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Evaluation of Wound Healing Activity of Banana Peels Extract

A graduation project is submitted to the pharmacy Department, Faculty of Medical Sciences, Azal University for Human Development, in partial fulfillment of the degree of Bachelor in Pharmacy

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الآية

قال تعالى:

﴿وَقُلِ اعْمَلُواْ فَسَيَرَى اللهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ﴾

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Dedication

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List of content

List of Table

List of figure

List of Abbreviation

Abbreviation	Meaning
%	Percentage
ABTS	2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) assay
COX-2	Cyclooxygenase-2
DM	Dry Matter
F1–F6	Formulations
$FeCl_3$	Ferric Chloride
FRAP	Ferric Reducing Antioxidant Power
G	Gram
GAE/g	Gallic Acid Equivalent
HPLC	High Performance Liquid Chromatography
IL-1β	Cytokine (Interleukin 1 beta)
IL-6	Cytokine (Interleukin 6)
Inos	inducible Nitric Oxide Synthase
M. paradisiaca	Musa paradisiaca
MEBO	Moist Exposed Burn Ointment

Abstract

Background: Wound healing is a complex biological process that involves tissue repair and regeneration. While various synthetic products exist, there is a growing Interest in natural alternatives due to their safety and efficacy. Banana peels (Musa paradisiaca), often discarded as waste, are rich In bioactive compounds such as flavonoids, tannins, and saponins, which possess antioxidant and anti-inflammatory properties that can promote healing.

Aims: The primary objective of this study was to investigate the wound-healing activity of Yemeni Banana peel ethanolic extract in rats. Specifically, the study aimed to prepare the extract, screen its phytochemicals, formulate it into an ointment at different concentrations (0.25% and 1%) and evaluate Its efficacy compared to a standard drug (MEBO) .

Method: An experimental study was conducted using eighteen female rats. Banana peels were extracted using 85% ethanol via maceration. The extract was then formulated into topical ointments. Animals were divided into groups: treated with 1% extract, 0.25% extract, MEBO (standard), and a control group (untreated). Wound contraction was monitored on days 3, 7, 14, and 21 post-wounding .

Result: Phytochemical screening confirmed the presence of tannins, flavonoids, phenols, and saponins. The animal study revealed that the 0.25% extract ointment was the most effective, achieving nearly 95% wound contraction by day 21 with minimal scarring. Complete wound closure was observed in treated groups by day 21, whereas the control group did not achieve full closure. Interestingly, lower concentrations showed better efficacy and fewer side effects compared to the 1% concentration, which caused some irritation .

Conclusion: The study concludes that Yemeni Banana peel extract, particularly at a 0.25% concentration, significantly enhances wound healing and tissue remodeling. These findings support the traditional use of banana peels and suggest they could serve as a cost-effective, natural alternative for wound care

Keywords:

Musa paradisiaca, Banana peels extract, wound healing, phytochemicals, ointment formulation, antioxidant activity, animal model

Chapter I

INTRODUCTION

1.1 Introduction:-

A wound is defined as physical injury that result in an opening or break of the skin that causes disturbance in normal skin anatomy and function (Srtodtbeck, 2001) Wound healing is body's natural reaction to tissue injury involving a series of cellular events that generates resurfacing, reconstitution, and restoration of the tensile strength of injured skin. Normal wound healing is a complex process consists of four highly integrated and overlapping phases: hemostasis, inflammation, proliferation, and tissue remodeling or resolution (Gosain and Dipietro, 2004).

The regeneration and repair of injured tissue are components of the biological process of wound healing. This method is necessary to keep skin healthy and free of infections. According to pervious study modification of extracellular matrix, particularly collagen, a variety of cellular processes, including as inflammation, migration to the injured area, proliferation, angiogenesis, deposition, and others, can be engaged in the intricate and varied process of wound healing. Ointments, creams, and powders are among the many synthetic and semi-synthetic wound healing products on the market. But in recent years, natural products have gained increased attention as possible wound healers due to their efficacy and safety. Natural substances have been used for thousands of years in traditional medicine and have shown promise in hastening the healing of wounds(Tanaka et al., 2012). These natural components can be used as drug delivery vehicles or applied directly to wounds, according to pervious study by promoting the growth of new blood vessels and acting as a scaffold for cell proliferation, they can help wounds heal. The use of herbal treatments in modern medicine has become increasingly significant for wound healing and tissue repair (Mone et al., 2021).

Wound care is constantly evolving with the advances in medicine but wounds are still a significant health problem worldwide, often having severe complications. In recent years wound care professional revisited the ancients healing methods by using traditional medicine in wound management. Traditional medicines which are more effective, nontoxic and cost-effective are gaining popularity throughout the world. The medicinal and biological effects of plants has urged scientists to examine these plants with a view to determine potential wound healing properties (Thakur et al., 2011).

Several herbs and medicinal plants exhibit remarkable wound-healing activity, such as, Curcuma longa, commonly known as Turmeric, is renowned for its potent wound healing and anti-inflammatory properties (Surjushe et al., 2008). Aloe barbadensis, commonly known as Aloe vera, is a medicinal plant widely used for its therapeutic and cosmetic properties; it contains bioactive compounds such as vitamins, minerals, enzymes, amino acids, and polysaccharides, which exhibit antioxidant, anti-inflammatory, and wound-healing effects (Parente et al., 2012).

Furthermore, Allium cepa (Onion) is a widely cultivated medicinal and dietary plant known for its rich content of organo-sulfur compounds, flavonoids (especially quercetin), and phenolic acids. Calendula officinalis is widely used for its effective wound healing, anti-inflammatory, and antimicrobial properties (Jain et al., 2013).

Additionally, Mangifera indica, commonly known as Mango, exhibits significant wound healing properties due to its rich content of polyphenols, flavonoids, and mangiferin (Lima et al., 2010).

The major classes of wound-healing phytoconstituents include polysaccharides, flavonoids, curcuminoids, triterpenoids, tannins, saponins, alkaloids, and essential oils (Cauich-Kumul and Segura Campos, 2019).

Banana peels have antioxidant, anti-inflammatory and several biological activities such as wound healing, hypoglycemic, hepatoprotective, antimicrobial, antifungal and others.

Raw navel skin also contains leucocyanidin which is a flavonoid that plays a role in inducing cell proliferation, accelerating the healing of wounds on the skin banana peel extract is considered to be a good antibacterial agent against gram-positive and negative bacteria. Banana peels are a source of potential bioactive compounds such as flavonoids and polyphenols that can eliminate free radicals the therapeutic agent chosen for wound healing should enhance the healing process with minimal side effects the content of banana peels such as glycosides, anthocyanins, tannins, and flavonoids, phenols, saponins.,, Agents such as alkaloids can affect the phase of the wound healing process permeability, extravasation of plasma, erythrocytes, platelets, and leukocytes, especially neutrophils, monocytes and macrophages. The inflammatory response is an important step in wound healing in the preparation of the wound area for the repair process.

Flavonoids are a common bioactive group found in foods of plant origin. Besides having the ability to help the wound healing process.

Research conducted by (Ambiga S et al, 2007) showed that the application of materials containing flavonoids had an impact on the final outcome of the wound, nameproviding a more compact and similar tissue regeneration result to normal tissue. The tannin content in banana peel extract has bactericidal and bacteriostatic abilities, so that the presence of tannin in the wound healing process can minimize wound healing obstacles that arise due to the presence of bacteria. Tannin has antioxidant abilities that have an impact other than on wound healing abilities.(Achmad&Putri, 2021).

Tthe saponins contribute to hemostasis by reducing blood clotting, and tannins can induce vasoconstriction in capillary blood vessels (Achmad & Putri, 2021) The Gallocatechin foundin banana peel is a prevalent group of natural phenolic compounds known for their antioxidant properties. The gallocatechin-rich extract (GE) from Musa peel (106.6 µg/mL) reduce the time required for epithelization, allowing the healing of lesions in just 9 days. Additionally, GE treatment lead to an increase in hydroxyproline content throughout the treatment period.(Achmad H, Putri AP.2021).

1.2Objectives

1.2.1. General objective

To investigate the wound-healing activity of Yemeni Banana peels (Musa paradisiaca) ethanolic extract in rats.

1.2.2. Specific objectives:

- To prepare the ethanolic extract of Banana peels using 85% ethanol.
- To screen for the main phytochemicals in the extract.
-To formulate the extract into a suitable formula (ointment) with different concentrations of 0.25% , 0.5% and 1%.
-To evaluate the efficacy of the formulated ointment in wound contraction using laboratory rats.
- To compare the healing activity of Banana peel ointment with MEBO as a standard drug.

1.2.3 Justification of Research

1-To support the scientific use of traditional medicinal plants. Banana peels are often considered agricultural waste; recycling them into medicine adds economic and environmental value.

There is an urgent need for natural, low-cost, and effective alternatives to expensive commercial products like MEBO for wound care.

1.2.4 Research Hypothesis

It is hypothesized that Yemeni Banana peels contain potent phytochemicals (especially Tannins and Saponins) that accelerate tissue repair.

The formulated ointment from Banana peel extract will significantly increase the rate of wound healing in rats.

Chapter II

LITERATURE REVIEW

2.Literature reveiw

2.1 Musa paradisiaca peel:-

Musa paradisiaca is cultivated in the tropical and subtropical countries around the world. Banana is the name commonly used to refer to the fruit of the species of *Musa* genre. The *M. paradisiaca* fruit is a good source of nutrients such as potassium, phosphorus, calcium, nitrogen, iron, vitamins C and E (Alabi et al., 2013).

Different parts of *M. paradisiaca* have been used in traditional medicine (Swathi et al., 2011), and also several biological activities have been reported, such as antiulcerogenic, antidiarrhoeal, hypoglycemic, hepatoprotective, antimicrobial, wound healing, hypocholesterolemic and antioxidant (Nirmala et al., 2012; Yakubu et al., 2015).

However, the biological activities of the *M. paradisiaca* peel have been poorly explored. To date only is known that *M. paradisiaca* peel shows protective role in atherosclerosis disease, regulation of thyroid function and bactericidal activity (Parmar and Kar, 2007; 2008; Alisi et al., 2008).

