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A REVIEW ON THE WOUND-HEALING AND ANTI-INFLAMMATORY ACTIVITIES OF REETHA (*Sapindus mukorossi* Gaertn.)

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ABSTRACT

Wound healing is a complex biological process involving inflammation, cell proliferation, tissue regeneration and remodelling. Prolonged inflammation and microbial contamination can interfere with normal tissue repair, creating interest in medicinal plants as potential sources of bioactive compounds for wound management. Reetha (*Sapindus mukorossi* Gaertn.), belonging to the family Sapindaceae, is traditionally known for its cleansing properties and is valued for its saponin-rich fruits. In addition to saponins, different parts of the plant contain phytochemicals that have attracted scientific interest because of their potential biological activities. The present review examines the available evidence on the wound-healing and anti-inflammatory potential of Reetha, with particular attention to its phytochemical constituents and possible mechanisms of action. Experimental investigations of Reetha seed oil have reported effects on fibroblast proliferation and migration, inflammatory responses, antimicrobial activity and wound closure in animal models. Studies of other seed-derived preparations have also explored their potential role in skin repair. These findings suggest that certain preparations of *S. mukorossi* may influence processes associated with wound healing and inflammation. However, the reported effects depend on the plant part, extraction method, formulation and experimental conditions. Findings obtained from laboratory experiments and animal models cannot be directly extrapolated to human clinical practice. Furthermore, evidence from well-designed clinical studies remains limited, and the safety and effectiveness of Reetha-based preparations for application to wounds require further investigation. This review highlights the pharmacological potential of Reetha while identifying important research gaps, including the need for phytochemical standardization, assessment of dermal safety, clarification of the underlying mechanisms and evaluation through controlled clinical studies. Such investigations may help determine whether Reetha has a meaningful role in the development of evidence-based herbal preparations for wound management.

KEYWORDS: Anti-inflammatory activity, phytochemicals, Reetha, *Sapindus mukorossi*, saponins, wound healing.

1. INTRODUCTION

Wound healing is a natural process through which the body repairs damaged tissues and restores the protective function of the skin. It involves a series of closely related events, including haemostasis, inflammation, proliferation and tissue remodelling. During these stages,

inflammatory cells remove damaged tissue and microorganisms, while fibroblasts, epithelial cells and newly formed blood vessels contribute to tissue repair. The successful completion of healing depends on the proper coordination of these processes. However, prolonged inflammation, microbial infection and other factors may interfere with normal repair and contribute to delayed or incomplete wound healing [1-11].

Inflammation plays an important role in the early stages of wound healing. It helps remove harmful microorganisms and damaged cellular material and initiates the processes required for tissue regeneration. Nevertheless, an excessive or persistent inflammatory response can damage surrounding tissues and delay the transition towards the proliferative phase. For this reason, the search for substances that may help regulate inflammation and support tissue repair has become an important area of pharmacological research. Medicinal plants are of particular interest because they contain diverse phytochemicals that may influence inflammatory responses, microbial growth and cellular activity. [12-17]



Figure 1:Plant of Sapindus mukorossi Gaertn. (Reetha) (Gannu03, n.d.)

Reetha, botanically identified as *Sapindus mukorossi* Gaertn., belongs to the family Sapindaceae and is commonly known as soapnut. The plant is widely recognized for its fruit, particularly the pericarp, which contains saponins responsible for its characteristic foaming and cleansing properties. Different parts of the plant have been investigated for their phytochemical composition and pharmacological activities. Previous reviews have described triterpenoid saponins as important constituents of *S. mukorossi*, alongside other compounds whose occurrence and concentration may vary according to the plant part and extraction method [18, 19].

Scientific interest in Reetha has expanded beyond its traditional cleansing applications. In a study published in 2019, researchers investigated the effects of *S. mukorossi* seed oil on skin wound healing using cell-based experiments and an animal model. The preparation showed effects on fibroblast proliferation and migration, reduced nitric oxide production in an experimental inflammatory model, and demonstrated antimicrobial activity under the conditions tested. Improved wound closure was also observed in treated rats [20]. A more recent investigation of Reetha seed hydrosol reported encouraging findings relating to fibroblast migration, inflammatory responses and wound closure in experimental models [21]. These studies provide a basis for further investigation, although their findings cannot establish clinical effectiveness or safety in humans.

Despite these promising experimental observations, the available evidence requires careful evaluation. Seed oil, seed hydrosol and fruit-pericarp extracts differ in composition and should not be considered equivalent preparations. Their biological effects may also depend on concentration, formulation, application method and experimental conditions. Therefore, distinguishing established findings from preliminary evidence is essential when assessing the therapeutic potential of Reetha.

