REVIEW ARTICLE

Wound healing properties of selected tropical fruits in Malaysia: A Narrative Review

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Abstract:

Reduction in healing time is crucial for minimizing pain and preventing wound-related complications. Wound dressings and topical products such as antibiotics are commonly used in chronic wound management; however, they can be costly and may be associated with adverse effects. Consequently, natural products have emerged as promising alternatives, as numerous plants and fruits possess wound-healing properties. This review focuses on five fruits from different genera—banana, papaya, mangosteen, pomegranate, and pineapple—that have been scientifically validated for their wound-healing potential between 2010 and 2025. Relevant studies were identified using the Scopus, PubMed, and ScienceDirect databases. Most wound-healing investigations employed *in vivo* models, demonstrating the efficacy of fruit extracts in accelerating wound closure and tissue repair. Although these fruits have shown significant wound-healing activity in experimental settings, further research, including the isolation and characterization of bioactive compounds, is necessary before the development of safe and widely accepted herbal therapies for wound management.

Keywords: Wound healing, banana, papaya, mangosteen, pomegranate, pineapple

1. INTRODUCTION

Wound refers to a physical injury that results in an opening or break in the skin, leading to disruption of normal anatomical structure and function (Farrow & Farrow, 2023). It may also be defined as a loss of tissue continuity with or without microbial infection (Schultz et al., 2023). Disruption of epithelial tissue can occur due to physical, chemical, thermal, immunological factors, or microbial colonisation (Schultz et al., 2023).

Wound healing, on the other hand, is a dynamic and complex biological process regulated by cytokines, growth factors, chemokines, and other mediators that coordinate tissue repair (Lukiswanto et al., 2019). It consists of four major phases: haemostasis, inflammation, proliferation, and remodelling. Haemostasis involves vasoconstriction and fibrin clot formation to prevent blood loss. The inflammatory phase begins when vascular leakage leads to local swelling, which helps control bleeding and reduce infection risk. During the proliferative phase, the wound undergoes contraction and is rebuilt with new extracellular matrix and collagen, a process that may extend over several weeks. Re-epithelialisation subsequently occurs as epithelial cells migrate across the wound bed to restore the protective barrier. In the final remodelling phase, collagen is reorganised from type III to type I until full wound closure is achieved. The progression of wound healing is commonly evaluated using parameters such as wound contraction rate, epithelialisation time, granulation tissue formation, and tensile strength. Histopathological analysis, particularly haematoxylin and eosin staining of granulation tissue, is widely used to assess cellular organisation, inflammation, and tissue maturation (Wallace, Basehore & Zito, 2023).

Healing is further impaired in individuals with conditions such as diabetes, obesity, anaemia, cardiovascular disease, immunosuppression, older age, smoking, and poor nutritional or hygienic status (Almadani et al., 2021; Gupta, Tan & Alvarez, 2024). Delayed wound closure increases susceptibility to infection and may lead to chronic wounds or keloids, both of which prolong recovery and elevate treatment costs. A wide variety of pathogens—including bacteria, viruses, and fungi—can infect wounds when they thrive within damaged tissues. Bacterial infection delays healing by degrading fibrin and reducing essential growth factors and extracellular matrix components (Okur et al., 2020).

Wound dressings and topical medications are commonly used to maintain a moist wound environment that promotes autolytic debridement, reduces pain, supports collagen

synthesis, and enhances keratinocyte migration (Nuutila & Eriksson, 2021). Examples of dressings include hydrogel, hydrocolloid, alginate, and polymeric membrane dressings (Britto et al., 2023). However, they may cause allergic reactions, irritation, discomfort, or pain. Due to these challenges, natural products have attracted increasing attention as safer alternatives, given their lower toxicity and broad therapeutic potential.

