller-Hinton agar with a bacterial suspension

5. Place the discs:

We gently placed the sterile paper discs (6 mm diameter) with sterile forceps, then the plant extract with a micropipette, a disc saturated with DMSO only as a negative control, and an antibiotic (antibiotic) as a positive control.

Figure III .7: Place a sterile blank disc on the inoculated agar using sterile forceps

Before use, the discs and micropipette tubes were sterilised in the autoclave for 15 minutes.

6. Incubation:

The plates were placed in the incubator at 37°C for 24 hours.

The diameter of the zone of inhibition around each disc was measured in millimeters

III.3.3. Evaluation of the effect of ointment on inflammation induced by formaldehyde.

Laboratory animals:

- The experiment was carried out on female Albino Wistar rats weighing between 180g and 250g.
    - They were divided into groups of similar weight in cages, each group comprising two rats. The animals underwent a 20-day adaptation period in the experimental environment to ensure their acclimatisation to the ambient conditions, which included a constant temperature of 24°C, a relative humidity of
    - 72%, and a light cycle of 12 hours of light and 12 hours of darkness. They had free access to food and water.
- **The rats were divided into four groups:**

Group 1 (negative control): injection of NaCl, used as a negative control.

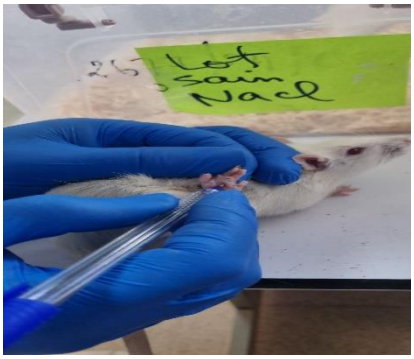


Figure III. 8: injection of NaCl

Group 2 (positive control): injection of formaldehyde, causing inflammation without treatment.

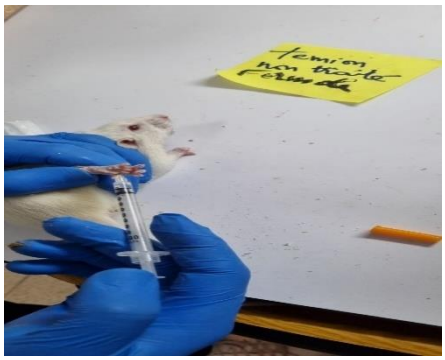


Figure III. 9: Injection of formalin

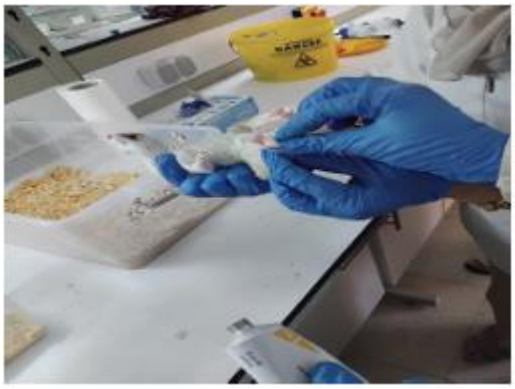
FigureIII.10: Swelling and redness (inflammation) After the injection

FigureIII.11: Measurement of a rat's leg after inflammation

Group 3: injection of formaldehyde, followed by application of an anti-inflammatory ointment for several hours.

FigureIII.12: Applying the ointment

Group 4: injection of formaldehyde, followed by application of diclofenac ointment, as a control, for several hours.



FigureIII.13: Application of Diclofenac

Figure III.14: The four groups are control, formaldehyde, test ointment, and diclofenac.

III.4. Ointment formulation

We formulated an ointment containing the following ingredients. (Table III 1).

Table III 1: Ointment compositions.

Constituent	Role
vegetable oil	Anti-inflammatory and antiseptic
vegetable oil	Similar in composition to the skin's natural sebum
Vitamin E	Preservative and Antioxidant
Zygophyllum	Antioxidant and antibacterial properties
Beeswax	Gives a solid texture to the pomade

III.5. Results and discussions:

Phytochemical screening

- Saponosides:

The appearance of a column of foam approximately 1cm long indicates the presence of saponosides.

- Coumarins:

When examined under UV light, the colour fluoresces yellow, indicating the presence of coumarins.

- Tannins:

The colour turns blue-black, indicating the presence of gallic tannins.