2.1.1 Plant taxonomy

Taxonomical classification (Singhal, et al,2022)

Table (2.1) Musa paradisiac plant taxonomical data

Kingdom	**Plantae**
Sub kingdom	**Tracheobionta**
Superdivision	**Spermatophyta**
Division	**Magnoliophyta**
Class	**Liliopsida**
Subclass	**Zingiberidae**
Order	**Zingiberales**
Family	**Musaceae**
Genus	**Musa L.**
Species	**Musa paradisica Linn**

2.1.2 Geographical distribution

It is a perennial plant that may grow to heights of ten to forty feet, giving it the appearance of a tree, and it can be found all across the tropics and subtropics. Its natural habitats span the entire tropical expanse of India and Burma. The biggest numbers of individuals belonging to this species can be found in the Indian states of Tamil Nadu, Andhra Pradesh, Bihar, Madhya Pradesh, West Bengal, Maharashtra, and Gujarat (Singhal et al., 2022).The tropics of the Americas, Australia, and Africa all fall within its natural habitat, making it one of the most widespread species in the world. There are only a few places in the globe where the plant may be farmed, and those places are Florida, the Canary Islands, southern Egypt, southern Japan, and southern Brazil (Singhal et al., 2022).

Figure (2.1): *Musa paradisiaca*

2.1.3 Habit:

One of the tallest herbaceous plants, Musa paradisiaca's pseudostem is created by the imbricate leaf sheaths and is soft and succulent. A substantial rhizome is another distinguishing feature (up to 9 m in length). (Tagliazucchi et al., 2009, Saura-Calixto et al., 2007).

2.1.4 Morphology:-

The inflorescence of flowers begins at the top of the false trunk and spirals downward, produces clusters of androgynous flowers first. After that, the inflorescence generates clusters of female flowers. Flowers are comprised of an upper ovary and five stamens. (Tagliazucchi et al., 2009, Saura-Calixto et al., 2007).

The cultivated versions of this berry typically do not contain seeds and take on a morphology that is fleshy and long. The exterior layer of fresh fruits has a bluish-green hue, is glossy, and is mucilaginous; in contrast, the inner layer of fresh fruits is white in colour, powdery, and contains very few seeds, if any at all. (Tagliazucchi et al., 2009, Saura-Calixto et al., 2007).

The evergreen plant has the potential to grow to a height of 6 metres. The leaves are most accurately described as being enormous, unbroken, and straightforward. In most cases, they take on a pinnatifid shape and originate from a rhizome that grows underground. The dried out leaf bases cluster together to form a fake trunk (Tagliazucchi et al., 2009, Saura-Calixto et al., 2007).

2.1.5 Traditional uses of banana peels

Traditional practices across various cultures have utilized banana peels for a wide range of dermatological and therapeutic purposes, often applying the inner side of the peel directly to the skin to treat conditions such as warts and minor burns, owing to its high potassium content and chemical composition (Mohapatra et al., 2010). Furthermore, the peel is widely employed in folk medicine as a cooling agent to alleviate skin irritation, itching from insect bites, and rashes caused by poison ivy, largely due to its anti-inflammatory properties (Someya et al., 2002). For oral hygiene, a common remedy involves rubbing the teeth with the inner peel, a practice believed to reduce stains and promote whitening through its mineral content (Wang et al., 2014).

2.1.6 Phytochemical constituents

Banana (Musa spp.) contains a variety of bioactive compounds derived from secondary metabolism, which contribute to antioxidant activity and potential therapeutic effects. The main phytochemicals present include phenolic compounds and carotenoids, which are commonly found in fruits and vegetables and are

associated with human health benefits.

Like other fruits, banana possesses a characteristic profile of bioactive compounds that play an important role in its nutritional and functional value.(Singh, B. et al. 2016).. It was in unripe bananas that researchers first found the flavonoid that is now known as leucocyanidin. The mineral makeup of the fruit includes magnesium, iron, potassium, zinc, copper, phosphorus, aluminium, sodium, manganese, and nitrogen. Manganese is also present in the fruit. In the fruit, there are high concentrations of molecules of varying sizes, including both small and large. The immature fruit is abundant in calcium and selenium, but the ripe fruit has a significantly larger quantity of phosphorus and manganese in it. Aspartic acid, glutamic acid, and leucine are the three amino acids that are found in mature fruit in the greatest quantities (Swennen et al., 1990.The fruit contains a compound referred to as sitoindoside IV, which is an acylsteryl glycoside. The ash of the mature fruit husk contains a number of different minerals, including carbonates of potash and soda, chloride of potassium alkaline phosphates, lime silica, and others. The green plantain contains a significant amount of tannin. The juice that is extracted from the stems of plantain flowers contains a variety of different chemicals, some of which are listed below: potash, soda, lime, magnesium, alumina, chlorides, sulphuric anhydride, phosphoric anhydride, silica, and carbon anhydride.(Singh, B. et al. 2016).

Table (2.2) Bioactive compound of banana peels and extraction method

Bioactive compounds	**Extraction**	**Variety of banana**	**Findings**	**Ref.**
Phenolic compound and antioxidant	Microwave-assisted extraction	*M. Cavendish*	At 30 °C, time 5 min and power 150 W, phenolic compounds yield increased by 23.49 mg, 39.46 mg of flavonoids, and 13.11 mg of proanthocyanidins in 1 g of banana (M. cavendish) peel.	**(Vu et al.,2017)**
Phenolic compound	Capillary zone electrophoresis	Yellow banana and red banana peel	Red banana peel extract had greater biological value than yellow banana peel extract in terms of antioxidant activity, antibacterial action, and cytotoxic activity on tumour cells.	**(Ahmed et al.,2021)**
Antioxidant	Solvent extractio	Xiem banana	At 60% solvent concentration, 68 °C temperature and 48 min time, TPC and	**(Robello et**

	n method		TFC were identified as 62.41 mg GAE/g and6.98 mg QE/g respectively.	**al.,2014)**
Phenolic compound	Solid-phase extraction	(Musa AAA) Cavendish	The total phenolic compound identified is 29.2 mg GAE/g.	**(Tsamo et al., 2015)**
Antioxidant	Solid-phase extraction	(Musa AAA) Cavendish	The antioxidant activity was identified as 14 M/g (FRAP); 242 M/g (ABTS) and in ORAC assay about 436 M/g. Banana peel flour is probably responsible for the extremely high antioxidant activity.	**(Tsamo et al., 2015)**
Flavanols: Rutin	Solvent extraction	Red yade (AAB)	The value of rutin was identified as 482 ± 206 µg/g DM.	**(Tsamo et al., 2015)**
Flavanols: Laricitrin-3-rutinoside	Solvent extraction	Cavendish (AAA)	The quantity of flavanol in cavendish-type banana peel is identified as 2.22 µg/g DM.	**(Tsamo et al., 2015)**
Carotenoid	Solvent extraction and HPLC	Dwarf cavendish variety	Three solvents (ethanol, ethyl acetate, and methanol) were employed to extract the banana peel. The best solvent was ethyl acetate. The best reading in this solvent for light absorption was 2.204 for ethyl acetate.	**(Sheikhzadeh et al., 2015)**
Phenolic compound and antioxidant	Pulse electric field	Kepok banana (*M. paradisiaca*. L)	The Kepok banana peel's best antioxidant activity was identi- fied as 13.086 mg/ml at 4 kv/cm for 4 min.	**(Hendrawanet al., 2019)**
Dopamine	Solvent extraction	*M. acuminata* Colla AAA	Methanol-produced extracts contain the most dopamine. The amount of dopamine dramatically increased when the extraction period was extended from 1 to 120 min (at 25 ^{o}C).	**(Gonzalez-montelongo et al., 2010)**
Catechin	Liquid-solid extraction	(*M. paradisiaca* L.)	The amounts of total phenolic, flavonoid, and tannin were found in the methanolic extract (80%) as 17.89, 21.04, and 24.21 mg/g DW, respectively. 30.21 µg/g amount of catechin present in banana peel.	**(Abo-Enein et al., 2016)**
Quercetin	**Liquid-solid extraction**	**(*M. paradisiaca* L.)**	**Amount of quercetin identified as 78.62 µg/g.**	**Abo-Enein et al., 2016]**

2.1.7 Pharmacological properties of banana peels:-

2.1.7.1 Antioxidant activity

Antioxidants are substances that remove free radicals from the body. One of the best sources of antioxidants is banana peel. Utilizing a variety of antioxidant tests, banana peel extracts were discovered to have a significant antioxidant capacity (Vu et al., 2017).Extracts from banana peels can be utilized in food products as a natural preservative to enhance the quality and shelf life of the food due to their powerful antioxidant and antibacterial properties Various types of dishes have been effectively enhanced with the use of banana peel extracts (Kumari et al., 2023).Banana peel has five times more gallocatechin than pulp, indicating that peel is a main source of the antioxidant molecule. Dopamine, ferulic acid, and caffeic acid are only a few examples of the individual phenolic chemicals in banana peel that have powerful antioxidant properties. Dopamine in Peel was discovered to have a greater ability to scavenge free radicals than glutathione, BHT, luteolin, or quercetin. And it has similar efficacy to gallocatechin gallate and ascorbic acid and outperforms catechin in terms of radical scavenging (Anjum et al., 2014)

2.1.7.2 Antimicrobial activity

The Banana peels showed strong antibacterial properties against several microorganisms, including Staphylococcus aureus (19.75 mm), Bacillus subtilis (20.60%), Pseudomonas aeruginosa (19.57 mm) and Escherichia coli (18.15 mm). Inhibition zones against alcoholic extract of peels of the bananas were 15 mm for Porphyromonas gingivalis and 12 mm for Aggregatibacter actinomycetemcomitans, respectively. As a negative control, 70% isopropyl alcohol caused P. gingivalis and A. actinomycetemcomitans to exhibit inhibitory zones of 8 and 10 mm, respectively. As a result, this finding indicated that P. gingivalis and A. actinomycetemcomitans were resistant to the antibacterial effects of the alcoholic extract of banana peel (Kapadia et al., 2015).