Many medicinal plants exhibit wound healing activity. Previous studies—predominantly preclinical investigations consisting of *in vivo* wound healing studies in rodent models—have explored extracts from fruit seeds, peels, and pulp. In Malaysia, numerous studies have examined the wound healing and antimicrobial activities of local fruits. Accordingly, this review focuses exclusively on preclinical evidence related to the wound healing property of selected Malaysian fruits. The fruits reviewed include *Musa spp*., *Carica papaya*, *Garcinia mangostana*, *Punica granatum*, and *Ananas comosus* (Figure 1). These fruits were prominently featured in wound healing investigations, largely due to their rich phytochemical profiles, including phenolics, flavonoids, tannins, and proteolytic enzymes. In addition, their long-standing ethnomedicinal use for treating skin injuries, infections, and inflammatory conditions underscores their therapeutic relevance. Their accessibility and traditional use further support their relevance as potential natural sources of wound-healing and antimicrobial agents. Collectively, their prevalence, accessibility, cultural importance, and substantial preclinical evidence provide a strong rationale for focusing on these five fruits. Relevant studies published between 2010 and 2025 were identified through Scopus, PubMed, and ScienceDirect.

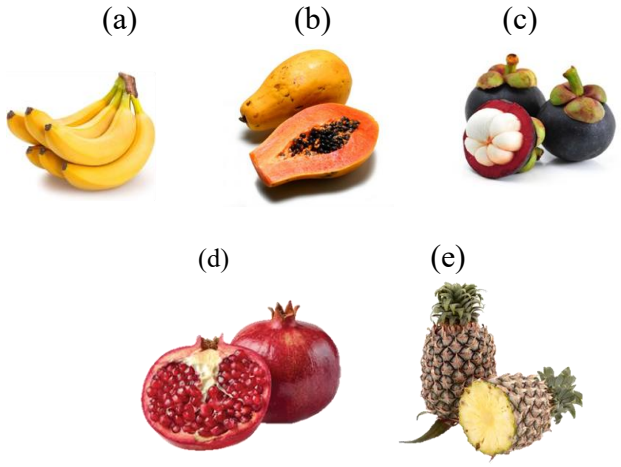

Figure 1. Tropical fruits in Malaysia (a) *Musa* spp. (banana), (b) *C. papaya* (papaya), (c) *G. mangostana* (d) P. *granatum* (pomegranate) (e) *A. comosus* (pineapple).

2. Selected Malaysian Fruits

These five fruits were selected for this review due to their widespread cultivation and ready availability in Malaysia.

2.1 Banana *(Musa* spp.*)*

Banana is the common name for the family Musaceae. It has been widely grown and the fruit is consumed all over the world. Banana fruits are known to have high nutrients that can give beneficial effects on the consumer. The highest percentage of minerals found in bananas is potassium, which prevents muscle spasms and reduces blood pressure, iron that can stimulate the production of hemoglobin, vitamin B6 which aids brain health and the body's immune system, vitamin C which promotes healing and growth of tissue, and fibres that can relieve constipation and diarrhea (Kumar et al., 2012). Other than that, various parts of banana plants such as leaves, stems, banana blossom, roots, and banana peel also have their own medicinal properties.

Banana peel extracts have been proven to have wound-healing properties. In 2023, Rizka et al. reported that their banana peel extract spray gel managed to enhance wound healing in a concentration-dependent manner via a rabbit burn model. The high-concentration formulation (20%) showed the most effective healing, comparable to the positive control. It also demonstrated faster wound closure and significantly increased collagen density and epidermal thickness compared to the negative control. In another study, excision wounds on rabbits treated with hydroalcoholic extract of 10% *Musa acuminata* peel with the addition of Eucerin, a commercial cream used as an ointment base showed complete healing on day 15 (Tamri et al., 2016). In addition, a group of researchers used unripe ground *Musa sapientum* peel with a combination of natrosol gel as treatment for surgical wounds in rats. Results of the study showed wound healing was more progressive in the experimental group compared to the control group. Application of the combination of *M. sapientum* peel extract and natrosol gel showed a significant difference in vascular proliferation, presence of mononuclear cells, fibroblast proliferation, and re-epithelisation at day 14 when compared to control (Von Atzingen et al., 2015).

The wound healing property of *M. sapientum* peel extract may be due to bioactive compounds in the extract. Puraikalan (2018) recorded the presence of a significant amount of tannin, which can promote wound healing by reducing the formation of reactive oxygen substances (ROS) in the extract of *M. sapientum* peel. High levels of ROS result in oxidative stress that can lead to cell and tissue damage causing delayed wound healing. In addition, it has been reported that the peels also harbor flavonoid, saponin,

and phenol (Kibria et al., 2019). According to Aslam et al. (2018), excessive fibroblast activity can cause a delay in wound-healing in which flavonoids can provide a synergistic effect that can promote wound-healing by inhibiting the growth of fibroblasts.

