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An Overview of Banana Pseudostem for the Study of Transdermal Patch

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ABSTRACT

Transdermal drug delivery systems offer a non-invasive manner of continuous pharmaceutical release and enhanced patient compliance by decreasing systemic side effects and preventing first-pass metabolism. Along with the advent of contemporary transdermal technology, herbal biomaterials are being researched as safe, biocompatible medicine delivery solutions. A range of bioactive phytochemicals, including tannins, saponins, flavonoids, terpenoids, phenolic compounds, glycosides, and polysaccharides, are found in banana pseudostem, which is obtained from Musa acuminata and Musa paradisiaca. These compounds have potent antidiabetic, anti-inflammatory, antibacterial, antioxidant, anticancer, anthelmintic, and anti-urolithic qualities. This review focuses on the phytochemical composition, traditional medicinal uses, and pharmacological properties of banana pseudostem, as well as an overview of transdermal patch types, formulation ingredients, techniques, and evaluation elements. The findings imply that banana pseudostem extract's therapeutic efficacy, biocompatibility, and wide pharmacological spectrum make it a suitable herbal choice for transdermal drug delivery.

Keywords: Musa paradisaca, Musa acuminata, banana pseudostems, Herbal transdermal patch, Phytochemicals.

1.INTRODUCTION

When compared to oral or parenteral procedures, transdermal delivery technologies are very effective and give several advantages. Avoiding first pass metabolism, preserving a constant level of active medication in the blood, enhancing patient compliance, and reducing side effects are a few advantages.[1,2] Transdermal patches (Emplastra transcutanea) were first employed as medicinal plasters to treat local ailments in Ancient China around 2000 BC. Many herbal medicine ingredients were typically put on an adhesive natural gum rubber foundation and fastened to a backing support made of cloth or paper in these early plasters.[3]

1.1Advantages of Transdermal Drug Delivery Systems

1.Transdermal medication gives a continuous infusion of a substance over a lengthy period of time. Adverse effects or treatment failures that are usually related with intermittent dose can be avoided.
2. By addressing concerns including gastrointestinal discomfort, limited absorption, hepatic "first-pass" action, metabolite production, short half-life, and frequent dosage, transdermal administration might boost the therapeutic effectiveness of drugs.
3.Due to the aforesaid benefit, it is feasible that an analogous therapeutic effect can be elicited by transdermal drug input with a lower daily dose of the drug than is necessary, if, for example, the drug is given orally.
4.The streamlined drug schedule leads to greater patient compliance and lower inter & intra – patient variability.
5. It is not always desirable to maintain the medication concentration within the diphase. Application and removal of transdermal patch generate the ideal sequence of pharmacological activity.
6. These systems enable self-administration.
7.The drug input can be halted at any point of time by removing transdermal patch.

1.2 Disadvantages of Transdermal Drug Delivery Systems

1. The medicine must have certain favorable physicochemical qualities to penetrate the stratum corneum, and if the drug dose necessary for therapeutic efficacy exceeds 10 mg/day, transdermal administration will be extremely problematic.
2. Only potent medications are effective for treating TDDS because the skin's impermeability restricts drug penetration.
3. Due to contact dermatitis at the application site, some patients cease using one or more system components.
4. Clinical necessity is another element to consider carefully before producing a transdermal product.

5. The skin's barrier function varies from one location to another, from person to person, and with age.[4]

2. A Brief Overview of Skin Structure

The largest and easiest-to-access organ in the body is the skin. It takes up about 16% of an individual's total body weight and has an average surface area of 1.7 m². Its main function is to serve as a barrier between the body and the external environment, protecting against allergies, chemicals, dangerous UV radiation, pathogens, and excessive water loss.
Three primary layers make up the structure of the skin:

2.1. Epidermis

The skin's outermost layer, the epidermis, acts as the body's first line of protection. Its thickness fluctuates, with the palms and soles having a maximum thickness of 0.8 mm. Multiple layers of epithelial cells make up this layer. The term "viable epidermis" is frequently used to describe the area underneath the stratum corneum.

The epidermis has special defensive qualities since it is directly exposed to the environment. These result from its comparatively low water content (15–20%) and high density (about 1.4 g/cm³ when dry).
The top layer of the epidermis, known as the stratum corneum, is mostly made up of lipids (20%) and insoluble keratin proteins (70%). Within the corneocytes, water in this layer is still closely linked to keratin.

2.2. Dermis

The dermis, a 2–3 mm thick layer rich in collagen (around 70%) and elastin fibers, is located underneath the epidermis. The skin's flexibility and strength are attributed to these structural proteins.
Along with nerves, lymphatic vessels, and immunological cells like macrophages, this layer also has blood vessels that provide nourishment to the dermis and epidermis.

