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Review Paper

Innovative Herbal Hydrogel Patches Strategy Utilising Pineapple Peel Extract

Dhanshri Nakhate^{1*}, Sejal Gajbhiye², Pooja waware³

School of pharmacy, G H Rasoni University, Saikheda, Dist-Pandhurna, Madhya Pradesh, India-480337

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ABSTRACT

Bromelain is mix of proteolytic enzymes principally extract from fruit and stem the pineapple plant (*Ananas comosus*). It have lengthy historical past of standard medicinal use in various cultures, particularly in Central, South America, the place pineapple is native. Wound management continue to be critical aspect of healthcare driving the demand for effective, affordable sustainable. A wide range of therapeutic benefits have been claimed for bromelain including reversible inhibition of platelet aggregation, angina pectoris, bronchitis, sinusitis, surgical traumas, thrombophlebitis, enhanced absorption of Biochemical experiment indicate that these pharmacological properties depend of proteolytic activity only partly, suggesting the presence of nonprotein factors in bromelain pineapple peel an abundant agro-industrial waste contains valuable bioactive compounds bromelain, polyphenols, flavonoids with reported anti-inflammatory, antimicrobial and proteolytic properties useful in wound management. The review summarize phytochemical attribute of pineapple peel extract hydrogel patch material fabrication strategy Pineapple has main role in ethnopharmacology its enzyme bromelain has been extensive investigated for medicinal properties. Pineapple peel, major waste, *Ananas comosus* processing, is becoming promising natural resource for biomedical applications, especially for wound management. Rich in bioactive compounds like bromelain, flavonoids, phenolics and vitamin C, pineapple peel has significant antioxidant, anti-inflammatory and antimicrobial properties necessary for proper wound healing. This study aims to perform the effect of application of hydrogel patch containing pineapple peel extract..

INTRODUCTION

The wound is fairly common injury faced by community. Injury can occur due to a deliberate

process that is wound due to surgery or accidental due to accidental injuries, and also burns. The existence of damage to the skin may reduce the ability of the first defence system in the body. Skin

***Corresponding Author:** Dhanshri Nakhate

Address: School of pharmacy, G H Rasoni University, Saikheda, Dist-Pandhurna, Madhya Pradesh, India-480337

Email ✉: dhanshrinakhate11@gmail.com

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is the first Barrier for the human body[1]. Bromelain has only come from the Hawaiian pineapple stems, although they also produce in Taiwan, Thailand, Brazil, & Puerto Rico. However, the variability of the product produced commercially and the variety of ingredients have prevented its development with success. While pineapple bromelain has found commercial applications as a meat-tenderising enzyme and a nutraceutical, work has been done to explore its potential for pharmaceutical use. Yet, the complex nature of the active components of bromelain have left some limitations on pharmaceutical research [2]. Traditional medical patches are commonplace for several biomedical applications. The common patches are sticking plaster and acrylic tapes. Although they are effective to a certain extent, these patches severely lack biological functionalities [3]. Agricultural waste has turned out to be an appealing cellulose nanobarns source for drug delivery purposes. Researchers have isolated cellulose nanobarns by different means, such as high-pressure homogenization, micritization, grinding, cry crushing, renin [4] or chemical methods from the waste parts (peels, leaves) of fruits and vegetables such as pineapple [5]. Its industrial processing generates a huge quantity of agri-food wastes, and among these, the peel uses a high percentage. Pineapple peel is a rich source of phenolic compounds with broad-ranging demonstrated antioxidant and anti-inflammatory properties [6]. The open burning of these wastes is a common practice in the past for the management of waste and despite this practice, it contributes to the pollution of the air[7]

Wound Healing

Non-surgical cosmetology & dermatological treatment are become more and more popular and widely used by wide range of people. Unfortunately, all treatments lead to lesions of skin to greater or lesser extent. The big challenge

is proper care and improvement of the wound healing process to minimise their visibility and prevent unsightly scars. It is important to use preparations that provide the best possible conditions for healing after each procedure, since tissue is broken during and at the same time skin damage occurs. A good strategy in his area is likely to avoid complications and appearance of unwanted and extensive scars. Fortunately, modern dermatology and cosmetology, through the formation of appropriate standards of care, including the use of hydrogel materials and appropriate prevention, can actively support the healing process of even the most problematic wounds [8]. Hydrogels were drawn attention over the last 50 years due to their beneficially properties of absorbing large amounts of water [9] as an effective and easy-to-apply drug delivery system.