At a dosage of 300 mg/mL, the methanolic extract from M. acuminata peel displayed varying levels of inhibition against E. coli (ATCC 25922), Lactobacillus casei, Bacillus sp., S. aureus (ATCC 25923), P. aeruginosa, and Saccharomyces cerevisiae (Niamah et al., 2014). The ethanol extracts of the plant varieties M. acuminata cv. Grand nain showed a variety of antibacterial activity against the investigated microbes, with

Salmonella paratyphi and Proteus vulgaris (Zaini et al., 2022). The three examined bacteria (E. coli, S. aureus, and P. aeruginosa) have shown some antibiotic activity in the presence of tannins (Aboul-Enein et al., 2016). Chabuck et al. (٢٠١٢) reported that the banana peel's aqueous extract has varied antibacterial activity. These findings demonstrated that this extract provides good gram-positive bacteria, such as Streptococcus pyogenes and S. aureus, are inhibited with inhibition zones of 30 and 18 mm, respectively, however, Candida albicans is not affected. Banana peel extract has an inhibitory impact on gram-negative bacteria, with an inhibition zone extending from 10 to 30 mm. Moraxella catarrhalis is most susceptible, followed by Klebsiella pneumoniae and Enterobacter aerogenes, apart from E. coli, which showed no susceptibility to the extract(Chabuck et al 2013).

2.1.7.3 Anticancer activity

Some fruit peels can act as anticancer agents, especially banana peels. The most dangerous substance against human colon cancer cells was a banana peel extract made from hexane solvent, which showed a 64.02% reduction in cell multiplication (Dahham et al., 2015).

Ruangtong et al. (٢٠٢٠) produced green synthetic ZnO nanorods and nanosheets by using zinc acetate and banana peel (M. sapientum) crude extract. ZnO nanosheets made by green synthesis have reportedly been used to develop antibacterial and anticancer medications(Ruangtong et al 2020).(Durgadevi et al. 2019) identified the antioxidant and anti-tumor properties of the aqueous methanol extract obtained from nendran banana peel, which is a promising source of bioactive substances for combatting cancer. The research revealed that this extract possesses substantial cytotoxic effects on MCF-7 breast cancer cells, which is valuable information in the fight against cancer(Durgadevi et al 2019).According to a study by Phacharapiyangkul et al., (٢٠١٩) Ferulic acid in sucrier banana peel may facilitate melanogenesis by regulating vascular endothelium growth factor expression, starting nitric oxide synthase, and acting as a tumor suppressor gene(Phacharapiyangkul et al. 2019) .

2.1.7.4 Antidiabetic activity

Banana flowers, leaves, pseudostems, roots, stalks, and peels were discovered to have an anti-diabetic effect. The peel of the banana can be used as a natural source of

diabetic-friendly food, medicine, or other substances. The diabetic drug lupenone was initially extracted from banana peel (Thomas et al., 2017). It is a potential complementary treatment for type 2 diabetes. The flavonoids of Banana peels have a crucial function in managing blood sugar levels and preventing diabetic complications (Genatrika et al., 2018).

2.1.7.5 Anti-inflammatory and wound healing activities

Bioactive compounds in the peel promote tissue regeneration and reduce inflammation when applied to skin wounds or burns (Mohapatra et al., 2010).

Anti-inflammatory components in banana peel banana peel contains several bioactive compounds with anti-inflammatory effects, especially phenolic compounds and antioxidants. These compounds reduce oxidative stress by scavenging reactive oxygen species (ROS), which play a key role in inflammation and tissue damage. They also protect cells and inhibit degradation caused by oxidative processes.

(J.Ethnopharmacol .(2015))

Role of sterols (Stigmasterol) Sterol compounds such as stigmasterol exhibit anti-inflammatory activity by inhibiting pro-inflammatory mediators including TNF-α, IL-6, IL-1β, iNOS, and COX-2, while increasing anti-inflammatory cytokines like IL-10. This helps regulate and reduce the inflammatory response. (Immunopharm .(2020))

Effect of antioxidants on inflammation antioxidants in banana peel help in reducing inflammation by neutralizing ROS, inhibiting protease activity, and protecting fibroblasts and other cells from oxidative damage. This contributes to decreased inflammatory processes in tissues. (J.Ethnopharmacol .(2015))

2.2 Wounds

Wounds are defined as a disruption of the normal structure and function of the skin and underlying tissues caused by external or internal factors. The wound healing process is a complex biological mechanism involving hemostasis, inflammation, proliferation,o and remodeling phases. Several factors such as infection, poor circulation, and systemic diseases can delay healing and lead to chronic wounds. Effective wound management is essential to accelerate healing and prevent complications (Guo, 2010).

2.2.1 Classification of Wound

Etiology, location, type of injury or presenting symptoms, depth of the wound, tissue loss, and clinical appearance are some of the ways that wounds can be categorized. Wounds are classified as open and closed wound on the underlying Cause of wound creation and acute and chronic wounds on the basis of physiology of wound healing(Kumar et al., 2007).

2.2.1.1 Open wounds

As blood exits the body in this case, bleeding is clearly visible. It is additionally categorized as an incised wound, wound From a tear or laceration, abrasions or minor injuries, wounds from punctures, Gunshot wounds Andpenetration wounds (Kumar et al., 2007).

2.2.1.2 Closed wounds

Blood stays in the body but leaves the circulatory system in closed wounds. Hematomas or blood tumors, contusions or Bruises, crush injuries, etc. are included (Kumar et al., 2007).

2.2.1.3 Acute wounds

Acute wound is a tissue injury that normally precedes through an orderly and timely reparative process that results in Sustained restoration of anatomic and functional integrity. Acute wounds are usually caused by cuts or surgical incisions And complete the wound healing process within the expected time frame (Roberts et al., 1998).

2.2.1.4 Chronic wounds

Chronic wounds are wounds that have failed to progress through the normal stages of healing and therefore entera State of pathologic inflammation chronic wounds either require a prolonged time to heal or recur frequently(Roberts et al., 1998).

2.2.2 Physiology of Wound Healing

It is possible to think of the wound healing process as a dynamic one in which matrix and cellular components work together to replace lost tissue and restore the integrity of

injured tissue regardless of the source or the extent Of tissue damage, under normal conditions the wound healing process occurs in predictable fashion in four stages: inflammation, migration, proliferation and maturation (remodelling). Wound Healing is considered to complete when The skin surface has reformed and has regained its tensile strength (Robbins and Cotran,2015)

2.2.3 Stags of wound healing :

2.2.3.1 Hemostasis

If the skin is injured, vasoconstriction of the vessel walls is the automatic reaction to stop bleeding. Next, two concurrent and mechanistically interconnected pathways contribute to primary hemostasis and secondary hemostasis (Guo et al., 2010).

The Platelet plug and the fibrin mesh combine to form a thrombus that stops bleeding, releases accompaniments and growth Factors, and provides a temporary scaffold for infiltrating cells that are necessary for wound healing (Li et al., 2007).

2.2.3.2 Inflammation

The inflammatory process occurs shortly after the injury, which typically lasts between 24 and 48 hours and may, in some cases last for up to 2 weeks. The inflammatory phase initiates hemostatic pathways immediately to stop the bleeding from the site of the wound. As a result, clinically identifiable cardinal signs of inflammation, redness of the skin, Color, tumor, pain, and functio-laesa emerge. Vasoconstriction and platelet aggregation to cause blood clotting and consequently, vasodilatation and phagocytosis to produce inflammation at the wound site are distinguished by this Process (Ghosh et al., 2025).

2.2.3.3 Proliferation

The proliferative process begins the following damage on the third day and continues for about 2 weeks afterward. It is characterized by fibroblast migration and newly synthesized extracellular matrix deposition, serving as a substitute for The fibrin and fibronectin provisional network. This process of wound healing can be seen at the macroscopic stage as an abundant development of granulation tissue (Novak et al., 2013).

2.2.3.4. Remodeling

This final stage of wound healing involves a gradual deterioration of the granulation tissue. In order to create functional tissue, the skeletal muscle epidermis, dermal vasculature, nerves, and myofibers undergo remodeling a scar of low cellularity is created when type I collagen, which is further rearranged into parallel fibrils, dissolves and replaces type III collagen of the granulation tissue due to the action of collagen metalloproteinases generated by fibroblasts and Macrophages. This final phase will take months to complete (Rocha et al., 2007).

2.2.4 Factors affecting wound healing :

I- Local factors

Local factors include infection by the organization of tissue that interrupts healing, exposure to ultraviolet light facilities curing, movement of the affected part of the healing delay, poor blood supply which shows delay in healing, exposure to ionizing radiation delay granulation, foreign bodies including sutures interferes in healing(Gujjula et al., 2002).

II- Systematic factors

Systematic factors comprise diabetics are more prone to infection and hence delay healing, wound healing is speedy in young and slow in aged people, hematological aberrations also disturbs healing, administration of glucocorticoids (anti-Inflammatory) interrupt healing, nutritional deficiency of vitamin C and zinc delay healing(Holt et al., 1992).

III- Age

Epithelialization is delayed in healthy individuals as they age. While wound non-collagenous protein deposition decreases with aging, collagen synthesis remains unchanged. This deterioration may jeopardize the mechanical Properties of scars in the elderly(Holt et al., 1992).

IV-Body type

Body form can also influence the healing of woundsFor example, insufficient blood supply to adipose tissue might Impede wound healing in obese patients. In addition,

there is protein malnutrition in some obese patients, which further Impedes recovery.On the other hand, when a patient is malnourished, the lack of oxygen and nutrition storage might impede the healing of wounds (Guo et al., 201)]

IIV.**Nutrition**

For over a century, food has been acknowledged as a crucial factor influencing the healing of wounds. The most obvious effect on wound healing is that hunger or certain nutritional deficiencies after trauma and surgery can have a significant effect. Patients with chronic or non-healing wounds and those with nutritional deficiencies also require special nutrients. The metabolism of energy, carbohydrates, proteins, fats, vitamins, and minerals will all affect the healing Process(Biswas et al., 2002).