2.3. Hypodermis

The skin's deepest layer is called the hypodermis, or subcutaneous layer. It is mainly made up of fat cells arranged in a network of support. This layer serves as insulation, protects the body from physical damage, and facilitates the transmission of vascular and neurological information to and from the skin.
Together with other cells like fibroblasts and macrophages, this layer stores almost half of the body's total fat. The skin only permits a very tiny amount of a medication to enter through its layers, which is a significant obstacle.[5,6,]

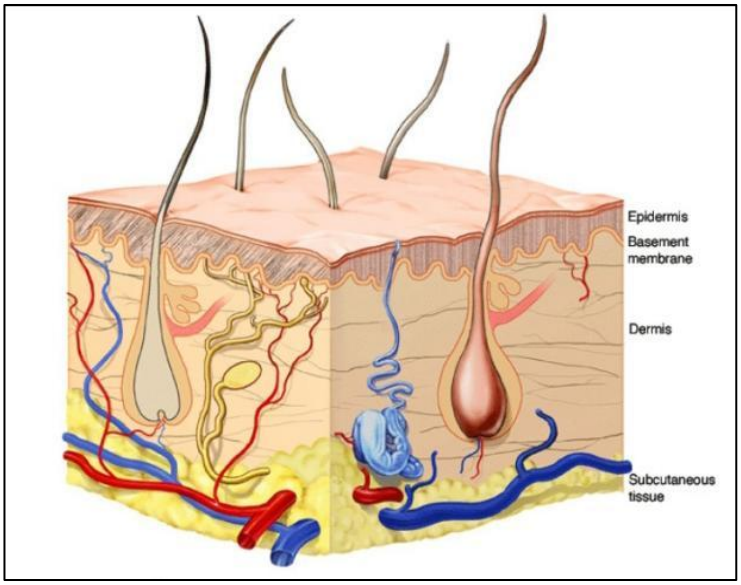

Fig.1. Layers of Skin

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3.BANANA PSEUDOSTEAM

M. paradisiaca is yet a mostly untapped source for the creation of novel medications. Plants are the source of about 85% of all drugs used to treat a variety of illnesses. Therefore, the purpose of the current study on M. paradisiaca is to compile all of the research on this important plant in one place so that researchers may learn more about it. It is a tall, robust plant with a fake stem (pseudostem) above the ground made up of concentrically built leaves, from which the inflorescence stalk grows. The actual stem, or rhizome, is underground. Numerous clusters of sterile male flowers surrounded by bright purple bracts can be found close to the top of the bloom stalk.

The fruit is formed by a cluster of lower female flowers on the same stalk. Numerous human illnesses have been treated with the complete plant as well as particular sections (flowers, banana bracts, ripe and unripe fruits, leaves, and stems) of plant extract and its active compounds. Traditionally the plant has been used for different purposes such as abscess, alopecia, burns, cancer, cataplasm, diabetes, diarrhea, dogbites, snake bite, dysentery, dyspepsia, fracture, gangrene, hematuria, emiplegia, hemoptysis, hemorrhage, hypertension, lizard bites, marasmus, migrain, ringworm, shingles, smallpox, syphilis, tuberculosis, tumor, uremia, otalgia, psoriasis, urticaria,warts and wounds.[8,9]

Table.1. Taxonomy[10,11]

Kingdom	**Plantae**
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Super kingdom	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Lilianae
Order	Zingiberales
Family	Musaceae
Genus	Musa
Species	acuminate

Fig.2. Banana Plant

3.1. Traditional applications

M. paradisiaca and M. sapientum fruit have historically been used to treat diabetes, dysentery, intestinal lesions in ulcerative colitis, diarrhea, sprue, uremia, nephritis, gout, hypertension, and heart problems. Flowers can be used to treat dysentery and menorrhagia. Diarrhea, dysentery, cholera, otalgia, and hemoptysis are all treated with the fruit plant's stem juice; menorrhagia, diabetes, and dysentery are treated with flower extract. Sexual infections, blood diseases, and anthelmintic medications are all treated with the root. The plant is also used to cure inflammation, discomfort, and snake bites[12].

4.TYPES OF TRANSDERMAL PATCHES:

a) Single-layer drug-in-adhesive system: The medication is included straight into the adhesive layer of this kind of patch. This adhesive regulates the medication's release in addition to aiding in the patch's adherence to the skin. A detachable liner hides the adhesive until the patch is placed, and a protective backing layer rests on one side.

b) Multi-layer drug-in-adhesive system: This design has multiple drug-loaded adhesive layers and is comparable to the single-layer variant. Usually, one layer offers regulated, prolonged distribution, while the other permits quick, instantaneous drug release. It has a permanent backing layer and a detachable liner for protection prior to use, just like the single-layer patch.

c) Vapour patch: The adhesive layer in this kind of patch aids in the release of medicinal vapors in addition to holding the patch together. Delivering essential oils for decongestion is a typical usage for vapor patches, which are relatively new. Other products on the market are intended to improve sleep quality or lessen urges for cigarettes.

d) Reservoir system: In this system, the medication is kept inside a reservoir that has a rate-controlling membrane and an impermeable backing layer. The membrane controls the rate of drug release, regardless of whether it is microporous or not. The medication within the reservoir could be dispersed throughout a solid polymer matrix, present as a gel, solution, or suspension. The outside surface can be coated with a skin-friendly layer that is compatible with the drug using a hypoallergenic adhesive polymer.

e) The matrix system

i. Drug-in-adhesive system: This design creates a reservoir by mixing the drug straight into an adhesive polymer. Then, using methods like solvent casting or hot-melt processing, this combination is applied to an impermeable backing layer. To preserve the reservoir, a drug-free layer of glue is applied.

ii. Matrix-dispersion system: In this technique, the medication is dispersed uniformly throughout a hydrophilic or lipophilic polymer matrix. Enclosed by a backing layer that prevents the drug from passing through, this drug-loaded polymer disk is fastened to an occlusive base plate. The glue is put around the drug reservoir's outer border rather than directly covering it, creating an adhesive rim that holds the system in place.