Other than the peel, the stem of the banana plant also showed promising potential in wound-healing properties. The methanolic extract of *M. paradisiaca* stem was studied by Amutha and Selvakumari and there was a significant increase in percentage of wound closure by enhanced epithelisation in the treated rats. The treated group exhibited a faster rate of tissue regeneration compared to the control group (Amutha & Selvakumari, 2016).

2.2 Papaya *(Carica papaya)*

Carica papaya which is also known as papaya is a tropical fruit belonging to the family Caricaceae. The plant grows in tropical regions of the world such as Australia, Indonesia, Malaysia, and Thailand. Papaya fruits are good sources of vitamins such as vitamins A, C, and E as well as minerals such as potassium, calcium, and magnesium. These nutrients are very helpful in reducing the risk of cardiovascular diseases. Besides, papaya fruits also contain fibre and the enzyme papain that can improve digestive disorders or disturbances in the gastrointestinal tract thus promoting digestive health (Leitão et al., 2022). Other parts of papaya plants such as seeds, leaves, latex, and root also have nutrients and bioactive compounds that can give medicinal properties such as antioxidant, antimalarial, anti-inflammatory, antimicrobial, and anti-helminthic (Santana et al., 2019).

Carica papaya has beneficial effect on reducing necrosis and is frequently utilized in the management of wound healing (Siva et al., 2023). Papaya fruits have been reported to have antioxidant activities that can improve the wound-healing process (Nafiu & Rahman, 2015). In their study, the effects of unripe papaya pulp extracts on wound-healing have been demonstrated using biochemical assay. The results showed these extracts can increase the activity of catalase, superoxide dismutase, and glutathione peroxidase in excision wounds of rats. These endogenous antioxidant enzymes were able to neutralize free radicals such as reactive nitrogen species (RNS) and ROS that were released excessively by inflammatory cells into the wound (Gupta et al., 2002). Due to these activities, papaya pulp extracts exhibited complete wound-healing with faster epithelisation than the control (Nafiu & Rahman, 2015). In another study, histological view of oral wounds on rats that were treated with 75% papaya fruit extracts for fourteen days showed a perfect arrangement of epithelial cells and extracellular matrix. In contrast, epithelial cells were arranged separately and showed incomplete fibrillation in the controls (Hakim et al., 2019). Their study also reported that *C. papaya* extract significantly influenced the process of epithelisation and fibrillation in wound-healing. These healing actions are attributed to several properties such as the active ingredient, papain, being responsible for the enzymatic debridement of wounds. The presence of vitamin C, which is necessary for the transformation of proline into hydroxyproline, a particular marker, and element of the granulation tissue of the extracellular matrix in wounds, is the other contributing factor. Vitamin C also plays an important role in the healing process via the enhancement of collagen formation to support new tissue growth (Sarpooshi et al., 2017).

Papaya leaves extract cream (40%) was also shown to significantly reduce wound length in treated rats (Winarjo et al., 2021). Saponins, flavonoids, and alkaloids present in papaya leaves contribute to wound healing, particularly during the proliferative phase. Saponins have been shown to promote angiogenesis, stimulate fibroblast proliferation, and enhance type I collagen synthesis, while flavonoids increase vascularity through their antioxidant and vasodilatory properties (Agyare et al., 2016; Alam et al., 2023). These phytochemicals also exhibit antimicrobial and antiseptic effects that support infection control during the inflammatory phase. In addition, papain, a proteolytic enzyme found in papaya leaves, exerts anti-inflammatory activity by enhancing macrophage function and facilitating granulation tissue formation, wound contraction, and re-epithelialisation (Natarajan et al., 2014; Marlinawati et al., 2022).

2.3 Mangosteen *(Garcinia mangostana)*

Mangosteen is an exotic and tropical fruit usually found in Southeast Asia, especially in Malaysia, Thailand, and Indonesia. Mangosteen is also referred to as “the queen of fruits” because of its thick sepals that resemble a crown, and because of its sweet-sour taste. Mangosteen has been traditionally used to treat diarrhea and has been used as a topical agent. In addition, mangosteen pericarp exhibits antibacterial, antifungal, and anti-inflammatory activities in *in vivo* and *in vitro* studies (Tatiya-aphiradee et al., 2019).