2.3. Traditional Therapies for Skin Wound Healing

therapies are classified into herbal-derived compounds, animal-derived compounds, living organisms, and silver and traditional dressings

A- Herbal-derived compounds

Herbal-derived compounds are the most commonly used traditional therapies for the treatment of skin lesions.

a:Aloe vera

Soluble sugars, nonstarch polysaccharides, lignin, polysaccharides, glycoproteins, and antiseptic agents anti-inflammatory and antimicrobial activities; stimulate cell proliferation, collagen synthesis and angiogenesis; promote wound contraction (Inpanya P, Faikrua A 2012)

b:Hippophae rhamnoides (sea buckthorn)

Flavonoids (e.g., quercetin, isorhamnetin), carotenoids (e.g., α-, β-carotene, lycopene), vitamins (C, E, K), tannins, organic acids, triterpenes, glycerides of palmitic, stearic, oleic acids and, amino acids , antioxidant and anti-inflammatory activities; stimulate the healing process; improve wound contraction and epithelialization; increase the hydroxyproline and protein content in the wound (Gupta A ,Kumar R 2006)

c:Angelica sinensis

Essential oils and water-soluble ingredients; ferulic acid is the main active constituent stimulate the proliferation of human skin fibroblasts, the secretion of collagen, and the expression of TGF- β in in vitro conditions.(Hsiao C-Y, Hung C-Y 2012)

d:Catharanthus roseus (Vinca rosea)

Contain two major classes of active compounds: alkaloids (e.g., vincamine) and tannins forms: leaf ethanol extract antimicrobial activity against Pseudomonas aeruginosa and Staphylococcus aureus; increase wound strength, epithelialization, and wound contraction.(Nayak,Pereira , 2006)

B - Animal-derived products

Animal-origin products, like honey and propolis, have been used in wound care since ancient times due to their therapeutic properties.

a:Honey

use of honey as a natural healing agent has been increasing in healthcare, primarily, due to its ability to provide topical nutrition to the wound, reduce inflammation, and absorb the excess of exudate, this way avoiding maceration.Several therapeutic activities have been assigned to the honey, including antibacterial, anti-inflammatory, antifungal, and the ability to stimulate angiogenesis, granulation, wound contraction, and epithelialization.Honey also provides a debriding effect, reduces edema, and deodorizes the wound.(Molan,2001)

b:Propolis

Propolis, also known as bee glue, is a resinous-like substance collected by the honeybees (Apis mellifera) from several tree species.

Several therapeutic activities have been claimed, such as the antimicrobial, antioxidative, antiseptic, antiviral, anti-inflammatory, immunomodulatory, and healing properties.(Burdock ,1998)

C- Living organisms

The interest in the use of living organisms for wound healing has been significantly increasing in last years, providing alternative approaches for skin repair.

Maggots have a remarkable antimicrobial activity and ability to stimulate the wound debridement, while leeches are very useful in the treatment of venously congested wounds.

a:Maggot debridement therapy

The use of fly larvae in wound care, also designated as maggot debridement therapy, larval therapy, or biosurgery, is rapidly growing due to its efficacy, safety, and simplicity. Medicinal maggots are extensively used to promote the debridement of diverse types of wounds through the digestion and removal of devitalized or necrotic tissue. Maggots also have the ability to decompose organic matter and exogenous pathogens, providing wound cleaning and disinfection, which is fundamental for a successful healing process.(Bodeker,Ryan ,1999)

b:Leech therapy

Leech therapy or hirudotherapy is an alternative therapeutic treatment for diverse skin disorders that involves the administration of medicinal leeches (Hirudo medicinalis) into the injured site. Hirudotherapy has been used in plastic and reconstructive surgery since the ancient times to promote the healing of a wide range of lesions, including venously congested tissues, free flaps, pedicled flaps, replanted tissues, and glucoma.The action mechanism that underlies the medicinal leeches relies on the secretion of a complex mixture of compounds (e.g., vasodilators, anticoagulants, anesthetics, and analgesics) with relevant biological and pharmacological properties from the salivary glands into the lesion site, locally stimulating the healing process. The main constituent of leech saliva is hirudin, which is a potent natural anticoagulant .(Singh AP, 2010)

D- Silver and traditional dressing

Silver is a broad-spectrum antimicrobial agent that is commonly used in the treatment of skin lesions, in particular, wounds and burns. Silver is one of the most commonly applied antimicrobial agents in wound care, being available as the active ingredient of

diverse products, such as solutions (e.g., silver nitrate), creams (e.g., SSD), gauze dressings (e.g., Urgotul® SSD), foams (PolyMem® Silver), and dressings (e.g., Acticoat™). Among the great variety of silver-based products, SSD is one of the most used, being considered the gold standard for the topical treatment of burns.(Raima,Yadava,2009)

Chapter III

MATERIALS AND METHODS

3.Materials and method

3.1 Materials

3.1.1 Plant material

Banana peels of Musa paradisiaca (family: Musaceae) were collected in November 2025 from Wadi Mor , Al-Hudaydah, Yemen. The collected peels were washed thoroughly with distilled water to remove impurities and then dried in an oven at 45 °C until complete drying. The dried peels were powder ed using a grinder, and the powdered material was soaked in 85% ethanol for extraction.


Figure (3.1) Banana peels drying

Table (3.1) the plant used in this study.

Botanical Name	Family	Arabic Name
Musa paradisiaca	Musaceae	الموز

3.1.2 Chemicals :-

Table (3.2) the chemical used in the study :

Material	Company	country
Distilled Water	Victoria city	Yemen
85% Ethanol	UMCO	Egypt
Methyl Acetate	HiMedia	India
Diluted Ammonia Solution	HiMedia	India

Ferric Chloride (FeCl3)	HiMedia	India
Vaseline (soft paraffin)	HiMedia	India
Wax (Beeswax or Paraffin Wax)	HiMedia	India
Liquid paraffin (paraffin oil)	HiMedia	India
Lanolin	HiMedia	India
Olive Oil	Alkouther	Syria
Povidone Iodine 10%	Pharmatex lab	Yemen
Diethyl Ether for anesthesia	HiMedia	India
MEBO ointment 25%	Julphar	UAE
Propylene glycol methyl paraben	HiMedia	India

3.1.3 Instruments:

Table(3.3) the instrument and tools used in the study.

Instrument	Company	Country
Gloves	Nigbo Mflab Medical instrument	China
Oven	Nigbo Mflab Medical instrument	China
Analytical Balance	HiMedia	India
Laboratory Grinder (Electric Mill)	HiMedia	
Büchner Apparatus	Nigbo Mflab Medical instrument	
Rotary Evaporator	Biobase	China
Water Bath	Nigbo Mflab Medical instrument	India
Electric clipper	HiMedia	India
10 mm Surgical Punch Biopsy	HiMedia	India
Rodent Anesthesia Chamber	HiMedia	India
Surgical instruments	HiMedia	India

3.2 Methodology:

3.2.1 Study design:

Experimental study.

3.2.2 Study area:

The work was performed in Azal University for Human Development, Department of pharmacy, pharmaceutical and analytical laboratories, and some peels were dried at Sana'a University and the extract was evaporated at Al-Nasser University.

3.2.3 Plant extraction

The powder extraction of plant were prepared by mixing with ethanol 85% in ratio (1:7). The extraction method was done by maceration. About 658g of peels powder was macerated in 4606 ml of ethanol for one week. Then the maceration was filtere d using a Buchner funnel. After that, the extract was concentrated through the removal of the solvent at reduced pressure with the help of the rotary vacuum evaporator. The concentrated extract was dried using the oven dryer at 42°C, yielding a viscous dark brown residue

Figure(3.2) Filtration proces

Figure(3.3) Extract evaporation by rotatory evaporator

3.2.4 Identification test for extract:-

3.2.4.1 Physical properties for the extract:

The color, texture, odor and solubility were inspected and the noted result recorded

3.2.4.2 Chemical test for the extract

The chemical tests used to screen the active constituents in the Banana peel extract as follow:

Test for Flavonoids:

Sample + 10 mL methyl acetate (mix) → heat until boiling → add 1 mL diluted ammonia → Test for Flavonoids: A sample was mixed with 10 mL of methyl acetate and heated until boiling. Then, 1 mL of diluted ammonia was added, and the formation of a yellow coloration indicated the presence of flavonoids.

Test for Saponins:

A sample (0.5 g) was mixed with 2‑3 mL of distilled water and shaken well. The formation of a stable foam indicated the presence of saponins.

Test for Tannins and Phenols:

A sample (0.5 g) was dissolved in 2 mL of distilled water, followed by the addition of 2 mL of ferric chloride ($FeCl_3$). The appearance of a dirty green coloration indicated the presence of tannins and phenolic compounds. In some samples, a purple coloration was observed, while others showed a green to brown color.

3.2.5 Formulation of Banana Peels extract as Ointment:

The extract formulated in the forms of ointment used topically for the purpose as wounds healing

.3.2.5.1 Formulation of ointment:

Six ointment formulations (F1–F6) were prepared using different combinations and ratios of soft paraffin, paraffin wax, olive oil, paraffin oil, lanolin, and other excipients to develop a suitable ointment base for incorporating banana peel extract. Each formulation was prepared at two different concentrations of the extract (0.25% and 1%). The detailed composition of each formulation, expressed as percentage (%), is presented.

Table (3.4) the ingredients and their corresponding percentages used in each ointment formulation.