- Flavonoids:

Wilstater test

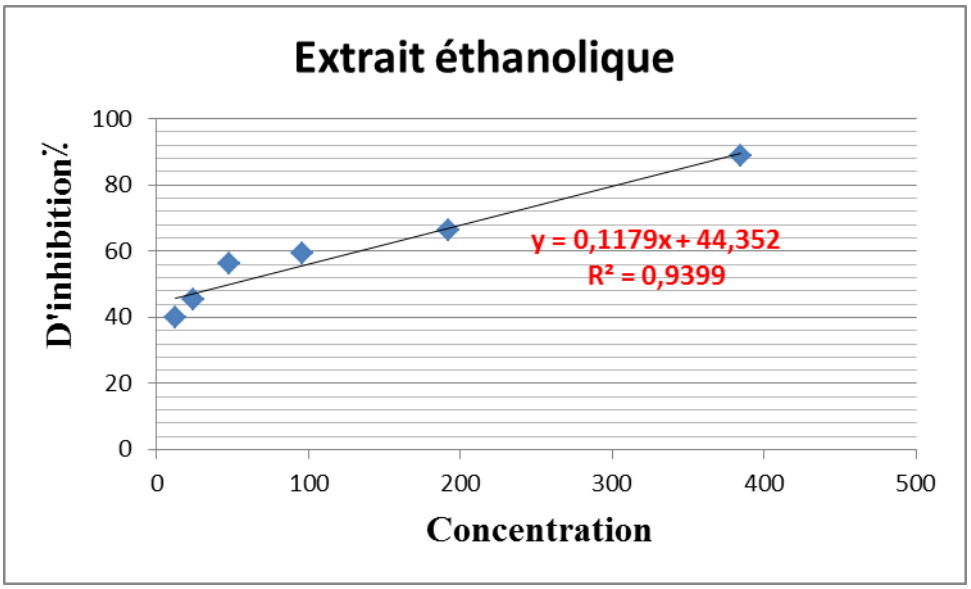
The colour change observed is purplish red, indicating the presence of a flavanone.

Libermann-Burshard test

The colour change is observed over one hour: a blue-green colour, indicating the presence of triterpenes.

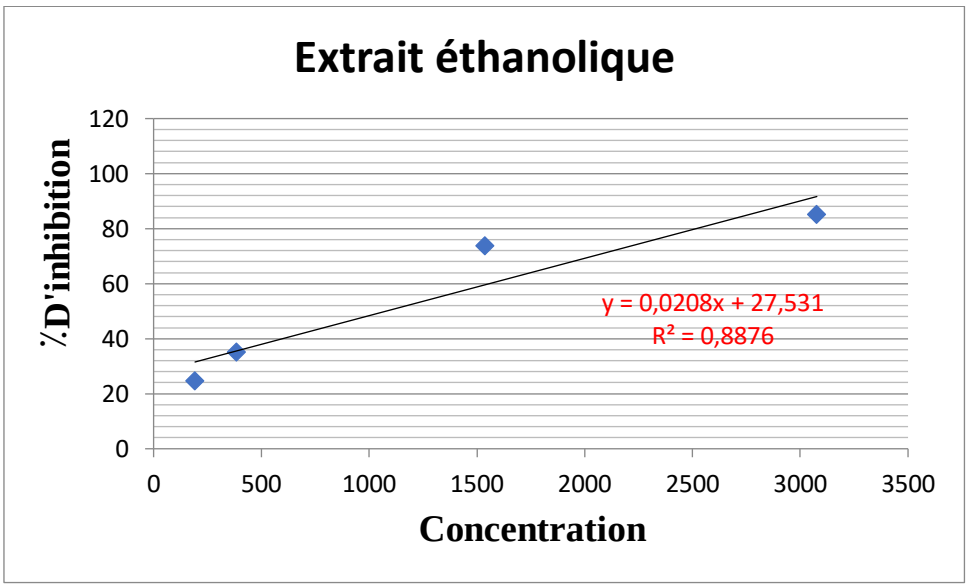
Antioxidant activity:

The antioxidant activity of the ethanolic extracts of *Zygophyllum* and *Solanum* was evaluated in vitro using the DPPH assay. Inhibition ratios were measured at different concentrations (mg/ml), and the results were used to plot dose-response curves.