The present review aims to examine the available literature on the wound-healing and anti-inflammatory activities of *Sapindus mukorossi* Gaertn., with particular emphasis on its phytochemical constituents, possible mechanisms of action and findings from experimental studies. It also considers the limitations of the current evidence, safety-related concerns and areas requiring further research to determine the potential role of Reetha in the development of scientifically evaluated herbal preparations for wound management.

2. PHYTOCHEMICAL CONSTITUENTS OF REETHA

The pharmacological properties of a medicinal plant are closely related to its chemical composition. *Sapindus mukorossi* Gaertn. contains several classes of phytochemicals, among which triterpenoid saponins are particularly important. The nature and concentration of these

constituents vary according to the plant part, geographical origin, maturity and extraction method. Understanding this variation is essential when investigating the possible wound-healing and anti-inflammatory activities of Reetha.

2.1. Triterpenoid saponins

Triterpenoid saponins are among the major phytoconstituents reported in *S. mukorossi*, particularly in its fruit pericarp. Phytochemical investigations have identified saponins belonging to different structural groups, including oleanane-, dammarane- and tirucullane-type triterpenoids [18, 22]. These compounds are known for their surface-active properties, which account for the characteristic foaming action of soapnut fruits. Saponins have also attracted pharmacological interest because certain members of this group exhibit biological activities in experimental systems. However, the presence of saponins in Reetha does not, by itself, establish that they are responsible for wound healing or anti-inflammatory effects. Such effects require investigation using isolated compounds and appropriately characterized extracts. [18, 23]

2.2. Fatty acids and Phytosterols

The seed oil of *S. mukorossi* contains a mixture of fatty acids and unsaponifiable constituents. In a study published by Chen and colleagues, gas chromatography–mass spectrometry analysis identified oleic acid and eicosenoic acid as major fatty acids in the investigated seed oil. The researchers also detected β-sitosterol and δ-tocopherol in the oil [20]. These findings are relevant because fatty acids and phytosterols may influence skin-barrier properties and biological responses associated with tissue repair. Nevertheless, their effects depend on the concentration, formulation and conditions of use, and the findings from one seed-oil preparation should not be generalized to all parts of the plant. [20, 24]

2.3. Tocopherols and other minor constituents

Tocopherols, including δ-tocopherol, have also been identified in Reetha seed oil [20]. Tocopherols are recognized for their antioxidant properties, which may be relevant to the management of oxidative processes in damaged tissues. β-Sitosterol, a plant-derived sterol, has likewise been investigated for its potential biological effects. Although these constituents provide a possible basis for further research into skin repair, their individual contributions to the wound-healing activity of Reetha have not been fully established.

2.4. Other reported phytochemicals

Phytochemical studies of *S. mukorossi* have reported additional compounds in different plant parts and preparations. The occurrence of phenolic compounds and other minor constituents may vary with the extraction procedure and analytical method. A study of seed hydrosol published in 2025 identified 1,3-bis(1,1-dimethylethyl)benzene and 2,4-di-tert-butylphenol by gas chromatography–mass spectrometry [21]. These findings relate specifically to the hydrosol examined in that investigation and should not be assumed to represent the chemical composition of the fruit pericarp or seed oil.

Table 1: Phytochemical constituents reported in different Reetha preparations

Plant part/preparation	Reported constituents or features	Relevance to the review
Fruit pericarp	Triterpenoid saponins	Characteristic foaming constituents; individual biological effects require investigation.
Seed oil	Fatty acids, β-Sitosterol, δ-tocopherol in the studied preparation	Possible relevance to skin-barrier and oxidative processes; contribution to wound repair is not established.
Seed hydrosol	Compounds identified by GC-MS in the investigated preparation	Composition is preparation specific.
Leaves and other parts	Various reported phytochemicals	Useful background for pharmacological research, but not direct evidence of wound healing.

Stem Bark and isolated fractions	Compounds investigated in anti-inflammatory and other experimental studies	Findings should not be generalized to seed or hydrosol.

Overall, the phytochemical composition of Reetha provides a basis for investigating its possible biological effects. However, the relationship between individual constituents and wound healing remains an important research question. Further studies involving standardized extracts, detailed chemical characterization and testing of individual compounds are needed to determine which constituents contribute to its reported anti-inflammatory and tissue-repair activities.