f) Microreservoir system:

This system combines elements of reservoir and matrix-dispersion designs. The medication is first suspended in a water-soluble polymer-containing aqueous solution. After that, this combination is uniformly distributed throughout a lipophilic polymer, creating thousands of tiny, discrete drug reservoirs. By cross-linking the polymer with appropriate cross-linking agents, this dispersion—which is not normally stable—is swiftly solidified, forming a stable network of micro-reservoirs.[13,14]

Table 2. Comparative Evaluation of Banana-Leaf-Based Materials and Conventional Polymers for Transdermal Patch Applications

Criterion	Banana-Leaf-Based Materials	Conventional Transdermal Patch Polymers	Critical Evaluation / Notes
Permeability	**Moderate–variable** depending on processing (cellulose content, extraction/purification)	**Tunable and well-characterized** (e.g., ethylcellulose, PVA, PU)	Banana leaf matrices offer natural porosity but inconsistent diffusivity. Conventional polymers allow precise control via formulation and plasticizer content.
Mechanism	Natural cell wall channels, hydrophilic pathways	Controlled diffusional pathways, engineered microstructure	The unpredictability of native pathways can lead to batch variability in flux. Engineered polymers yield predictable, reproducible drug flux profiles.
Antimicrobial Efficacy	**Intrinsic phytochemical activity** (polyphenols, flavonoids may impart antimicrobial function)	**Usually absent**, requires incorporation of additives (e.g., silver nanoparticles, loaded agents)	Banana leaf extracts may provide baseline inhibition of microbes; however, efficacy depends on extraction and retention in matrix. Conventional systems need active additives for antimicrobial action.
Spectrum	Broad but **unstandardized**	Can be tailored to target microbes	Conventional patches with embedded agents allow specific targeting; plant-derivative efficacy may fluctuate with source and season.
Mechanical Strength	**Low to moderate** tensile strength (without modification), brittle if poorly plasticized	**High** tensile strength and elasticity (designable for flexibility)	Native banana leaf materials lack mechanical robustness. They often require blending (e.g., with biopolymers, plasticizers) leading to complex formulations.
Elasticity & Conformability	Limited unless modified; tends toward rigidity	Excellent; engineered to conform to body contours	Conventional polymers minimize patient discomfort through elasticity. Banana leaf films require additives to approach comparable flexibility.
Water Vapor Transmission (WVT)	**High variability**; inherently hydrophilic → higher WVT	**Controllable** via polymer selection & additives	High WVT can dry out active agents; conventional films maintain moisture balance better.
Biocompatibility	Generally **good**, plant-based cellulose; low toxicity	**Excellent**, standardized for clinical use	Both can be biocompatible; conventional materials have documented safety profiles.
Biodegradability	**High** (environmentally friendly)	Varies; many are non-biodegradable or require special disposal	Banana leaf films offer sustainability advantages; clinical adoption needs regulatory safety data.
Processing & Scalability	Requires **pre-treatment**, extraction, purification; batch variability	**Established**, industrial-scale production	Conventional polymers benefit from mature manufacturing. Banana leaf materials need standardization and quality control.

5. USED INGREDIENTS

5.1 Matrices or Polymer Matrix

The structural foundation of a transdermal medication delivery system is composed of polymers. Achieving the intended drug release profile and patch performance requires careful matrix design and polymer selection.

Three types of polymers are typically utilized in transdermal systems:

Materials like zein, gelatin, cellulose derivatives, gums, natural rubber, shellac, waxes, and chitosan are examples of natural polymers.

Hydrin rubber, polyisobutylene, polybutadiene, silicone rubber, nitrile rubber, neoprene, butyl rubber, and acrylonitrile-based polymers are a few examples of synthetic elastomers.

Synthetic polymers: Polyvinyl chloride (PVC), polyethylene, polyvinyl alcohol (PVA), polypropylene, polyamide, polyacrylates, polyurea, polyvinylpyrrolidone (PVP), and polymethyl methacrylate (PMMA) are often utilized choices.

Plasticizers: Plasticizers aid in enhancing the polymer matrix's handling and flexibility. Usually, 5–20% (w/w, dry basis) concentrations are utilized. Glycerol, sorbitol (around 15% w/w), fatty acid esters, phosphate and phthalate esters, and glycol derivatives like PEG 200 and PEG 400 are a few examples.

5.2 Solvents

Drug reservoirs in transdermal systems can be made using a variety of solvents. Methanol, dichloromethane, acetone, isopropanol, and chloroform are typical examples. In order to create a homogenous mixture, these solvents aid in the dissolution of the medication and the polymers.

5.3 Transdermal Patch Development

The solvent-evaporation process was used to prepare the patches. Initially, the medication (250 mg) and the polymers (500 mg) were precisely weighed according to the necessary polymer ratios (PVP and HPMC K100LV). After that, these components were dissolved in an appropriate solvent.
Oleic acid was utilized as a drug solvent and as a permeation enhancer at 12% w/w of the polymer content, while PEG 4000 was added as a plasticizer at 46% w/w of the polymer content.

A glass petri dish was filled with the finished polymeric mixture, which included the medication, plasticizer, and enhancer. The film was left undisturbed for a whole day after a funnel was installed over the dish to enable regulated drying. The created spots were carefully removed by running a sharp blade along the film's edges after it had dried.