IC_{50}=47.905004 mg/mL

Figure III.15: DPPH radical inhibition curve of *Solanum* extract



IC 50= 1080.25 mg/mL

Figure III.16: DPPH radical inhibition curve for *Zygophyllum* extract

For *Zygophyllum*, an IC50 = 1080.25 mg/mL was determined. In contrast, *Solanum* showed much stronger antioxidant activity, with an IC50 = 47.905004 mg/mL. Experimental curves show a gradual increase in the percentage of DPPH free radical inhibition as the concentration of the extract increases. The results indicate that both extracts possess a remarkable inhibition capacity, but with a clear difference in the level of efficacy.

Zygophyllum extract showed moderate efficacy, which can be attributed to the relatively low content of phenolic compounds and flavonoids, which are responsible for the antioxidant activity.

While *Solanum* extract showed very strong antioxidant activity, as evidenced by its significantly lower IC_{50} value, indicating that it contains a high concentration of active compounds such as phenols and flavonoids.

The comparison between the two plants shows that *Solanum* is a more promising source of natural antioxidant compounds than *Zygophyllum*.

Antibacterial activity:

Antibacterial activity of ethanolic extracts of *Zygophyllum* and *Solanum* was evaluated by measuring the diameter of inhibition zones surrounding the leaf discs after a 24-hour incubation period at 37°C. These zones are an indication of the ability of the extracts to inhibit the growth of the tested bacterial strains, *Pseudomonas aeruginosa* and *Staphylococcus aureus*.

Table III 2: Antibacterial activity of ethanolic extracts of Zygophyllum and Solanum

Bacterial strains		Muting zone diameters mm				
		1 extract *Zygophyllum*	1'The diluted extract of *Zygophyllum*	2extract Solanum	2' The diluted extract of *Solanum*	Gentamicin
1	*Pseudomonas aeruginosa* ATCC 27853	15	14	11	8	18
2	*Staphylococcus aureus* ATCC 25923	7	6	7	6,5	22

3	*Escherichia coli* ATCC 25922	6	6	6	6	20

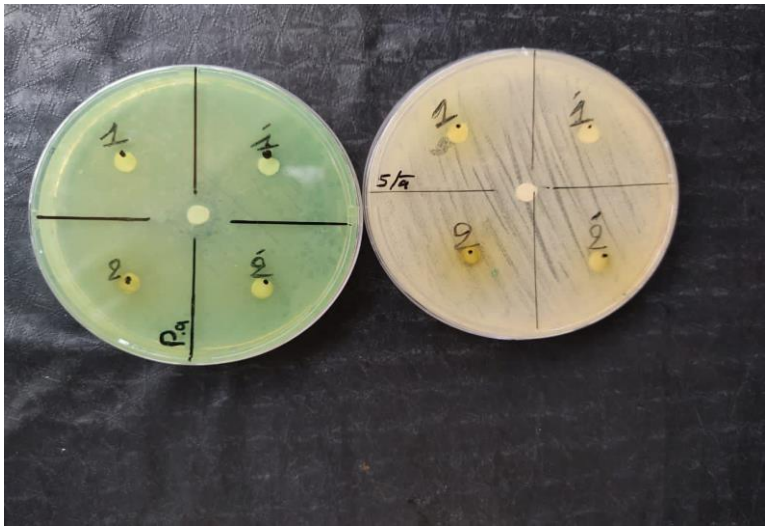


Figure III .17: Antimicrobial activity of extracts

Study of the antibacterial activity of ethanolic extracts of *Zygophyllum* and *Solanum*

We evaluated the antibacterial activity of ethanolic extracts obtained by maceration extraction of the plants *Zygophyllum* and *Solanum*, as well as their diluted forms, against two reference bacterial strains: *Pseudomonas aeruginosa* and *Staphylococcus aureus*, using the agar diffusion method.

The crude extract of *Zygophyllum* (1) showed good activity against *P. aeruginosa*, with a zone of inhibition of 15 mm, while its diluted extract (1') showed a slight reduction in activity (14 mm). On the other hand, low activity was observed against *Solanum*. aureus, with respective zones of 7 mm for the crude extract and 6 mm for the diluted extract.

For *Solanum*, the crude extract (2) inhibited the growth of *P. aeruginosa* with a zone of 11 mm, while the diluted extract (2') showed reduced activity (8 mm). Against *Solanum.* aureus, the activity was moderate with 7 mm (crude extract) and 6.5 mm (diluted extract).