Pineapple Peel Extract

Pineapple skin is removed by the maceration method. The stages of the maceration process are collecting materials, sorting, washing, drying, grinding and soaking in 96% ethanol for 3 x 24 hours in a container protected from direct sunlight. The filtrate was obtained by filtering using the filter paper and evaporation using rotary evaporator at a temperature of 40-50 C until a thick extract was formed [10]. Bromelain is the extract from the stem and fruit of pineapple which contains a high level of Proteolytic enzymes and the combination depends on the method, resource, and purification. Bromelain is directly active on pain mediators such as bradykinin [4]. Also, its anti-pain features are significantly associated to its anti-inflammatory features. It has been found that this Fibrinolytic agent may reduce swelling, bruising, pain and duration of wound healing after trauma and surgery [11]. Waste samples (pineapple skin-PS) were gathered and pulp of pineapple were removed manually [12]. Pineapple is perennial plant which belongs to family



Bromeliaceae. Fruit is consumed in form of jams, concentrates, canned fruits and juices [5]. Pineapple peel waste has also been used as raw material in extracting pectin, as fermentation substrate for production of solvents (ethanol, butanol), biogases (hydrogen, methane), sources of bromelain (protease enzymes), phenolic flavour compounds, antioxidants and organic acids [10].

Active substances in herbal medicine on wound study

Active element of medical treatment of different types of wounds since herbal medicine. The repair mechanism of burns mainly includes the starting of the inflammatory process, development of granulation tissue, forming of new blood vessels, wound contraction and wound healing process. Extracts from medicinal herbs are very important constituent for wound healing and provide the best environment for wound cleansing [8]. Click or tap here to enter text.

THE SKIN

The skin is the most remarkable multifunctional organ of human body. It plays a crucial role in protection against a wide range of exterior hazards while preserving the internal environment. In virtue of its physical and sensory functions, this multilayered, complex organ plays a vital role in the body's defence. Human skin consists of three different layers, epidermis, dermis & hypodermis. Epidermis is majorly composed of keratinocytes, an integral contributor to cutaneous protective barrier function of skin [1]. For the use of electrochemical electrodes in these sensors, two reference electrodes and two ion selective electrodes for a desired analyte are required [3]. The skin represents the main defence system of the human body, which can protect the human body from microbial infection and external environmental damage [13]. The skin as primary barrier between

body and environment, is susceptible to damage. Skin injuries can be acute, mechanical or chemical, or chronic, as a result of burns, infections [6]. Skin injury disrupts the integrity of the skin's framework and this results in a wound healing process which is characterised by a well-coordinated series of cellular and molecular reactions that aim to recuperate or replace the injured tissue [1]. Skin abnormality can usually be seen at a distance. They include change in the hair or wool, abnormal sweating, presence of discrete or diffused lesions and evidence of soiling by discharges and itching. The human skin is one of the largest tissues present in body. Although it covers the entire body & shields it from harm coming from outside, it is also vulnerable to injuries [1].

Wound healing process

When skin is damaged and a wound is formed, the body creates a healing process, which consists mainly of haemostasis, inflammation, proliferation, & remodelling processes. Haemostatic process entails some complex biological activities. First, the small blood vessels & capillaries around the wound have a reactive constriction to minimize the local blood flow. Subsequently, the platelets are attracted towards a clumping together into clots by the exposed fibres [14].