6.EVALUATION PARAMETERS:

1. Research on Interactions

Almost all pharmacological dose forms heavily rely on excipients. Making sure the medicine and excipients work well together is one of the most crucial aspects of formulation development. The stability and bioavailability of the finished product may be impacted if they are not.
Compatibility testing becomes crucial when new excipients are employed, particularly those that have never been mixed with the active medication. These investigations aid in determining any potential chemical or physical interactions.

Thermal analysis, FT-IR, UV spectroscopy, and chromatographic techniques are frequently employed in interaction research. To find any possible interactions, these tests examine a variety of physicochemical characteristics, including drug assay, melting point variations, distinctive wave numbers, and absorption maxima.

2. **Patch thickness:**

The thickness of the drug-loaded patch is measured at various spots with a digital micrometer, and the average thickness and standard deviation are calculated to ensure the thickness of the prepared patch.

3. **Weight uniformity**:

The produced patches should be dried at 60°C for 4 hours prior to testing. A defined area of patch is split into distinct sections and weighed in a digital balance. Individual weights are used to establish the average weight and standard deviation**.**

4. **Folding endurance**:

A strip of a certain area is cut uniformly and repeatedly folded at the same location until it breaks. The number of times the film could be folded in the same spot without breaking determined the folding endurance.

5. **Percentage Moisture Content**:

Weigh each manufactured film individually and place it in a desiccator with fused calcium chloride at room temperature for 24 hours. After 24 hours, the films should be reweighed to calculate the percentage moisture content using the formula below.

Percentage moisture content = [Initial weight- Final weight/ Final weight] ×100.

6. **Moisture uptake percentage:**

The weighed films should be stored in a desiccator at room temperature for 24 hours with a saturated potassium chloride solution to maintain a RH of 84%. After 24 hours, the films should be reweighed to measure the percentage moisture uptake using the formula below.

Percentage moisture uptake = [Final weight - Initial weight/Initial weight] ×100.

7. **Water vapour permeability (WVP) evaluation:**

The foam dressing method can be used to measure water vapour permeability when an air-forced oven is substituted with a natural air circulation oven. The WVP can be determined using the following formula:

WVP=W/A

Where WVP is represented in gm/m² per 24hrs, W is the amount of vapour permeated through the patch expressed in gm/24hrs, and A is the surface area of the exposed samples expressed in meters.

8.Drug Content:

A certain portion of the patch must be dissolved in a suitable solvent in a defined volume. The solution is then filtered through a filter media and analysed for drug content using the appropriate method (UV or HPLC). Each number is the average of three separate samples.

9.Uniformity of dose unit test:

An accurately weighed portion of the patch is sliced into small pieces and transferred to a precise capacity volumetric flask, dissolved in a suitable solvent, and sonicated to extract the drug completely from the patch and made up to the mark with the same. The resultant solution was allowed to settle for about an hour before the supernatant was diluted to the required concentration with the appropriate solvent. The solution was filtered through a 0.2m membrane filter and analyzed using appropriate analytical techniques (UV or HPLC), and the drug content per piece was estimated.

10.Polariscope examination:

This test will be performed to evaluate the drug crystals from the patch using a polariscope. A certain surface area of the piece should be placed on the object slide and examined for drug crystals to determine whether the drug is present in the patch in crystalline or amorphous form.

11.Shear Adhesion Test:

This test measures the cohesive strength of an adhesive polymer. It can be impacted by the molecular weight, degree of crosslinking, polymer composition, type, and amount of tackifier used. An adhesive-coated tape is placed to a stainless steel plate; a specific weight is suspended from the tape, causing it to pull in a direction parallel to the plate. The time required to pull the tape off the plate is used to assess shear adhesion strength. The shear strength increases with the length of the removal time.

12.Peel Adhesion Test:

Peel adhesion refers to the force necessary to remove an adhesive coating from a test substrate. The peel adhesion capabilities are determined by the molecular weight of the sticky polymer, as well as the type and amount of additives. To test the force necessary to remove a single tape, it is placed to a stainless steel plate or backing membrane. The tape is then pulled at a 180º angle.

13.Thumb tack test:

This is a qualitative test used to determine the tack properties of adhesives. Simply pressing the thumb on the adhesive reveals the relative tack property.

14.Flatness test:

Three longitudinal strips are cut from each film at different points, one from the center, one from the left side, and one from the right side. The length of each strip was measured, and the variation in length due to non-uniformity in flatness was calculated using percent constriction, with 0% constriction corresponding to 100% flatness.

15.Percentage Elongation Break Test:

The percentage elongation break is determined by noting the length shortly before the break point. The percentage elongation can be calculated using the formula below.