Anti-inflammatory activity:

Table III 3: Effect of Ointment on Induced Inflammation in Rats

	Before the injection	After Injection	T_1	T_2	T_3	T_4
Healthy group NaCl	R_1: 3,7	3,7	3,7	3,7	3,7	3,7
	3,7	3,7	3,7	3,7	3,7	3,7
	3,5	3,5	3,5	3,5	3,5	3,5
	R_2: 2,8	2,8	2,8	2,8	2,8	2,8
	2,8	2,8	2,8	2,8	2,8	2,8
	3	3	3	3	3	3
Non-treated group (Injected formulation)	R_1: 2,1	5,5	6,1	6,1	6,4	7
	2,1	5,6	6,1	6,3	6,3	7,1
	2,3	5,7	6,2	6,4	6,3	7,1
	R_2: 2,8	5,6	6,4	5,8	6,2	7,4
	2,9	5,4	6,1	5,9	6,2	7,5
	3	5,4	6,4	6,1	6,1	7,3
Formulation	R_1: 2,7	5,6	5,1	3,9	3,9	3,3
	2,9	5,7	5,1	4,1	4	3,3
	3	5,9	4,9	4,1	4	3,5
	R_2 2,6	5,3	5,1	3,9	3,7	3,4
	2,8	5,4	4,9	3,8	3,6	3,4
	2,9	5,5	4,6	3,9	3,7	3,5
Diclofenac group	R_1: 2,7	5,5	4,5	3,3	3,7	3,1
	2,9	5,8	4,6	3,3	3,8	3,1
	2,9	6	4,5	3,4	3,6	3,2

	R_2: 2,7	5,4	4,4	3,6	3,7	2,9
	2,8	5,4	4,4	3,6	3,5	3,2
	2,9	5,6	4,6	3,4	3,6	3,1

The anti-inflammatory efficacy of pomade prepared from *Zygophyllum* extract was evaluated using a formaldehyde-induced inflammation model in rats. The results of the untreated group (control +) showed a significant increase in tumour size, reflecting the successful induction of inflammation. In contrast, the pomade-treated group showed a gradual decrease in the severity of inflammation over time, with values at the end of the trial reaching levels comparable to those of the Diclofenac group, which served as a pharmacological reference. This apparent reduction indicates that the formulation possesses anti-inflammatory properties, possibly due to the presence of bioactive compounds in the extract, such as flavonoids, polyphenols, or saponins, which are known to inhibit inflammatory mediators.

General Conclusion

General Conclusion

This study focused on the phytochemical and biological analysis of two Algerian medicinal plants: *Zygophyllum* and *Solanum*. The extraction process was carried out using an ethanol/water solvent via Macération and Soxhlet extraction methods, followed by a qualitative and quantitative study of the polyphenolic and flavonoid content.

Biological evaluations showed significant antioxidant and antibacterial activity in both extracts, confirming the presence of bioactive compounds with therapeutic potential. The anti-inflammatory evaluation of the ointment prepared from *Zygophyllum* extract was clearly effective in reducing formaldehyde-induced inflammation in rats.

These results reinforce the traditional use of these two plants in folk medicine and highlight their promising potential in the pharmaceutical and cosmetic fields. Additional studies, including accurate isolation of active compounds, toxicological evaluation, and clinical validation, are recommended to support their development as safe and effective natural remedies.

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APPENDIX

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي و البحث العلمي

جامعة محمد بوضياف- المسيلة

عنوان المشروع:

مرهم مضاد للالتهاب مستخلص من نباتات طبية

مشروع لنيل شهادة مؤسسة ناشئة في اطار القرار الوزاري 1275

الاسم التجاري

Sami bio

بطاقة معلومات:

حول فريق الاشراف وفريق العمل

1- فريق الاشراف:

فريق الاشراف	
(01): المشرف الرئيسي مرتات فائزة	التخصص: الكيمياء العضوية

2- فريق العمل:

فريق المشروع	التخصص	الكلية
الطالبة: لبزي سميحة	الكيمياء العضوية	كلية العلوم

فكرة المشروع (الحل المقترح)

جال النشاط: صناعي – مستحضرات تجميل طبيعية وعلاجية

يف بدأت الفكرة؟ انطلقت الفكرة من رغبتي في استغلال النباتات الطبية المحلية لإنتاج
رهم مضاد للالتهاب مستخلص من نباتات طبية

- ما الذي قمت به؟ قمت بتطوير تركيبة فعالة مستخلصة من نبات **Zygophyllum**
- كيف تم ذلك؟ تم تنفيذ المشروع عبر مراحل علمية دقيقة شملت: تجميع النباتات، استخلاص المكونات الفعالة، اختبار الأنشطة البيولوجية (النشاط المضاد للأكسدة والمضاد للبكتيريا)، ثم تركيب المرهم
- من أنجز ذلك؟ أنجزتُ المشروع بنفسي تحت إشراف أكاديمي مباشر وتوجيه علمي متخصص.
- أين تم إنجازه؟ في مخبر حاضنة جامعة المسيلة.