It comprises phytochemicals, flavonoids, and polyphenols such as xanthones, anthocyanins, and phenolic acids (Zamarudin et al., 2023). Xanthones are among the metabolite components that are present in mangosteens and have been shown to possess anti-inflammatory activities toward wound healing. In 2019, Shafy et al. reported that the application of creams with mangosteen peel extracts (MPE) on excision wounds of rats was more effective for wound

healing than Fucidin which was used as a standard treatment. In the same year, Sombolayuk et al. observed the effects of 5% and 10% MPE cream on the wounds of mice. In their study, they analysed the diameter of the wounds, re-epithelisation (RE), granulation tissue formation (GTF), and inflammatory cell count (ICC). The results showed both concentrations of MPE cream had significantly reduced the diameter of the wound when compared to the control after day 8 post treatments. In addition, both concentrations of MPE cream significantly decreased the number of ICC and significantly increased GTF and RE in wounds, thus showing better wound-healing compared to the control.

Anti-inflammatory activities in both MPE and α-mangostin was also reported by Tatiya-aphiradee et al. (2019) in which α-Mangostin is the most abundant xanthone in the mangosteen peel. Both α-mangostin and MPE were able to suppress the expression of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-1β, and interleukin-6 (IL-1β & IL-6), as well as toll-like receptor-2 (TLR-2) in MRSA, infected wounds of mice. A decrease in TLR-2 from day 5 to day 10 promoted wound-healing in both groups due to the suppression of TNF-α, IL-1β, and IL-6 when compared to the control. TLR-2 is involved in the detection of lipoteichoic acid derived from gram-positive bacteria and causes the release of TNF-α by macrophages and mast cells (Schröder et al., 2003). Over-excretion of these cytokines leads to excessive ROS formation causing tissue damage and degradation of the extracellular matrix, which can delay the process of wound-healing (Sombolayuk et al., 2019). A study by Wathoni et al. (2020) also demonstrated that the wound-healing ability of α-mangostin was enhanced when complexed with 2-hydroxypropyl-β-cyclodextrin in hydrogel formulation. However, MPE treatment showed better wound-healing than α-mangostin treatment. It may be due to the expression of the cytokines released from wounds treated with MPE was slightly lower than in wounds treated with α-mangostin. This may be explained by the presence of other constituents such as β-mangostin and phenolic compounds in MPE that also have anti-inflammatory properties (Aizat et al., 2019).

2.4 Pomegranate *(Punica granatum)*

Punica granatum is a scientific name for pomegranate and belongs to the Punicacae family. Pomegranate fruit is categorized as a berry and contains hundreds of edible seeds surrounded by red arils. Pomegranate fruit is a rich source of sugars, vitamins B and C, β-carotene, and organic acids. In addition, its peel, flesh, and seeds also contain various bioactive compounds such as alkaloids, polyphenols, flavonoids, and anthocyanins that exhibit antioxidant, antimicrobial, anti-inflammatory, and anti-cancer activities. It is also traditionally used as a treatment for diarrhea and hemorrhoids, and also to stop gum and nose bleeds (Shaygannia et al, 2016).

Various studies have shown that pomegranate extracts have beneficial effects on the process of wound-healing. Hayouni et al. (2011) applied methanol extracts of pomegranate peel ointment on the excision wounds of guinea pigs. The results showed wounds treated with methanol extracts of pomegranate peel ointment demonstrated 83.5% healing meanwhile untreated wounds showed 43% healing on day 16. In another study, pomegranate peel extracts (PPE) can heal deep-second degree burn wounds in rats faster than the control (Ma et al., 2015). On day 21, the area of the burn wound treated with PPE (0.21 cm^2) was smaller than the control group (2.42 cm^2). Indeed, histological findings on day 14 showed the increase of collagen fibres, fibroblasts, and new granulation tissues, and inflammatory cells were decreased in wounds treated with PPE. Whereas in the control group, only a few fibroblasts and granulation tissues were found. Furthermore, Lukiswanto et al. (2019) also reported similar findings on burn wounds of albino rats that were treated with 10% whole pomegranate fruit extract that was standardised with 40% ellagic acid. It was suggested that 40% or more of ellagic acid in pomegranate extracts can support the optimal process of burn wound-healing which showed significant results in collagen formation.