16. Studies on In Vitro Drug Release

The paddle-over-disc method (USP Apparatus V) is used to assess the drug release from the produced patches. Dry films of a given thickness are first cut into a particular form, weighed, and then adhered to a glass plate. This glass plate is submerged in 500 millilitres of a dissolution medium, typically pH 7.4 phosphate buffer. In order to replicate skin temperature, the system is kept at 32 ± 0.5°C.
Rotating at 50 rpm, the paddle is placed 2.5 cm above the glass plate. To find out how much medicine has been released, little samples (5 mL) are taken out at predetermined intervals—up to 24 hours—and examined using an HPLC or UV spectrophotometer. The average results are utilised for reporting after the test is run three times (in triplicate).[15,16]

17. Studies on In Vitro Skin Permeation

A diffusion cell is frequently used in in vitro skin penetration investigations. Male Wistar rats (200–250 g) with full-thickness abdomen skin are employed. After using an electric clipper to gently remove the hair from the abdomen, the dermal side of the skin is properly cleaned with distilled water to get rid of any blood vessels or leftover tissue. The skin is immersed in phosphate buffer (pH 7.4) for approximately an hour to allow it to equilibrate before the experiment starts.
To guarantee even medium mixing throughout the investigation, the diffusion cell is set on a magnetic stirrer equipped with a tiny magnetic bar. The temperature is kept near to human skin temperature, at 32 ± 0.5°C. The prepared rat skin is then positioned with its epidermal side towards the donor compartment between the diffusion cell's donor and receptor compartments.
To maintain sink conditions, samples of a specified volume are removed from the receptor compartment at predetermined intervals and replaced with new medium. A UV spectrophotometer or HPLC are used to filter and analyse the gathered samples.
The slope of the linear part of the graph showing the amount of medication penetrated (mg/cm2) vs time (hours) is used to calculate the flow. The flow is divided by the starting drug concentration (mg/cm²) to determine the permeability coefficient.[16, 17, and 18.]

18. Research on Skin Irritation

Tests for skin irritation and sensitisation are performed on healthy rabbits that weigh between 1.2 and 1.5 kg. The rabbit's dorsal region, which is roughly 50 cm², is cleansed, shaved, and wiped with rectified spirit. This cleaned area is subsequently treated with the test formulation. The patch is taken off after a day, and any indications of skin discomfort are assessed. The severity of the skin injury is then used to assess the reaction on a scale of 1 to 5.[19.]

19. Research on Stability

ICH guidelines are followed when conducting stability testing. For six months, the transdermal patches are kept at 40 ± 0.5°C and 75 ± 5% relative humidity. Samples are collected at certain intervals (0, 30, 60, 90, and 180 days) and examined to ascertain the drug content and look for any alterations during storage.[16.]

7.CHEMICAL CONSTIUTENTS

Plant extracts, including flowers, banana bracts, ripe and unripe fruits, leaves, and stems, have been used to cure a variety of diseases. The flower contains tannins, saponins, reducing and non-reducing sugars, sterols, and triterpenes. The structure of a novel tetracyclic triterpine isolated from the flowers of M. Paradisiaca Linn was revealed to be (24R)-4á-14á, 24-trimethyl-5-cholesta-8, 25-dien-3â-

ol [20]. Anthocyanins reported include 3-rutinoside derivatives of dephinidin, pelargonidin, peonidine, and malvidin [21].Fruit is composed of carbs, amino acids, sugar, and starch. The fruit's skin contains 10% cellulose and 7% hemicelluloses. The pulp protein contained arginine, aspartic acid, glutamic acid, methionine, and tryptophan [22]. A novel bicyclic diarylheptanoid, 8-hydroxy-3-(4-hydroxyphenyl)-9-methoxy-4a,5,6,10b-tetrahydro-3Hnaphthopyran, as well as four known chemicals 1,2 Dihydro 1,2,3 Trihydroxy-9-(4-methoxyphenyl)phenalene 2-hydroxy anigorufone; 2-(4-hydroxy phenyl) naphthalic anhydride; and 1,7 bis (4-hydroxy phenyl) Hepta-4,6-diene-3-one was extracted from the ethyl acetate soluble fraction of a methanolic extract of fruits [23].Peeled fruits include two novel acyl steryl glycosides: Sitoindoside-III and Sitosterolmyo-inositylbeta-Dglucoside [24]. Fruit pulp contains three types of á-glucan phosphorylase [25]. The mature banana leaf contained two different types of starch phosphorylase [26].

7. PHYTOCHEMICAL ANALYSIS

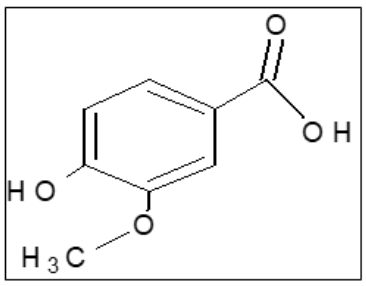
Plants are a key source of bioactive chemicals, thus ethnobotanical, phytochemical, and biological approaches must be combined in a multidisciplinary approach to the production of novel chemical compounds. Saponins, terpenoids, steroids, anthocyanins, fatty acids, tannins, phenols, and alkaloids have all been found in the fruit, peel, flower, leaf, pseudo stem, and rhizome of the plant. Phytochemical levels can vary depending on the extraction technique. [11] Different kinds of Musa stem have been reported to contain bioactive compounds such as Lupeol, Ferulic acid, Vanillic acid, Trans-cinnamic acid, p-Hydroxybenzoic acid, p Coumaric acid, Rutin, Catechin/Epicatechin, Chlorogenic acid, Gallic acid, Caffeic acid, and Nicotiflorin [27].

Musa species have also been proven to have impacts and medicinal activities, including anti-inflammatory, immunostimulatory, anti-cancer, antiulcerogenic, hypolipidemic, hypoglycemia, anthelmintic, and leishmanicidal properties Some formulations such as microemulsion also beneficial in such disease Usually made up of water, oil, surfactant, and co-surfactant, these systems create nanoscale droplets of one immiscible phase dispersed across another[28].