1. القيم المقترحة

يمكن أن تنشأ القيم المقترحة أو المقدمة للزبائن من خلال العناصر التالية:

- الحداثة: أول منتج يُطوّر اعتمادًا على نبات **Zygophyllum** ، وهي تركيبة مبتكرة لم تُستخدم تجاريًا من قبل.
- الأداء:فعالية مثبتة مخبريًا كمضاد أكسدة وبكتيريا.
- التكييف: إمكانية تعديل التركيبة حسب نوع البشرة.
- إنجاز المهمة :يساعد هذا المرهم الطبيعي، المستخلص من نباتات طبية، على تخفيف الالتهابات والآلام الموضعية بشكل فعّال وآمن، دون الحاجة إلى اللجوء للمركبات الكيميائية القاسية أو الأدوية الصناعية. تركيبته النباتية تساهم في تهدئة المناطق المصابة، دعم الدورة الدموية الموضعية، وتوفير إحساس بالراحة يدوم، مع الحفاظ على صحة الجلد وتوازنه الطبيعي..
- التصميم:تم تصميم هذا المرهم بتركيبة نباتية لطيفة على البشرة، خالية من المواد الكيميائية القاسية، بملمس ناعم وسهل الامتصاص. يتميز بقوام مناسب للتطبيق الموضعي دون أن يترك أثرًا دهنيًا مزعجًا. تم اختيار مكونات طبيعية تمنح إحساسًا بالراحة والتهدئة، مع عطر عشبي خفيف غير مزعج. كما تم اعتماد تغليف عملي وصحي، يحافظ على جودة المنتج وسهولة استعماله بشكل يومي.
- خفض التكاليف: منتج اقتصادي مقارنة بالمستحضرات الأجنبية.
- الحد من المخاطر: يساهم هذا المرهم الطبيعي في تقليل مخاطر التهيج أو التحسس الجلدي بفضل تركيبته النباتية الخالية من المواد الكيميائية القاسية.تم اختياره بعناية ليمنح المستخدم تجربة علاجية موضعية آمنة، مع تقليل احتمالية الآثار الجانبية المرتبطة بالمراهم الصناعية، مما يجعله مناسبًا لمختلف أنواع البشرة، حتى الحساسة منها.
- سهولة الوصول: بفضل توفر المواد الأولية محليًا وسعره المناسب، سيكون المرهم متاحًا لشريحة واسعة من الزبائن، خاصةً في المناطق التي تفتقر لمنتجات تجميل طبيعية فعالة.

- الملاءمة/سهولة الاستخدام: مناسب للاستخدام اليومي

2. فريق العمل :

تم إنجاز المشروع من طرف الطالبة سميحة لبزي تحت إشراف أكاديمي الدكتورة مرتات فائزة

مهارات الطالبة تتمتع الطالبة بخلفية علمية في الكيمياء العضوية، مع مهارات تطبيقية في

تقنيات الاستخلاص النباتي (**Maceration** و**Soxhlet**) اختبارات النشاط البيولوجي تحضير التركيبات التجميلية التحليل العلمي والبحث في قواعد البيانات العلمية

دور الأستاذة المشرفة: أشرفت الدكتورة على التوجيه الأكاديمي والعلمي، وساهمت في التدقيق في مراحل البحث وضمان المنهجية العلمية السليمة

التنظيم : تولّت الطالبة الجانب العملي والتطبيقي بالكامل، في حين تولّت الأستاذة الإشراف والتقييم والتصحيح العلمي للمراحل الأساسية

طرق التواصل : اعتمد الفريق على لقاءات أسبوعية منتظمة في المخبر، بالإضافة إلى التواصل عبر البريد الإلكتروني والرسائل الفورية لتبادل الملفات والنتائج

3. أهداف المشروع

يهدف هذا المشروع إلى تحقيق مجموعة من الأهداف الابتكارية، تتمثل فيما يلي

1. تم تطوير تركيبة طبيعية فعّالة بالاعتماد على مستخلص نبات**Zygophyllum** ، تعتمد على فوائد النباتات الطبية التقليدية..