The antioxidant properties of pomegranate extracts play an important role in promoting wound-healing. Hayouni et al. (2011) reported that pomegranate peel extracts exhibited strong antioxidant activity, which was comparable to known antioxidants; Trolox and BHA. Due to its antioxidant activity, it can promote wound-healing by protecting the cells and tissue from oxidative stress. Various bioactive compounds were found in the pomegranate peel extracts which may contribute to the antioxidant properties such as ellagic acid, delphinidin-3-glucoside, punicalagin A, and punicalagin B (30).

2.5 Pineapple *(Ananas comosus)*

Pineapple belongs to the family Bromeliaceae and it has become one of the major crops in Malaysia, besides banana and papaya. Its fruits are best consumed fresh or as juice, since it exhibits high sugar and moisture content that can keep the body hydrated. Pineapple fruits contain essential nutrients, minerals, and enzymes that can give health benefits when consumed. For example, vitamin B and fibre are good for digestive health, vitamin C can prevent gum disease, manganese, is a mineral that is required for the development of bones and tissue, and bromelain that can reduce redness and swelling. Furthermore, pineapple can be

used as disinfectant, anti-inflammatory, and anti-helminthic agents (Hossain et al., 2015; Sharma et al, 2024; Rahminiwati et al., 2025).

Several studies have reported that pineapple peel and pulp were widely administered as wound healing agents. A study was conducted to compare the efficiency of pineapple peel extracts and povidone-iodine on the wound of rats. The results showed pineapple peel extracts reduced the length of the wound (0.36 cm) faster than povidone-iodine (0.56 cm) after day 8. These results indicated that pineapple peel extracts were more efficient as a wound treatment than povidone-iodine, even though it is usually used as an antiseptic agent to treat the wound (Arif & Siwanto, 2017).

Similarly, in another study, the application of base cream with pineapple fruit extracts on wounds infected with MRSA rats showed almost complete healing (99.06%) at day 15 compared to control which showed 54.36% of wound-healing (Prakoso et al., 2018). The histological observation of the wound that was treated with pineapple fruit extracts showed the presence of fibroblast, an increase in collagen deposition, and predominant CD8+ infiltration in the dermal part of the skin of rats. Meanwhile, in control, it showed minimal expression of collagen deposition with severe hemorrhage and mild expression of CD8+. CD8+ plays an important role in immune defense as its function is to kill bacteria by detecting foreign antigens that are expressed by infected cells (Shepherd & McLaren, 2020).

Colletti et al. (2024) demonstrated that bromelain, a proteolytic enzyme complex derived from pineapple, modulates key inflammatory pathways by reducing pro-inflammatory mediators and promoting tissue remodeling, highlighting its therapeutic potential in enhancing wound-healing processes. Recently, Handajani et al. (2025) reported that a nanoemulgel formulation significantly accelerated healing of traumatic ulcers in a preclinical model. In another study conducted by Badriyya et al. (2020), bromelin was found to decrease the volume of exudate in inflamed wounds of mice and decrease the number of leucocytes from 4 to 6 days after the application of bromelain gel. Bromelain, which can also be found in pineapple crown leaves aids in necrotic tissue debridement and hastens the healing process with the presence of escharase. This compound remains among the primary options for burn wound treatments as well as in cases of postoperative injuries, easing patients' pain and inflammation (Chakraborty et al., 2021).

4. CONCLUSION

Wound healing is a great challenge in many health conditions, especially involving infections of the skin and the wound itself, which are the most frequent complications affecting humans and animals. Thus, the search for new wound-healing agents continues unabated. Medicinal plants have been used for a long time in wound-healing, despite the lack of scientific evidence verifying their efficacy. This review, therefore, describes the wound-healing activity of five tropical fruits in Malaysia. Extracts prepared from different parts of banana (*Musa* spp.), papaya (*C. papaya)*, mangosteen (*G. mangostana)*, pomegranate (*P. granatum)*, and pineapple (*A. comosus)* have been demonstrated to have properties that may benefit wound-healing. However, despite the success of these fruit extracts in promoting wound-healing there was little information on the specific bioactive compounds responsible, nor elucidation of their mode of action. In addition, it is difficult to hypothesize which fruit will give the best wound-healing effect. Even though experimental evidence has been acquired for each documented fruit, their studies are not comparable as their assays and models used were not standardized. We provide this data in the belief that these fruits could one day deliver novel remedies and therapy for today's therapeutic challenges.

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