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Formula	Ointment with 0.25% extract		Ointment with 1% extract	
F1	Soft Paraffin	95%	Soft Paraffin	95%
	Paraffin	4.75%	Paraffin wax	4%
	Banana peel extract	0.25%	Banana peel extract	1%
F2	Soft Paraffin	90%	Soft Paraffin	90%
	Paraffin wax	4.75%	Paraffin wax	4%
	Paraffin oil	5%	Paraffin oil	5%
	Banana peel extract	0.25%	Banana peel extract	1%

F3	Soft Paraffin Paraffin wax Olive oil Lanolin Banana peel extract	80% 4.75% 5% 10% 0.25%	Soft Paraffin Paraffin wax Olive oil Lanolin Banana peel extract	80% 4% 5% 10% 1%
F4	Soft Paraffin Paraffin wax Olive oil Banana peel extract	90% 4.75% 5% 0.25%	Soft Paraffin Paraffin wax Olive oil Banana peel extract	90% 4% 5% 1%
F5	Soft Paraffin Paraffin wax Olive oil Lanolin Banana peel extract	70% 4.75% 10% 15% 0.25%	Soft Paraffin Paraffin wax Olive oil Lanolin Banana peel extract	70% 4% 10% 15% 1%
F6	Soft paraffin Lanolin Propylene glycol Methyl paraben Banana peel extrat	75% 15% 9.5% 0.25% 0.25%	Soft paraffin Lanolin Propyleneglycol Methyl paraben Banana peel extract	74.75% 15% 9% 0.25% 1%

3.2.5.2 Procedure of the ointement formulation

Preparation of ointment formulations (F1–F5) using the ointment technique, all ingredients were accurately weighed using a calibrated analytical balance according to the required proportions as shown in Table (3.4) and allowed to melt until the mixture became transparent. The mixture was then removed from the heat and allowed to cool slightly to avoid degradation of the active constituents. Finally, the extract was added to the mixture and stirred until a homogeneous ointment was obtained.

Preparation of optimized formulation (F6)

All ingredients were accurately weighed using a calibrated analytical balance. Soft paraffin (vaseline) and lanolin were melted together in a water bath at 80 °C. In a separate container, propylene glycol and methyl paraben were dissolved in a water bath at 45 °C.

The oil phase was then removed from the water bath and allowed to cool slightly. After that, the second mixture was added, followed by the gradual incorporation of banana peel extract with continuous stirring until a homogeneous ointment was obtained. The final preparation was left to cool at room temperature and then filled into suitable containers.

Methyl Paraben was added as a preservative to both the banana peel extract and the formulated ointment in order to prevent microbial growth and maintain product stability.

The total bacterial count of both the banana peel extract and the formulated ointment was evaluated using the plate count method. samples were inoculated onto nutrient agar and incubated at 37Cfor 72 hours using Bacillus as a test strain.

3.2.6 Animal study:

3.2.6.1 Preparation of Animals.

The study was conducted on eighteen (18) female rats aged between three to four months, with body weights ranging from 150–300 g.

The experimental area was prepared by shaving the hair using an electric clipper, extending from the tail region to the upper mid-dorsal area, in order to accurately define the application site.

Figure (3.4) experimental animal after shaving their hair

3.2.6.2 Division of the experimental animals

The animals were divided into four groups as follows :

-First group:

It consisted of five rats, and they were numbered using the blue color for identification.

An ointment at a concentration of 1% was applied to the group, which is the extract ointment of the study being evaluated in this research .

-Second group:

It consisted of five rats, and they were numbered using the black color.

An ointment at a concentration of 0.25 % was applied to the group, which is the extract ointment of the study being evaluated in this research .

-Third group:

It consisted of four rats, and they were numbered using the green color.

MEBO ointment was applied to this group at a concentration of 0.25% .

-Fourth group (Control group):

It consisted of four rats, and they were distinguished using a different color, the red color.

No ointment was applied to this group, as it was considered a control group for comparison.

All procedures were performed according to organized laboratory steps to ensure accuracy, sterilization, and animal safety, as follows :

3.2.6.3 Animal Anesthesia:

Each animal was placed individually inside the Rodent Anesthesia Chamber and anesthetized using Diethyl Ether until reaching the appropriate level of anesthesia for the procedure .

3.2.6.4 Sterilization and Surgical Preparation:

The work surface (bench) was sterilized by covering it with a sterile cover and then disinfecting it with 10% Povidone-Iodine solution. All surgical instruments used to create the wound were sterilized before starting the procedure and re-sterilized after each use and before use on the next animal to ensure prevention of infection transmission and compliance with standard sterilization conditions .

All procedures were carefully performed to ensure uniformity of wound dimensions and consistency among experimental animals, adhering to sterilization and animal safety standards throughout the work and the wound was washed with normal saline, then disinfected with iodine, and then dried to apply the ointment.

Figure (3.5) animals after wounding immediately

3.2.6.1.5 Apply the ointement on the wound

The ointments were applied to them, and each group was isolated separately

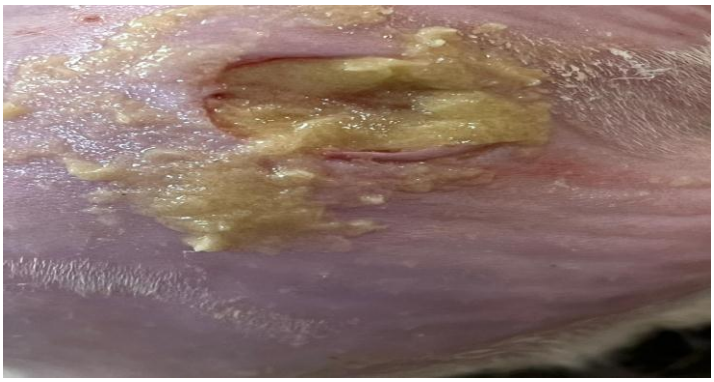

Figure (3.6) experimental animal after applying the ointement immediately

Experimental wounds were induced according to the approved protocol. Subsequently, the respective treatments were applied to each experimental group in accordance with the study design, noting that not all groups received an ointment; rather, each group was subjected to its designated treatment. All treatments were administered three times daily on a regular basis throughout the study period.

Wound healing was evaluated by measuring wound dimensions at specific time points: Day 0 (immediately after wound induction), Day 3, Day 7, Day 14, and Day 21.

These time points were selected based on the well-established physiological phases of the wound healing process, including the inflammatory phase, the proliferative phase, and the remodeling phase.

3.2.3.7.2 Macroscopic evaluation:

This evaluation include determination the range of wound contraction Of each wound (measurement the wound size) after measuring the area of Wound in indicated interval, and calculated by using the following Equation (Agren et al., 1997) to explain the wound contraction as percentage .

$$\frac{(A_{day0} - A_{dayX})}{A_{day0}} * 100$$

- Where X = 3, 7, 14 and 21 day post wounding.

- A = wound surface area.

CHAPTER IV

THE RESULT

4.The result

4.1 Quantity of collected extract:

The result in table (4.1) shown the percent of the dried extract 12.4%

Table (4.1) Percentage of ethanolic extract collected from Banana peels.

Type of plant	Pure quantity collected	Percentage from total quantity extract%
Musa paradisiaca peel	81.6g	12.4%

4.2 The physical properties of Musa paradisica peels extract

Table (4.2) Physical properties of Musa paradisica peels extract

Parameter	Musa paradisiaca peel extract
Color	**Dark brown**
Odor	**Strong odor**
Texture	**Vicous (Honey-like)**
Solubility	**Soluble in water, ethanol**

4.3 Phytochemical screening:

The phytochemical screening of the peels extract of Musa paradisica revealed the presence of various bioactive compound such as tannins, phenols, saponins and flavonoids that shown in table (4.3)

Table (4.3) Pytochemical screening of Banana peels extract

Type of plant	Phytochemical components			
	Saponins	**Tannins**	**Phenols**	**Flavonoids**
M.paradisiaca peel	+	+	+	+

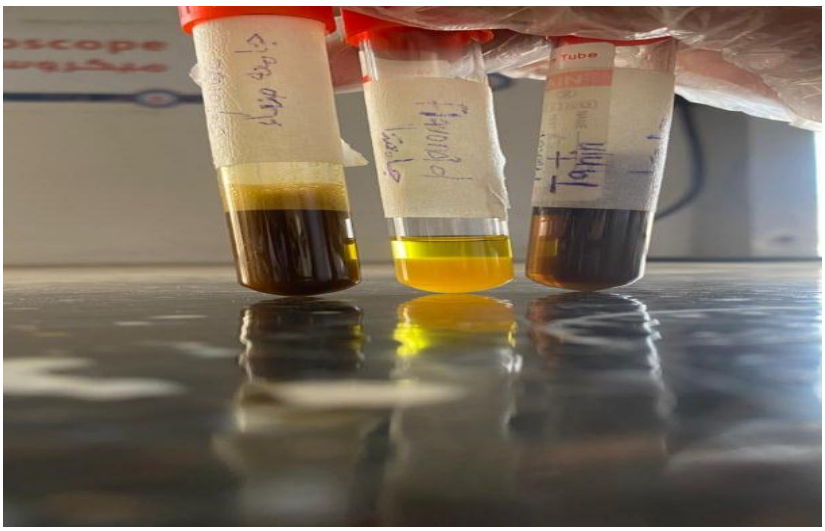

Figure (4.1) Phytochemical screening of Banana peels extract

4.4 Formulation

Six different ointment formulations (F1–F6) were prepared using varying ratios of base components to achieve optimal ointment consistency. The initial formulations (F1–F5) exhibited undesirable physical characteristics, particularly excessive hardness and poor spreadability, rendering them unsuitable for topical application.

To overcome these limitations, several modifications were introduced in the formulation composition, including adjustments in the proportions of paraffin wax, soft paraffin, and other excipients. The final formulation (F6) demonstrated acceptable physicochemical properties, characterized by a smooth texture, appropriate consistency, and improved spreadability. Accordingly, formulation F6 was selected as the optimized formulation for further evaluation.