2. إثبات الفعالية البيولوجية علميًا للمركبات النشطة في هذين النباتين (نشاط مضاد للأكسدة ومضاد للبكتيريا)، وربطها بشكل مباشر بالأثر التجميلي.

3. تحضير نموذج أولي قابل للتطوير والتسويق يمثل منتجًا مبتكرًا يُلبي حاجة المستهلك المحلي لمستحضرات طبيعية فعالة وآمنة.

4. تمهيد الطريق نحو تسجيل براءة اختراع أو علامة تجارية باسم المؤسسة الناشئة، مما يدعم مسار تحويل نتائج البحث العلمي إلى منتج اقتصادي فعلي.

5. تعزيز استغلال الموارد النباتية المحلية في الصناعة التجميلية، والمساهمة في اقتصاد المعرفة من خلال منتج ذي قيمة مضافة عالية.

4. جدول زمني لتحقيق المشروع :

	البحث في قواعد البيانات الخاصة ببراءات الاختراع وجمع المعلومات	✓	✓				
	الشروع في الاختبارات المخبرية لإعداد النموذج الأولي		✓	✓			
	تجريب النموذج الأولي		✓	✓	✓		
	تجربة النموذج الأولي خارج المخابر			✓	✓	✓	
	تسجيل براءة الاختراع من اجل الحصول على رقم الإيداع والحماية الصناعية					✓	
	متابعة عملية الحصول على براءة الاختراع وتصحيح ملاحظات الممتحنين من **inapi**						✓

5. عرض القطاع السوقي :

- ✓ السوق المحتمل: كبار السن، المستخدمون العاديون لمنتجات العناية، الأسواق الخارجية المهتمة بالمنتجات الطبيعية والعضوية.
- ✓ السوق المستهدف (الشريحة): الأشخاص الذين يعانون من آلام المفاصل والعضلات، الرياضيون، والفئة التي تفضّل العلاجات النباتية، بالإضافة إلى الصيدليات ومحلات الأعشاب.

- ✓ مبررات اختيار السوق المستهدف:
  نقص البدائل المحلية ذات الجودة العالية بأسعار مقبولة.
  تزايد الوعي الصحي والطلب على المنتجات الخالية من المواد الكيميائية.
  ثقة المستهلك المحلي في المنتجات النباتية الطبيعية المستخرجة من البيئة الجزائرية.
- ✓ تحديد إمكانية ابرام عقود شراء مع بعض الزبائن المهمين.إمكانية عالية لعقد شراكات مع صيدليات، محلات الأعشاب، ومنصات بيع إلكترونية، وذلك بفضل بساطة التركيبة، وانخفاض التكلفة، ووضوح الفعالية المخبرية.

6. قياس شدة المنافسة :

- ✓ المنافسون المباشرون: علامات محلية ، منتجون صغار على مستوى محلي (صناعة يدوية – عبر فيسبوك وإنستغرام).
- ✓ المنافسون غير المباشرين: العلامات التجارية الكيميائية المستوردة)،مستحضرات طبية من الصيدلية (أدوية وكريمات مركبة صناعيًا).
- ✓ الحصص السوقية: المنتجات الكيميائية تهيمن على السوق بنسبة تفوق(60%) المنتجات الطبيعية المحلية ما زالت ضعيفة في الانتشار (أقل من 15%).
- ✓ نقاط القوة للمنافسين :تسويق قوي، انتشار واسع، ثقة المستهلك في العلامات المعروفة.
- ✓ نقاط الضعف: أسعار مرتفعة، مكونات صناعية، ضعف التكيف مع احتياجات البشرة الحساسة.

7. التكاليف والأعباء :

- ✓ التكاليف الثابتة :تجهيزات مخبرية وأوانٍ زجاجية.آلات مزج وتحضير، عبوات تغليف أولية.
  تكاليف تسجيل المنتج قانونيًا وإنشاء العلامة التجارية.
- ✓ التكاليف المتغيرة :المواد الخام النباتية (تجميع أو شراء).مذيبات، مواد حافظة طبيعية، زيوت أساسية.الطباعة والتغليف والتسويق الرقمي.مصاريف تحليل مخبري وتحاليل الجودة.