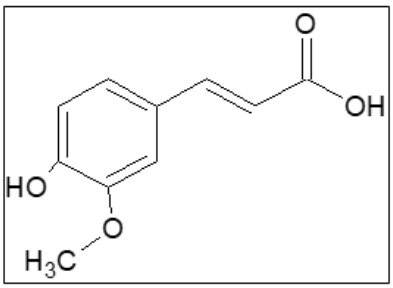
Table.3. Phytochemical Analysis

Plant part	Bioactive compound	Medicinal Properties & Applications	Notable Example/Finding
Flowers	Tannins, Saponins, Sugar, Steroids triterpenes	Antioxidant, Antiinflamatory, antimicrobial	Noveltetracyclic triterpene:(24R)-414a,24-trimethyl-5-cholesta-8,25-dien-3a-ol
Fruit(pulp)	Carbohydrates, amino acids, sugar, starch	Energy source, nutritional benefits	Contains arginine, aspartatc acid ,glutamic acid , methionine, triptophan
Fruit(skin)	Cellulose (10%), hemicellulose (7%)	Dietary fiber, Gut health	High cellulose and hemicelluloses content
Leaves/ stems	Flavonoids, Phenolic compounds	Antioxidant, anti-inflammatory, antimicrobial	Used in traditional remedies for various ailments
Extract(General)	Anthocyanins (e.g.3-rutinoside derivative), diarylheptanoids, acylsteryl glycoside	Antidiabetics, antibacterial, antifungal	Novel compounds like Sitoindoside-III and sitosterolmyo-inositylbeta-Dglucoside

7.1. Structures of phytoconstituents



Vanilic acid



Ferulic acid

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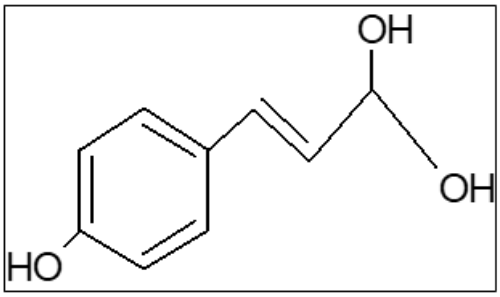
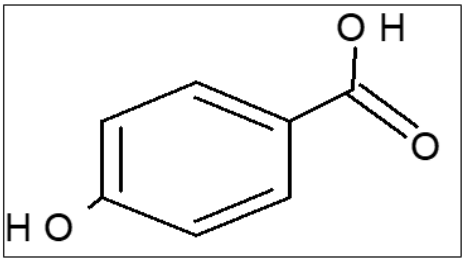
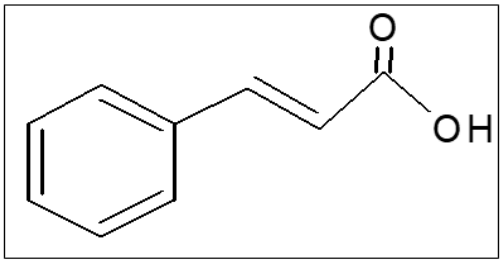