4.5 Physical tests of the formula (F6):

This test evaluates the physical properties of the formulated F6 such as textu, consistency homogeneity, color and odor show in table (4.4)

Table (4.4) Physical tests of the formula **F6**

Parameter	The formula
Color	Pale yellow
Viscosity	Suitable
Homogeneity	Homogeneous
Spreadability	High speardability
Solubility	Insoluble in water

Figure (4.2) Formulation of banana peel extract ointment

4.6 Microbiology examination:

. Total bacterial count test result :-

No bacterial growth was observed in all samples (0CFU/g), indicating the absence of microbial contamination in both the extract and the formulated product, and confirming the effectiveness of the preservative in inhibiting microbial growth

4.7 Result of wound healing activity:

The research evaluated the change of wounds area in treated, control(untreated) and standard (Mebo) wounds as a mean and percent of wound contraction at 3^{rd} ,7^{th} ,14^{th} and 21^{th} days post wounding the contraction rate is greater in treated wound than control and standard. The results demonstrated that complete wound closure was achieved by Day 21 post-wounding in the treated groups, whereas the control group failed to achieve complete closure by the end of the experimental period.

In addition, a Depend on concentration effect of Banana peel extract was observed. Higher concentrations were associated with increased irritation, inflammation, and hypersensitivity reactions, while lower concentrations showed greater efficacy in accelerating wound healing. This observation was supported by the percentage of wound contraction, where lower doses exhibited higher contraction rates compared to higher doses.

Furthermore, wounds treated with the 0.25% concentration showed noticeable healing by Day 14 post-wounding. However, the continuation of treatment until Day 21 was intended to minimize scar formation and improve the final appearance of the healed tissue.

Table (4.5) effect of plant extract on wound contraction rate as mean ± standard error (SE).

Time day	Contraction rate %			
	Control (untreated)gr.	Standred (Mebo)gr.	Extract treated gr.	
			0.25%	1%
Zero	144mm ±20	144mm ±36	144mm ±0	144mm ±29
3rd	106mm ±14	103mm ±16	72mm ±3	88mm ±16
7th	91mm ±14	72mm ±20	34mm ±5	73mm ±11
14th	29mm ±5	12mm ±5	5mm ±2	17mm ±2
21th	3mm ±3	2mm ±2	0mm ±0	20mm ±2

Table (4.6) wound healing contraction rate during 21 days

Time day	**Contraction rate %**			
	Control (untreated) gr.	Standard (Mebo) gr.	**Extract treated gr.**	
			0.25%	**1%**
3rd	26.4%	28.5%	50%	38.9%
7th	36.8%	50%	76.4%	49.3%
14th	79.9%	91%	96.5%	88.2%
21th	97.9%	98.6**%**	100**%**	86.1%

Control gr. Standard(Mebo)gr. Treated gr.(0.25%) Treated gr.(1%)

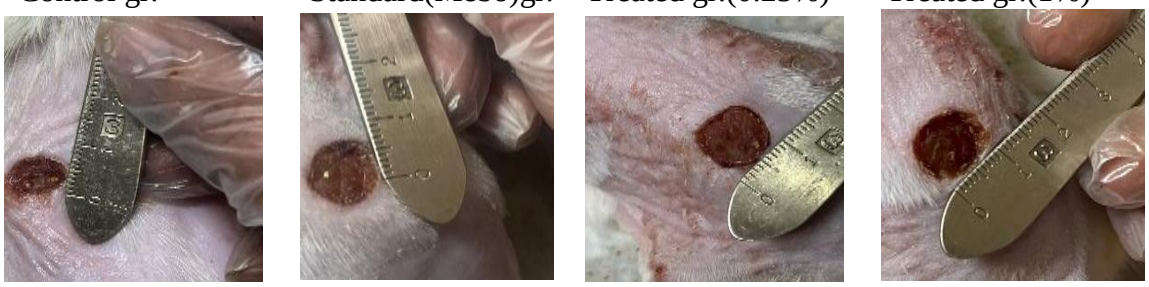

Figure (4.3) Macroscopic evaluation of wound healing in 3rd day.

Control gr. Standard(Mebo)gr. Treated gr.(0.25%) Treated gr.(1%)

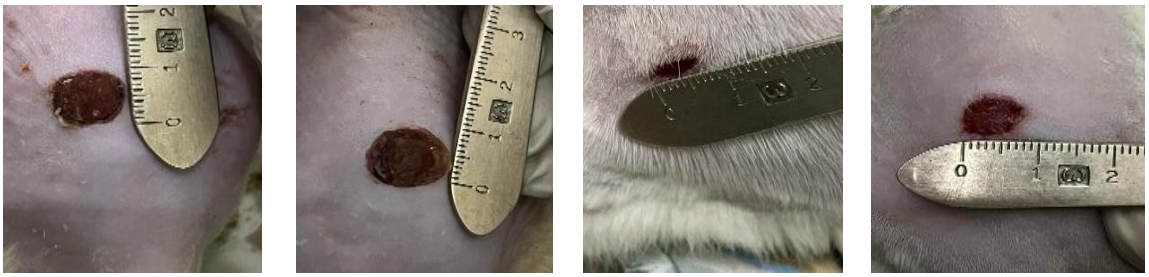

Figure (4.4) Macroscopic evaluation of wound healing in 7th day.

Control gr. Standard(Mebo)gr. Treated gr.(0.25%) Treated gr.(1%)

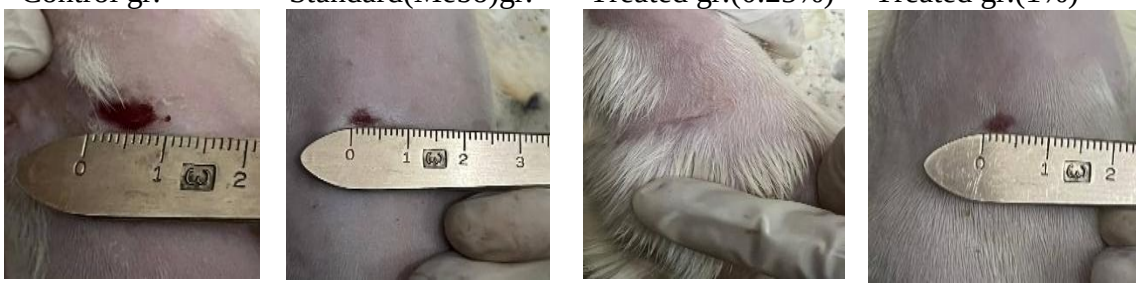

Figure (4.5) Macroscopic evaluation of wound healing in 14th day.

Control gr. Standard(Mebo)gr. Treated gr.(0.25%) Treated gr.(1%)

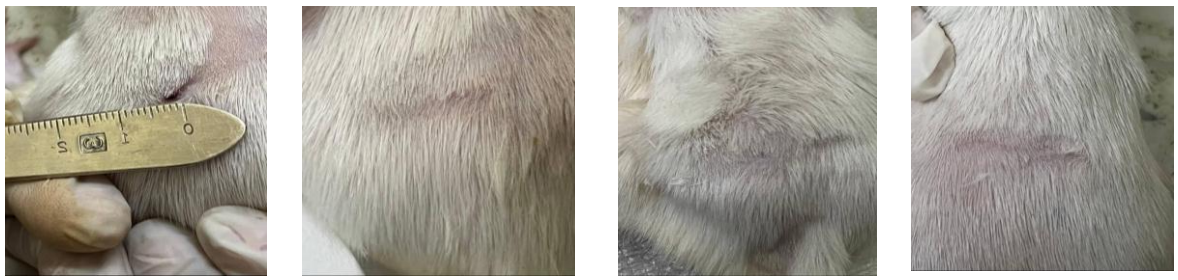

Figure (4.6) Macroscopic evaluation of wound healing in 21th day.