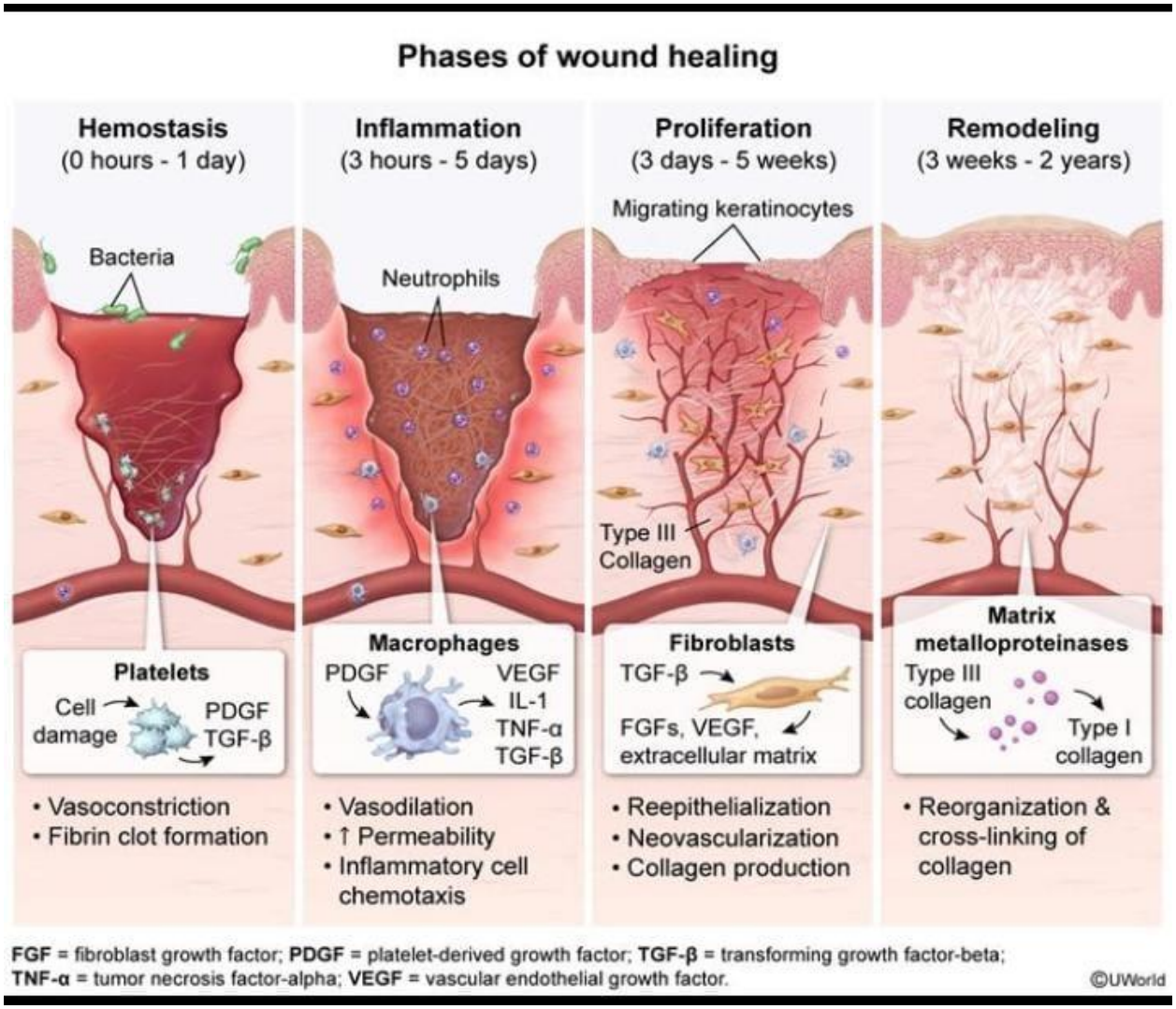

Figure 2: Major phases of the wound-healing process. **(Leukocyte Adhesion Deficiency – Allergy & Immunology, n.d.)**

3. WOUND-HEALING ACTIVITY OF REETHA (*Sapindus mukorossi* Gaertn.)

Wound healing involves a series of biological events that restore the structure and function of damaged skin. Following an injury, the body initiates haemostasis and inflammation, followed by the formation of new tissue and remodelling of the wound area. Fibroblasts play an important role in this process by producing components of the extracellular matrix and contributing to tissue repair. Migration and proliferation of skin cells are also necessary for re-epithelialization, which restores the epidermal barrier. Any substance investigated for wound-healing activity must therefore be evaluated in relation to these processes rather than on the basis of wound closure alone [1-11].

The wound-healing potential of *Sapindus mukorossi* has received scientific attention through experimental investigations of its seed-derived preparations. One of the important studies in this area was conducted by Chen and colleagues in 2019, who examined the effects

of Reetha seed oil using cell-based experiments and an animal wound model [20]. Their findings provided preliminary evidence that the tested preparation could influence cellular activities associated with tissue repair.