الملحق رقم 04: نموذج العمل التجاري

شرائح العملاء customer segments	العلاقات مع العملاء customer relationship	القيم المقترحة value proposition	الأنشطة الرئيسية key activities	الشراكات الرئيسية key partners
المستهدف : الأشخاص الذين يعانون من آلام المفاصل والعضلات، الرياضيون ، والفئة التي تفضّل العلاجات النباتية، بالإضافة إلى الصيدليات ومحلات الأعشاب. المحتمل: كبار السن، المستخدمون العاديون لمنتجات العناية، الأسواق الخارجية المهتمة بالمنتجات الطبيعية والعضوية.	خلق العلاقة : تقديم عينات مجانية – فتح صفحة على مواقع التواصل – الاستماع لمشاكل الزبائن واقتراح حلول طبيعية. تطوير العلاقة : برامج ولاء – تخفيضات للعملاء الدائمين – إطلاق منتجات جديدة بناءً على آراء الزبائن. استدامة العلاقة: نشر محتوى تثقيفي – الاستجابة السريعة للاستفسارات – التواصل المستمر عبر البريد أو الرسائل. ضمان العلاقة : ضمان الجودة والفعالية – إتاحة الشهادات المخبرية – إرجاع المنتج في حال عدم الرضا.	منتوج(مرهم مضاد للاتهاب مستخلص من نباتات طبية) هو مشروع يقدم القيم التالية: الحداثة:إدماج النباتات الطبية المحلية في تركيبات تجميلية مبتكرة ومستندة على نتائج علمية. القيمة بالحد من المخاطر:منتج طبيعي يقلل من احتمال الحساسية والآثار الجانبية. القيمة بالتخصيص او التمييز:تركيبات موجهة حسب نوع البشرة أو المشكلة الجلدية. القيمة بالخدمة الشاملة:من الاستشارة إلى تقديم الحلّ مع المتابعة بعد البيع.	التخطيط:دراسة السوق – تحديد احتياجات الزبائن – وضع خطة إنتاج وتسويق. الإنتاج :استخلاص النبات – تحضير التركيبة – تعبئة وتغليف المنتج. التسويق :تصميم الهوية البصرية – إدارة صفحات التواصل – إطلاق حملات ترويجية.	الشركاء الرئيسيون :مخابر تحليل – خبراء تجميل – صيدليات وشبه صيدليات. بالإضافة الى : حاضنات الاعمال البنوك (لتمويل) تعاون مع جامعات أو مراكز بحث تعاونيات نسوية توفر النباتات
	القنوات channels التطبيق او المنصة :موقع إلكتروني بسيط أو		الموارد الرئيسية key resources	

	تطبيق يعرض المنتجات ويتيح الطلب المباشر. مواقع التواصل الاجتماعي :إنستغرام – فيسبوك – تيك توك (محتوى توعوي وترويجي). تنشيط حملات تعريفية للمشروع عبر الإذاعة والتلفزيون برامج محلية تعرض قصص نجاح ومشاريع نسوية.	القيمة بالأداء العالي:فعالية مثبتة مخبريًا ضد الأكسدة والميكروبات. القيمة بالسعر:سعر في المتناول مقارنة مع المنتجات المستوردة. التقليل من التكاليف عن طريق: استخدام موارد محلية – الاستخلاص بتقنيات بسيطة لكنها فعالة. سهولة الاستخدام:تركيبات سهلة التطبيق – تعليمات واضحة على الغلاف.	المادية :أدوات استخلاص وتحضير – أواني – مواد أولية. البشرية:صاحبة المشروع – تقني تجميل – مساعد في التسويق. المالية:تمويل ذاتي أو عن طريق حاضنة – دعم بنكي صغير. التكنولوجية :أجهزة استخلاص – أجهزة تحليل – كمبيوتر وبرامج تصميم وتسويق.	
	مصادر الإيرادات revenue streams سعر المنتج :بيع الكريم بسعر مدروس حسب السوق المحلي. عوائد الإعلانات :شراكة مع مؤثرين أو شركات تعرض المنتج مقابل نسبة.		هيكل التكاليف cost structure التكاليف الاستثمارية :اقتناء الأدوات – تطوير الهوية البصرية – إطلاق الدفعة الأولى. التكاليف التشغيلية :شراء المواد الخام – الطباعة والتغليف – الحملات التسويقية – مصاريف التوصيل.	