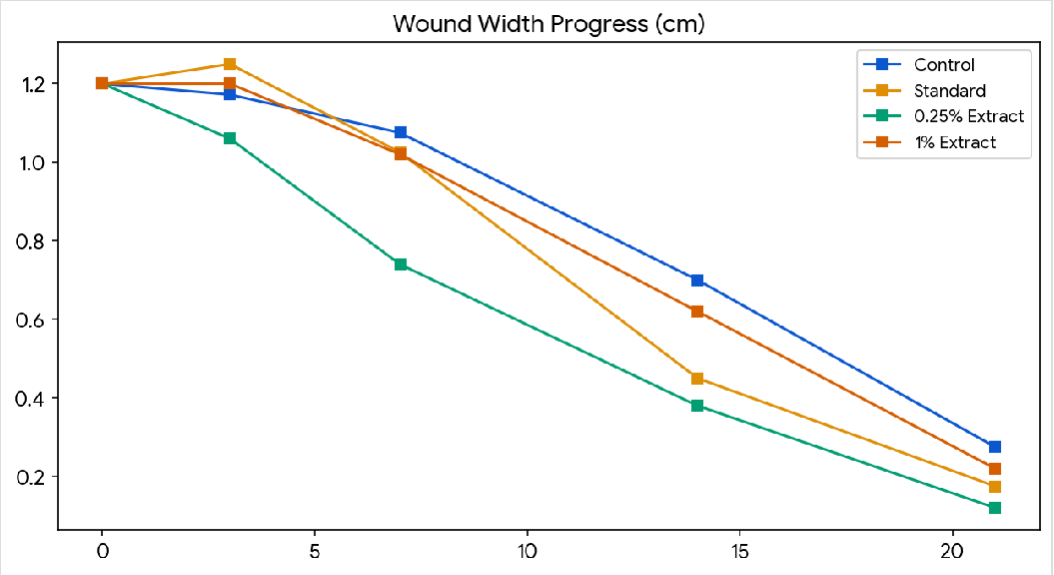

Figure (4.7): show decrease in wound length over 21 days as mean

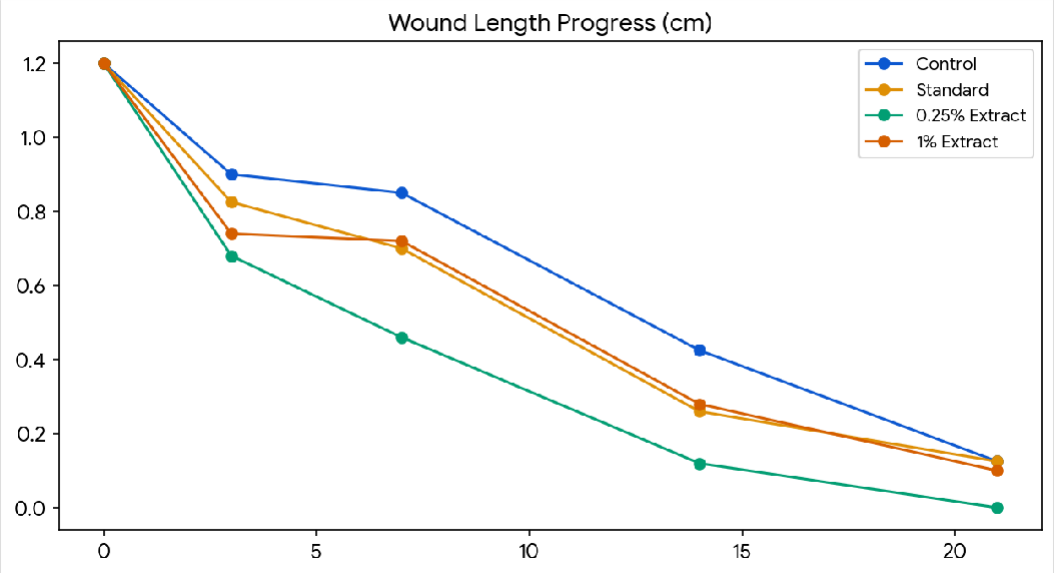

Figure (4.8): show decrease in wound width over 21 days as mean

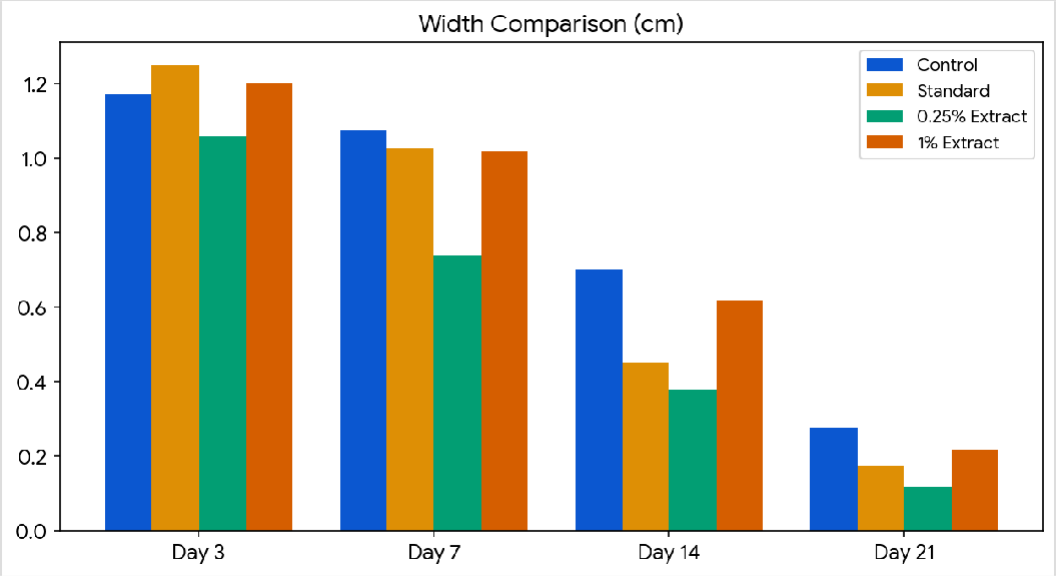

Figure (4.9): progression of wound width (cm) across treatment group over 21 days