Wound types

Depending on the depth of lesion, wounds can be classified as epidermal, superficial, deep dermal, or full-thickness. Although healing phases are the same across all wounds, the process is dependent on the individual characteristics of each wound. Cutaneous wounds are categorized based on the nature of cut and specific layers that are impacted. These wounds can be divided into incisional and excisional wounds [15].



PHASES OF WOUND HEALING

Figure no1. The 4 phases of wound healing and their approximate duration for acute and chronic wounds.

ACUTE WOUND		CHRONIC WOUND	
1. Hemostasis-Blood clotting	Day1-3	1. Inflammation-Frame work for Blood vessels	>4weeks
2. Inflammation-Frame work for blood vessels	Day3-20	2. No healing occurs	-
3. Proliferation or wound closure-pull the wound closed	Week 1-6	Extracellular matrix destroyed and reactive oxygen species are manufactured	
4. Remodelling-full healing of wound at the remodelling stage	Week 6-2years		

It is imperative that all four physiological phases, which are closely interlinked, interdependent, and at times overlapping with each other, happen in the right sequence and within an acceptable period [1]. Haemostasis starts the wound healing process which takes place when the ruptured tissue allows the flow of blood into the open lesion. Upon sustaining an injury, there is an initial physiological response which is restriction of blood vessels, known as vasoconstriction, which impedes the bleeding process. It is necessary to keep the integrity of the skin intact. In order to successfully progress through the wound to achieve full healing succession, an intricate biological wound healing process of haemostasis, inflammation, proliferation and remodelling must be achieved [[1]. The remodelling stage is final stage of wound healing which can take years. The granulation tissue is transformed into scar tissue by the transformation of fibroblasts into myofibroblast [3]. Wounds has become one of main causes of death in the world, cause great inconvenience to the health of human body & economic development. Wound healing generally has four highly integrated stages, which are haemostasis, inflammation, proliferation and remodelling. These 4 stages start in definite order and last for period of time, & there may be partial overlap in time and space between these stages. Creating a clean and moist environment for the

wound can help the wound heal faster without inflammation [13].

Acute and Chronic Wounds

Acute and Chronic Wounds Acute and chronic wounds are determined based on the healing period following initial injury and more importantly by the presence of physiological damage. Acute wounds are breaks in the integrity of the epidermis which heal completely with minimal scarring. Acute and chronic wounds are determined according to the period of healing after initial injury, but more significantly according to the occurrence of physiological damage. Acute wounds are a breach in the integrity of the epidermis that is eventually repaired with minor scarring and progresses through a structured process of recovery that takes about 8 to 12 weeks. The etiologic of these injuries is mainly mechanical trauma such as abrasive interaction and incisions made during the surgical procedures, thermal traumas, chemical burns and electrical accidents [1]. The resultant hydrogels had superior mechanical property and water holding capacity. Due to good gel features, matrine (MT) has loaded & showed sustained release properties with swelling properties. In case of poor drug release, the ultra-low temperature enzymatic process may be a viable process [16]. Hydrogel- promote wound repair, mainly by stimulating fibroblast

proliferation, accelerating synthesis of endogenous collagen in wound area & promoting angiogenesis, without any adverse effects. These authors also proved that the developed collagen hydrogel has a similar role in wound healing as recombinant growth factors [8]. Crosslinked cationic hydrogel that in itself result for reduced inflammatory response, in combination with antioxidative property of NAC. Firstly, our Nanohydrogel dressing radiates anti microbial bacteria from the wound site. The removal of bacteria from the site leads to a significant decrease of the number of influx of inflammatory cells usually present with infection [17]