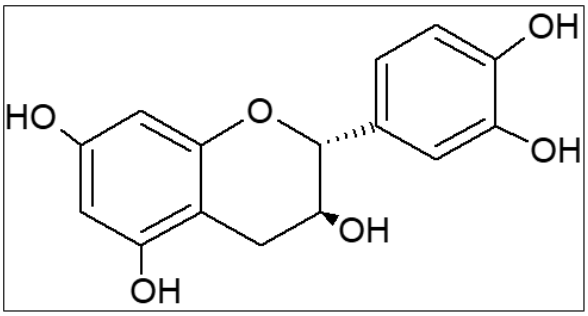
P -Coumaric acid



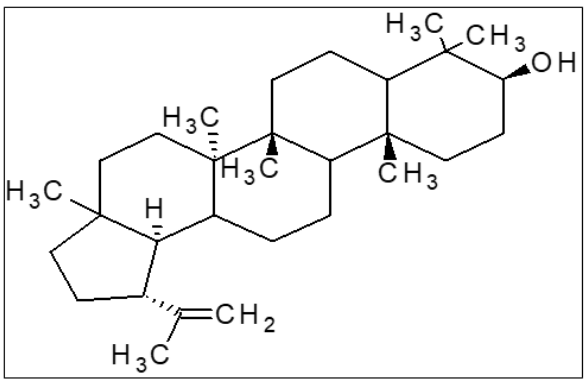
P-Hydroxybenzoic acid



Trans-Cinnamic acid



Catechin



Lupeol

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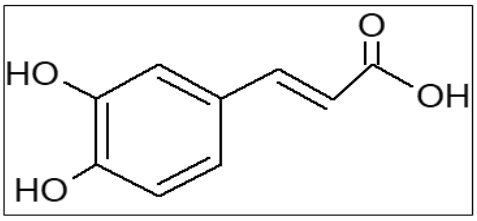
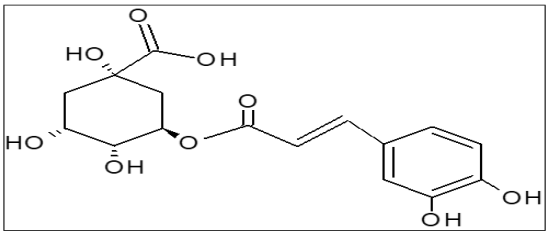
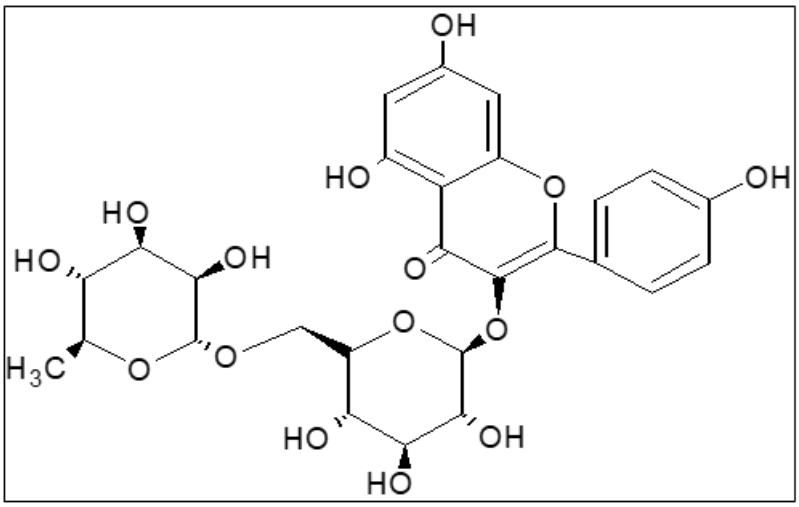


Caffeic acid



Cholorogenic acid



Nicotiflorin

8. PHARMACOLOGICAL ACTIVITY

Anti-Diabetic Effect of Banana Stem Juice

The bioactive components in Musa stem extract promote insulin production and reduce blood glucose levels [29]. The antihyperglycemic action of banana stem juice, which circulates glucose for glycogen production, aids in blood glucose regulation [30]. Because banana stem juice includes a variety of bioactive compounds, it inhibits glycogenolysis and gluconeogenesis, which helps to regulate blood sugar levels in the body [31]. Alkaloids, saponins, flavonoids, tannins, phlorotannins, phenolics, glycosides, terpenoids, and steroids are low-molecular-weight bioactive phytochemicals found in the pseudo stems of numerous Musa species[32] and are responsible for the anti-diabetic action. In many tropical countries, banana stem juice has long been used to treat diabetics.

Anti-Inflammatory Effect

Previous research on Musa acuminata Stem Extract (MASE) found that it had antibacterial, antifungal, and antioxidant effects [33]. The most common bioactive material in MASE is tannin, which contains polyphenols. The polyphenol component inhibits TNF-α and NF-κB signaling, promoting anti-inflammatory effects. TNF-α is a pro-inflammatory cytokine released when the NF-κB is activated. The anti-inflammatory effect inhibits NF-κβ and TNF-α components, accelerating wound healing [34,35]. As a result, the purpose of this study was to see if Musa acuminata has an anti-inflammatory effect by evaluating TNF- and NF-B expression after three days of MASE treatment on oral mucosal lesions.

Anti-Microbial Effect

During the preliminary phytochemical screening of extracts from the Banana pseudo stem, phenolic compounds, flavonoids, terpenoids, alkaloids, proteins, tannins, saponins, and cardiac glycosides were found, which are responsible for the antibacterial action. The phytochemical contents were: alkaloids (8.16%), flavonoids (4.02%), saponin (3.5%), phenols (5.57 mg/kg), tannin (9.13%), oxalate (0.162%), haemagglutinin (1.8814 mg/kg), phytate (1.2967 mg/kg), and cardiac glycoside (1.6%) [36]. Tannic acid is formed by combining Gallic acid molecules and glucose. It is astringent, antibacterial, and anti-enzymatic [37].

Wound Healing Property

The aqueous extract of Banana pseudo stem had the largest zone of inhibition against Streptococcus sp. at 21 mm, compared to 14 mm for the methanolic extract [36]. The extract from the pseudo banana stem (Musa paridasiaca) showed the strongest antibacterial effect on Staphylococcus aureus. Other organisms, such as Bacillus subtilis, Bacillus cereus, and E. coli, had antimicrobial activity but were less effective than the commercially available antibiotic ampicillin [38].Banana stems include phytochemicals such as ascorbic acid, lycopene, saponin, tannin, flavonoid, and beta carotene, which have been shown in prior studies to increase macrophage populations and speed up wound healing. The antimicrobial activity of tannins can help to reduce inflammation. It causes blood vessels to contract and promotes epithelial development. The purpose of this study was to evaluate how effective Musa acuminata Stem Extract (MASE) is at treating traumatic oral ulcers in rats. The study found that a 25% ethanol extract of Mauli banana stem in rats enhanced the thickness of the oral mucosa epithelium on the third day (51.26 m), fifth day (108.49 m), and seventh day (170.66 m). On the seventh day, the mucosa epithelium reached its maximal thickness. Thus, it was discovered that 25% ethanol extract on Mauli bananas might increase the thickness of the oral mucosa throughout the healing phase [39]. According to previous research, Mauli banana stem extract gel at a concentration of 37.5% can speed up the healing of traumatic ulcers by increasing fibroblast cell count. The bioactive substance in banana stem juice can serve as an immunomodulatory agent to speed up wound healing by stimulating fibroblast proliferation and ECM (Extracellular Matrix Reorganization) production [40]. earlier research serves as more evidence. Researchers came to the conclusion that the stem of the Ambon banana, a variety of banana, can likewise hasten the healing of wounds. It accelerates the pharmacological properties of banana juice by influencing inflammatory cells. mechanisms of angiogenesis, connective tissue formation, and epithelialization [41].