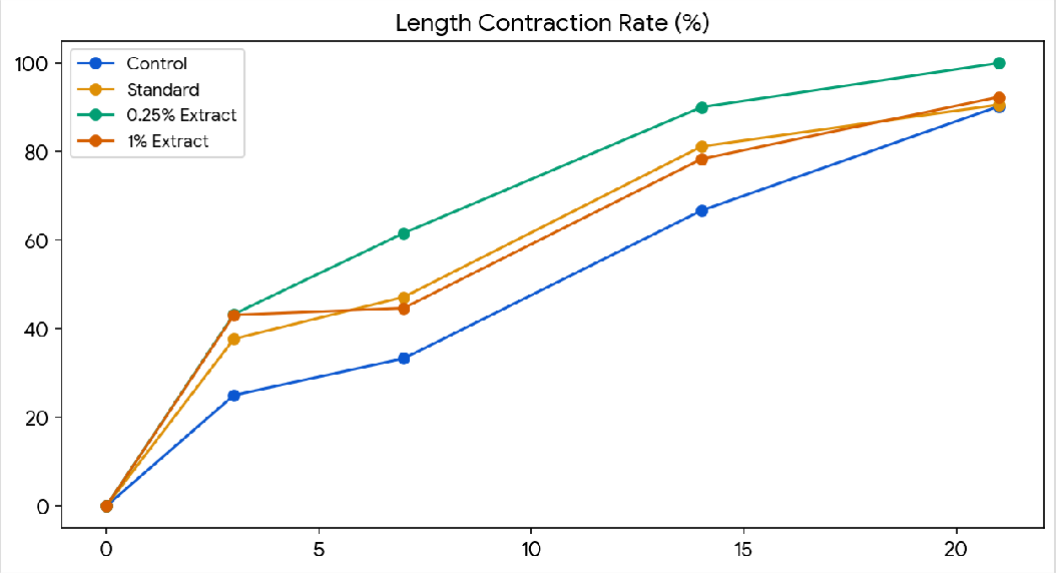

Figure (4.10): rate of wound length concentration (%) during 21 days

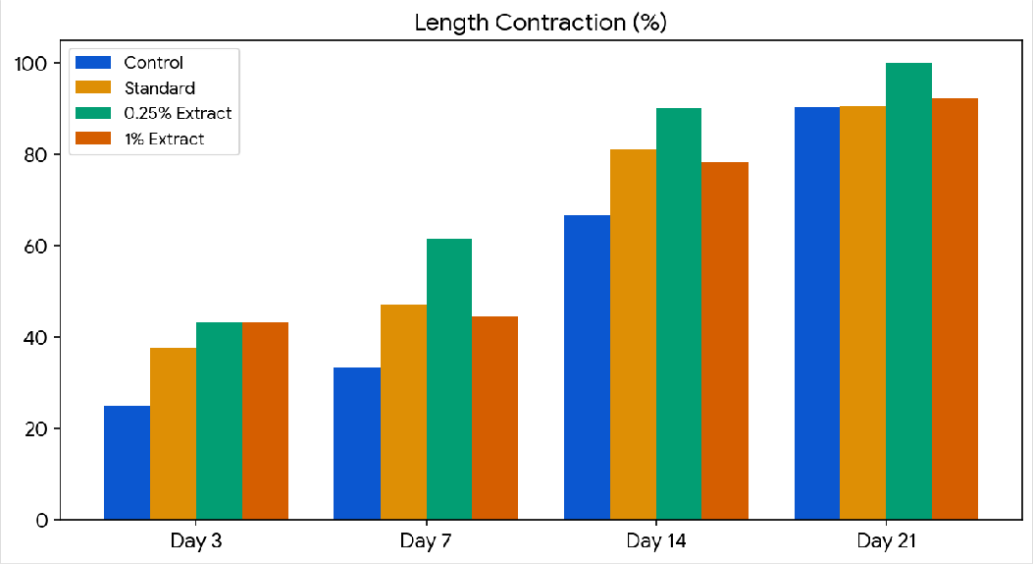

Figure (4.11): percentage of wound length concetration (%) over 21 days

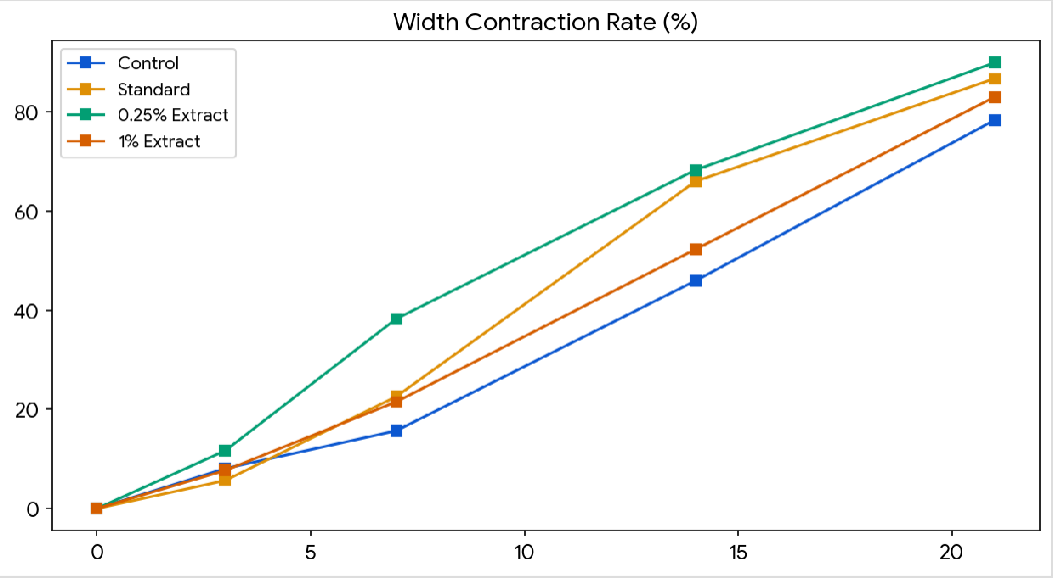

Figure (4.12): rate of wound width concentration (%) during 21 days

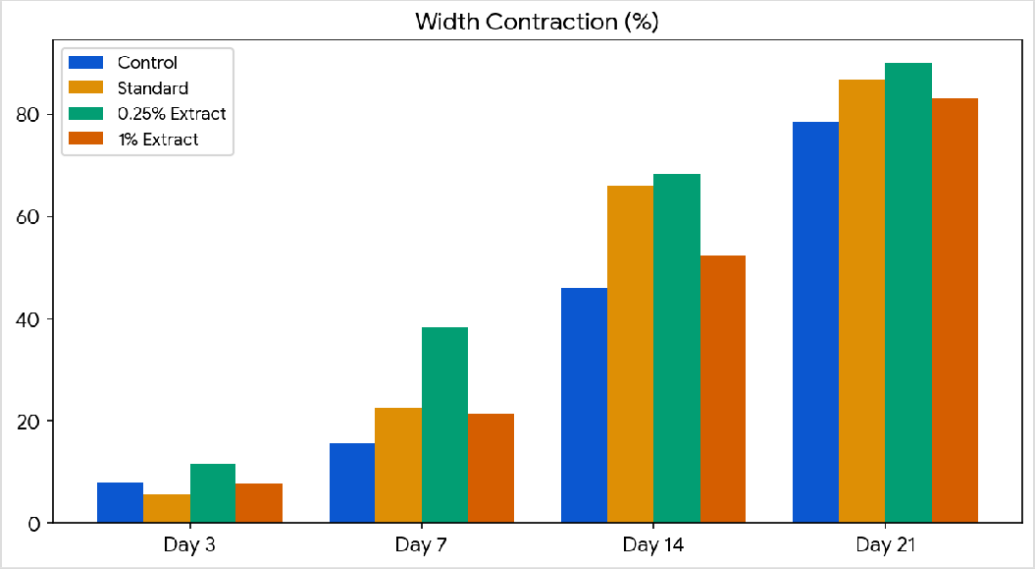

Figure (4.13): percentage of wound width concetration (%) over 21 days

CHAPTER V

DISCUSSION

5.1 Discussion

In the present study, banana peel extract was obtained by using 85% ethanol through the maceration extraction method for one week, the dried extract represent (12.4 %). Where,(Vu et al. 2021) applied ultrasound assisted extraction using 60% ethanol and reported significantly higher phenolic yields compared with conventional maceration methods.

Similarly, (Nguyen et al. 2022) used microwaveassisted extraction which reduced extraction time, that explained the different methods of extraction led to differences in the time of extraction and in the results of extraction.

The current research revealed the presence of tannins, flavonoids, phenols, and saponins. According to(Kanugonda et al. 2023) and(ArribasLopez et al. 2022), these

compounds exhibit catechin, quercetin, gallic acid, dopamine, and caffeic acid, and (Agarwal et.al.2019), recorded the presence of compounds such as phenolics ,tannins ,saponins and alkaloids.

In the present study, the extract was formulated as topical ointments containing 0.25% and 0.5% extract using paraffin, lanolin, propylene glycol as a base

(Basha et al. 2023) developed a chitosan based hydrogel containing plant extracts which demonstrated better moisture retention and controlled drug release compared with traditional ointments.

In (Agarwal et.al.2019) study, the ointment containing 10% banana peel extract used topically to treat wounds

The animal experiment in the current study used rats to evaluate the wound healing activity which produced nearly 95% wound contraction over 21 days by using 0.25% extract ointment. However, (Swathi Krishna et al. 2024) demonstrated that ethanolic banana peel extract produced nearly 90% wound contraction within 14 days in rat models and (Breijyeh and Karaman 2024) reported that phenolic rich plant extracts stimulate angiogenesis and collagen deposition, which are essential for tissue regeneration.

In addition, (Agarwal et.al.2019) demonstrated that ethanolic banana peel extract produced nearly 90-94% wound contraction within 14 days in wistar albino rat models.

Overall, the results demonstrated progressive wound healing over the 21-day period in all groups, with marked differences between treated and control animals. By Day 21, near-complete to complete wound closure was observed in all treated groups, while the control group showed the least healing with residual wound traces. Among treatments, the 0.25% banana peel extract

group exhibited the most effective outcome, achieving almost complete healing with minimal or no visible scars, followed by the MEBO ointment group and the 1% extract group, which both showed strong but slightly lower efficacy. Early and mid-phase assessments (Days 3, 7, and 14) consistently indicated faster wound contraction, reduced inflammation, and improved tissue regeneration in treated groups compared with controls, with the 0.25% concentration showing the most consistent anti-inflammatory and pro-healing effects. In contrast, the higher concentration (1%) showed relatively less pronounced improvement, suggesting a possible dose-dependent response.These findings suggest that banana peel extract, particularly at lower concentration, enhances wound contraction, reduces inflammation, and promotes tissue remodeling due to its bioactive compounds. This is supported by both numerical data and visual observations. Similarly, (Nair et al. 2024) reported that Musa paradisiaca peel is rich in phenolic compounds such as gallic acid and catechin, which reduce oxidative stress by neutralizing reactive oxygen species (ROS), thereby promoting fibroblast proliferation and faster epithelialization. In addition, (Okon and Bassey 2024) found that the ethanolic extract was more effective than the aqueous extract, showing higher wound contraction rates due to its greater content of tannins and its ability to enhance fibroblast activity and collagen formation.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6. Conclusion and recommendation

6.1. Conclusion

The study demonstrated that the ethanolic extract of Musa paradisiaca (banana peels) possesses significant wound healing activity due to the presence of bioactive compounds such as flavonoids, tannins, phenols, and saponins. These compounds contribute to antioxidant, antiinflammatory, and antimicrobial effects that enhance the healing process. The results showed that topical application of the extract ointment improved wound contraction and accelerated healing compared to the control group. In addition, treated wounds exhibited better tissue regeneration and reduced inflammation. Interestingly, the lower concentration (0.25%) showed better efficacy than the higher concentration (1%), suggesting that optimal healing may be achieved at lower doses**.**

In addition, when compared to the standard treatment (MEBO ointment), banana peel extract demonstrated comparable wound healing efficacy, further supporting its potential as a natural, cost-effective, and accessible alternative for wound management. This is particularly relevant in low-resource settings, where affordable and effective treatment options are highly needed.

Overall, the results of this study validate the traditional use of banana peels in wound care and highlight their promising role as a source of natural therapeutic agents. Furthermore, this research emphasizes the importance of utilizing agricultural waste materials, such as banana peels, as valuable pharmaceutical resources, thereby contributing to both environmental sustainability and the development of innovative, plant-based medicinal products.

6.2. Recommendation

1- Investigating the potential use of banana peel extract in the treatment of burns.

2- Perform an Assay test to accurately determine the concentration and percentage of active constituents in the extract, ensuring the quality and efficacy of the prepared formulation.

3- HPLC analysis (High-Performance Liquid Chromatography) is recommended to separate and identify the active chemical compounds present in banana peel extract in a precise and detailed manner.

4- Evaluate the safety and efficacy of the extract on a larger scale before its potential clinical application

5- Perform histopathological studies on tissue samples obtained from treated animals to evaluate tissue regeneration, collagen formation, and structural restoration at the microscopic level.

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الملخص

المقدمة: يُعد التئام الجروح عملية بيولوجية معقدة تتضمن إصلاح الأنسجة وتجديدها. وبينما توجد منتجات صناعية متنوعة، هناك اهتمام متزايد بالبدائل الطبيعية نظراً لأمانها وفعاليتها.

قشور الموز، التي غالباً ما تُهمل كنفايات، غنية بالمركبات النشطة بيولوجياً مثل الفلافونويد، التانين، والصابونين، والتي تمتلك خصائص مضادة للأكسدة والالتهابات يمكن أن تعزز عملية الشفاء.

الأهداف: كان الهدف الرئيسي من هذه الدراسة هو استقصاء فعالية مستخلص الإيثانول لقشور الموز اليمني في التئام الجروح لدى الفئران. وبشكل محدد، هدفت الدراسة إلى تحضير المستخلص، وفحص مكوناته الكيميائية النباتية، وصياغته في مرهم بتركيزات مختلفة (٠.٢٥% و١%)، وتقييم فعاليته مقارنة بالدواء التجريبي ميبو.

المنهجية: أُجريت دراسة تجريبية باستخدام ثمانية عشر من إناث الفئران. تم استخلاص قشور الموز باستخدام الإيثانول بتركيز ٨٥% عن طريق النقع، ثم صياغة المستخلص في مراهم موضعية. قُسمت الحيوانات إلى مجموعات: عولجت بمرهم المستخلص بتركيز ١%، وتركيز ٠.٢٥%، ومجموعة الميبو (كمعيار قياسي)، ومجموعة ضابطة (غير معالجة). تمت مراقبة انكماش الجرح في الأيام ٣، ٧، ١٤، و٢١ بعد الإصابة.

النتائج: أكد الفحص الكيميائي النباتي وجود التانينات، الفلافونويدات، الفينولات، والصابونين. وأظهرت الدراسة على الحيوانات أن المرهم بتركيز ٠.٢٥% كان الأكثر فعالية، حيث حقق انكماشاً للجرح بنسبة ٩٥% تقريباً بحلول اليوم ٢١ مع حد أدنى من الندبات. لوحظ انغلاق كامل للجرح في المجموعات المعالجة بحلول اليوم ٢١، بينما لم يحقق الجرح في المجموعة الضابطة انغلاقاً كاملاً. ومن المثير للاهتمام أن التركيزات المنخفضة أظهرت فعالية أفضل وآثاراً جانبية أقل مقارنة بتركيز ١% الذي تسبب في بعض التهيج.

الاستنتاج: تخلص الدراسة إلى أن مستخلص قشور الموز اليمني، خاصة بتركيز ٠.٢٥%، يعزز بشكل كبير من التئام الجروح وإعادة بناء الأنسجة. تدعم هذه النتائج الاستخدام التقليدي لقشور الموز وتشير إلى إمكانية استخدامها كبديل طبيعي وفعال من حيث التكلفة في رعاية الجروح.

الكلمات المفتاحية:

مستخلص قشور الموز ، التئام الجروح، المركبات الكيميائية النباتية، تحضير المراهم، النشاط المضاد للأكسدة، نموذج حيواني

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قسم الصيدلة

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Ministry of Education and
Scientific Research
Azal University for Human Development
Faculty of Medical sciences faculty
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تقييم فعالية مستخلص قشور الموز في التئام الجروح

مشروع تخرج مقدم الى قسم الصيدلة بكلية العلوم الطبية جامعة آزال للتنمية البشرية، كجزء من متطلبات نيل درجة البكالوريوس في علم الصيدلة .

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