Hydrogel dressings

Unlike traditional dressings, such as bandages & gauzes, hydrogel dressings are widely acknowledged for their excellent property, including mechanical properties that are compatible with biological tissues & exceptional water retention capacity which keep the wound moist & continuously absorb exudate. In addition, their appropriate biodegradation prevents secondary damage during dressing replacement, which makes them very suitable wound dressing materials [14]. Wound dressings play a significant role in wound healing as they may offer a physical barrier to the wound and external environment to prevent further injury or infection [4]. Traditional dressings like gauze can attach to the new granulation tissue and hurt when it is removed. In addition, it does not have any antibacterial, antioxidant or other active functions [13]. The development of hydrogel as potential wound dressings for pressure ulcers, dry chronic wounds, necrotic wounds, burns, etc. has received a lot of attention because of its 3-dimensional (3D) porous structure mimicking extracellular matrix (ECM), its high water absorption and its mechanical properties (e.g. elasticity, softness) providing a cooling/soothing effect and facilitating the

dressing application and removal of the dressing, oxygen permeability and its ability to encapsulate various active ingredients (e.g. pharmaceuticals, growth factors) [18].

Hydrogel production process

The assembly of polymers, whether they are natural or synthetic, to create hydrogels is a crucial determinant of hydrogel functionality [15].

Inflammation

Wound healing is retarded by prolonged inflammation due to bacterial infection. Therefore, antibiotics are utilised to fight bacterial infections in the wound site and are commonly used as one of the standard treatments for wound care management [18].

Remodelling

The final stage of healing is remodelling, which is meant to remove unnecessary vessels, fibroblasts and inflammatory cells. Granulation & re-epithelialization are the primary processes involved in wound closure. Granulation tissue is a temporary matrix - nevertheless [18]. The treatment of wounds and the therapeutic challenge they present have become major issues of healthcare with a significant financial cost globally. The skin, one of the most fundamental organs in the body, which protects us from the harsh external environment, is often damaged by traumas, severe burns, ulcers and other wounds which impair its ability to act as a protective barrier and play an important role in sensory perception [18].

Wound healing and chronic wound physiology

Wounds are grouped into two categories, acute and chronic, this is based on the duration of healing time.13 Generally if the duration of healing time



exceeds 12 weeks the wound can be considered chronic. However, in case the healing process reaches 30 days, it can be categorised as wound that does not show any signs of healing.14-16 The rate of healing is dependent on a number of internal and external factors [4].

Chitosan

Chitosan (CS) is the only natural cationic polymer which has a biocompatibility, biodegradable ability, non-toxic, antibacterial, antifungal and anti-tumour properties. It is widely used as biomedical materials. CS is also useful to the healing of wounds as it promotes haemostasis and boosts tissue formation. CS based hydrogel play important role in wound healing. We fabricated self-healing hydrogels by dynamic imine bonding using COL and CS. The addition of COL makes the COL-CS hydrogels to be injectable, to have a rapid self-healing ability and good moldability [13].

CONCLUSION

Creating herbal hydrogel patches with pineapple peel extract is a promising and environmentally friendly way of wound care and skin treatment. Pineapple peels, which are usually discarded as waste, are actually full of beneficial compounds such as bromelain, flavonoids and antioxidants which help to reduce inflammation, fight bacteria and promote the healing process. By the incorporating of these natural extracts into hydrogel patches, not only are we improving the outcome of healing, we are using agricultural by-products, which in turn promotes sustainability. This innovative solution will fit in very well with the growing interest in natural, affordable and environmentally conscious healthcare products. With more research and testing, these patches can be great addition to modern medical treatments and consumer health products.