Anti-Cancer Effect

Bananas' polyphenolic components were analyzed both in vitro and in vivo, and the results showed that flavonoids, cinnamic acids, and other substances with chemopreventive potential predominated. By inducing concentration-dependent apoptosis in vitro assays, an aqueous methanol extract of the banana peel of Nendran demonstrated significant anti-cancer efficacy against the MCF-7 breast cancer cell line [42]. In vitro anti-cancer efficacy against the HCT 116 colon carcinoma cell line was demonstrated by banana peel and pulp in hexane. It was demonstrated that the peel and pulp extract inhibited HCT-116 cell growth and proliferation by causing cytotoxicity [43].

Anti-Oxidant Activity

The antioxidant activity of Musa extract mediated Copper-based nanoparticles (Cu-NPs) improves the treatment of ROS-related illnesses by boosting the ability of various antioxidants to scavenge free radicals. Cu-NPs have high catalytic activity for scavenging H2O2 and O2, but not OH·-. They can trigger electron transport pathways, making H2O2 or OH·- inactive [44]. Tannin is the most bioactive molecule in banana stems, followed by ascorbic acid, saponin, β-carotene, total flavonoid, lycopene, alkaloid, and flavonoid. These compounds can trap free radicals and protect cells [45].Previous research has shown that the chemical compounds in banana stem sap have antioxidant qualities and play a role in the healing process. Furthermore, they can reduce bleeding and clotting time by activating clotting factors and stimulating endothelial glycoprotein-Ib (GPIB) [46].

Anti-Helminthic Activity

M. paradisiaca cv. Puttabale is a plant that has traditionally been used to remove parasitic worms. Sincere efforts have been made to investigate the antihelmintic activity of corm ethanol extracts of M. paradisiaca cv. Puttabale uses Pheretima Posthuma as an experimental model to back up his ethnomedicinal claims with scientific data. This study looks into their effect on the duration of worm paralysis and death. The results indicate that the ethanol extract at a dosage of 100 mg/ml had a substantial impact on paralysis time at 42.331.45 min and death time at 54.000.58 min when compared to the control group's paralysis time at 142.671.45 min and death time at 168.001.53 min.Piperazine citrate, a common drug, led to death at 59.0 minutes and paralysis at 39.67 minutes. The high pectin and lignin content of banana stem juice contributes to its anti-helminthic andhypoglycemic properties [47].

Anti-Urolithic Activity

Banana stem juice is low in calories, high in nutritional fiber, and encourages the delayed release of simple carbohydrates. It also has a low glycemic index, which aids in digestion and bowel motions. It acts as a diuretic, flushing out toxins that have accumulated in the body and frequently cleaning the urinary system. The banana stem juice has aided in the breakdown of existing kidney stones and also helps to avoid the build-up of numerous kidney stones in the urinary bladder. This is due to the presence of inorganic elements such as magnesium, potassium, and nitrate. The main active elements of Musa stem juice are magnesium nitrate and potassium nitrate, which serve as crystal inhibitors and hence contribute in the treatment and prevention of kidney stones. The diuretic action is caused by saponin, flavonoids, and terpenoids found in banana stem juice.

Table.4. Pharmacological Activity[48,49]

Effect	Simplified Explanation	Key Components
Anti-Diabetic	Helps increase insulin and lowers blood sugar by slowing sugar production and release	Alkaloids, saponins, flavonoids, tannins, glycosides
Anti-Inflammatory	Reduces inflammation and helps wounds heal by blocking certain inflammatory signals	Tannins (polyphenols)
Anti-Microbial	Kills or stops harmful bacteria and fungi, helping fight infections	Phenolics, flavonoids, alkaloids, tannins, saponins
Wound Healing	Speeds up healing by increasing cells that repair tissue and reducing inflammation	Ascorbic acid, lycopene, saponin, tannin, flavonoid
Anti-Cancer	Certain banana parts can kill or stop cancer cells in lab tests	Flavonoids, cinnamic acids
Anti-Oxidant	Helps protect cells by neutralizing harmful molecules called free radicals	Tannins, ascorbic acid, beta-carotene, flavonoids
Anti-Helminthic	Helps kill or paralyze parasitic worms	High pectin, lignin
Anti-Urolithic	Acts as a diuretic to flush out toxins and helps break down and prevent kidney stones	Magnesium nitrate, potassium nitrate, saponins

9. CONCLUSION

With a rich phytochemical profile and a variety of pharmacological actions, banana pseudostem is a plentiful and underutilized natural resource that supports its potential as a biocompatible component for transdermal drug administration systems. Its incorporation into TDDS presents opportunities for more effective, long-lasting, and safe therapeutic results. However, phytochemical heterogeneity, a lack of standardized extraction techniques, inadequate mechanical strength, uneven skin penetration, and a lack of thorough safety and clinical data hinder clinical translation. To enable the development of dependable and clinically viable banana pseudostem-based transdermal treatments, future research should concentrate on formulation optimization, standardization, permeation and stability investigations, and regulatory-aligned toxicological and clinical evaluations.

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