REFERENCES

1. Gounden V, Singh M. Hydrogels and wound healing: current and future prospects. *Gels*. 2024 Jan 5;10(1):43.
2. Kansakar U, Trimarco V, Manzi MV, Cervi E, Mone P, Santulli G. Exploring the therapeutic potential of bromelain: applications, benefits, and mechanisms. *Nutrients*. 2024 Jun 28;16(13):2060.
3. Chakraborty A, Alexander S, Luo W, Al-Salam N, Van Oirschot M, Ranganath SH, Chakrabarti S, Paul A. Engineering multifunctional adhesive hydrogel patches for biomedical applications. *Interdisciplinary Medicine*. 2023 Oct;1(4):e20230008.
4. Dam P, Celik M, Ustun M, Saha S, Saha C, Kacar EA, Kugu S, Karagulle EN, Tasoglu S, Buyukserin F, Mondal R. Wound healing strategies based on nanoparticles incorporated in hydrogel wound patches. *RSC advances*. 2023;13(31):21345-64.
5. Bhatia M, Rani P, Verma V. Extraction of cellulose nanofibers from pineapple crown waste: Characterisation and evaluation in topical drug delivery.
6. Romero Robles LE, Antunes Ricardo M, Bustamante Maeda I. Use of Pineapple Peel as a Source of Bioactive Compounds for the Manufacture of Hydrogels. *LACCEI*. 2023;1(8).
7. Bertan FA, da Silva Pereira Ronning E, Marchioro ML, Oldoni TL, Dekker RF, da Cunha MA. Valorization of pineapple processing residues through acetification to produce specialty vinegars enriched with red-Jambo extract of *Syzygium malaccense* leaf. *Scientific Reports*. 2022 Nov 12;12(1):19384.
8. Zagórska-Dziok M, Sobczak M. Hydrogel-based active substance release systems for cosmetology and dermatology application: A



- review. *Pharmaceutics*. 2020 Apr 26;12(5):396.
9. Al-Rajabi MM, Teow YH. Temperature-responsive hydrogel for silver sulfadiazine drug delivery: optimized design and in vitro/in vivo evaluation. *Gels*. 2023 Apr 13;9(4):329.
10. Hening PT, Sari AP, Nikita M, Al Fatah AM, Riyadi FR, Rahayu ID. Development of Pineapple Skin Extract Hydrogel Patch Applications (*Ananas comosus* L.) as Wound Dressing in Diabetic Ulcers in Mice (*Mus musculus*). *Media Farmasi Indonesia*. 2024 Oct 28;19(2):166-76.
11. Banihashemrad SA, Nasrabadi N, Rajabi O, Kanafi AR, Taher M. Impact of bromelain on wound healing and complications after periodontal surgery. *Archives of Pharmacy Practice*. 2020;11(1-2020):38-41.
12. Ghazi HH, Aljeboree A. Highly Surface Activated Phosphoric Acid Clove Leaf Agro Waste Micro/Nano Bio Sorbent: Characterization, Regeneration, Equilibrium Isotherm of Safranin T. *Journal of Nanostructures*. 2024 Jan 1;14(1):176-83.
13. Su J, Li J, Liang J, Zhang K, Li J. Hydrogel preparation methods and biomaterials for wound dressing. *Life*. 2021 Sep 27;11(10):1016.
14. Huang C, Dong L, Zhao B, Lu Y, Huang S, Yuan Z, Luo G, Xu Y, Qian W. Anti-inflammatory hydrogel dressings and skin wound healing. *Clinical and translational medicine*. 2022 Nov;12(11):e1094.
15. Sawadkar P, Lali F, Garcia-Gareta E, Garrido BG, Chaudhry A, Matharu P, Kyriakidis C, Greco K. Innovative hydrogels in cutaneous wound healing: current status and future perspectives. *Frontiers in Bioengineering and Biotechnology*. 2025 May 12;13:1454903.
16. Han SS, Ji SM, Park MJ, Suneetha M, Uthappa UT. Pectin based hydrogels for drug delivery applications: a mini review. *Gels*. 2022 Dec 17;8(12):834.
17. Pranantyo D, Yeo CK, Wu Y, Fan C, Xu X, Yip YS, Vos MI, Mahadevegowda SH, Lim PL, Yang L, Hammond PT. Hydrogel dressings with intrinsic antibiofilm and antioxidative dual functionalities accelerate infected diabetic wound healing. *Nature communications*. 2024 Feb 1;15(1):954.
18. Arbab S, Ullah H, Muhammad N, Wang W, Zhang J. Latest advance anti-inflammatory hydrogel wound dressings and traditional *Lignosus rhinoceros* used for wound healing agents. *Frontiers in bioengineering and biotechnology*. 2024 Nov 28;12:1488748.

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