3.1. Effect on fibroblast proliferation and migration

Fibroblasts are important cells in wound repair because they contribute to the formation of granulation tissue and the deposition of extracellular matrix components. Their migration towards the injured area and subsequent proliferation help support tissue regeneration. In the 2019 study, Reetha seed oil was evaluated using CCD-966SK human skin fibroblast cells. The investigators reported improved cell proliferation and migration under the experimental conditions used [20]. These observations suggest that the tested seed-oil preparation may influence cellular events involved in wound repair. [6, 12-14, 16, 17, 25-27]

A further investigation published in 2025 examined Reetha seed hydrosol using cell-based assays and an animal model. The authors reported improved fibroblast survival under serum-free conditions and faster closure of the artificial gap in a scratch assay at 24 and 48 hours compared with the control [21]. Although these findings are encouraging, scratch assays provide information about cell migration and gap closure under controlled laboratory conditions; they do not reproduce the full complexity of a wound in living human skin.

3.2. Findings from experimental wound models

Animal studies provide additional information about the potential effects of preparation on the healing process. Chen and colleagues evaluated Reetha seed oil delivered through a hydrogel-based dressing in rats with experimentally created skin wounds. The treated group showed a greater reduction in wound area than the control group, with differences observed during the study period. By day 8, the remaining wound area in the treated animals was approximately half that recorded in the control animals [20]. These results support further investigation of the particular seed-oil formulation tested.

In the 2025 study, Reetha seed hydrosol was applied topically to experimentally induced wounds in rats. The authors reported that the treated wounds had smaller residual wound areas than the control wounds on day 14. Histological examination also indicated improved re-epithelialization in the treated group [21]. However, the experiment involved a small number of animals, and the findings require confirmation in larger, independently conducted studies.

3.3. Possible contribution of antimicrobial activity

Microbial contamination can complicate wound management and interfere with tissue repair. Therefore, antimicrobial activity may be relevant when evaluating a plant-derived preparation for potential wound-care applications. In the seed-oil study, Reetha seed oil showed activity against selected microorganisms, including *Staphylococcus aureus*, under laboratory conditions [20]. The seed-hydrosol investigation also reported a reduction in S. aureus colony counts following treatment [21].

These findings suggest that certain Reetha-derived preparations warrant further investigation for their antimicrobial properties. Nevertheless, laboratory antimicrobial activity does not establish that preparation can prevent or treat wound infections in patients. Its effectiveness will depend on factors such as formulation, concentration, stability, contact time and the conditions of the wound.

3.4. Interpretation and limitations of the evidence

The experimental findings available to date suggest that selected preparations of *S. mukorossi* may influence fibroblast activity, inflammatory responses, microbial growth and wound closure. However, the evidence remains preliminary and is based mainly on laboratory assays and animal studies. The seed oil and seed hydrosol also differ in their chemical composition and method of preparation, so their reported effects should be considered separately.

Further research is needed to establish the active constituents, determine appropriate concentrations, assess irritation and other dermal safety concerns, and investigate the reproducibility of the reported effects. Well-designed clinical studies will ultimately be required to determine whether Reetha-based preparations offer meaningful benefits for wound healing in humans. At present, the published

experimental findings provide a rationale for further research rather than sufficient evidence to recommend Reetha as an established wound-healing treatment.

Table 2: Experimental evidence for the wound-healing activity of Reetha

Study	Experimental model	Main findings reported	Main limitation
Chen et al. (2019), seed oil	Human skin fibroblast assays and rat wound model	Effects on fibroblast proliferation and migration, selected inflammatory and antimicrobial endpoints, and wound closure	Preclinical evidence involving a specific seed-oil formulation
Lai et al. (2025), seed hydrosol	Fibroblast assays and rat wound model	Effects on fibroblast-related responses, inflammatory assays and residual wound area	Small animal groups; independent replication and safety assessment are needed

4. Anti-Inflammatory Activity of Reetha (*Sapindus mukorossi* Gaertn.)

Inflammation is an essential component of the wound-healing process, as it helps remove damaged tissue and supports the body's initial response to injury. However, excessive or prolonged inflammation may interfere with normal tissue repair and delay wound closure. For this reason, substances that can modulate inflammatory responses are of interest in the search for potential wound-care ingredients.

Sapindus mukorossi contains several classes of phytochemicals, including triterpenoid saponins and other constituents whose biological activities have been investigated. Nevertheless, the anti-inflammatory potential of the plant should be assessed in relation to the specific plant part, preparation and experimental model, because the chemical composition of different extracts and formulations may vary [18, 22, 28, 29].

4.1. Experimental Evidence for Anti-Inflammatory Activity

Chen et al. investigated *S. mukorossi* seed oil in laboratory experiments and a rat wound model. Their study examined inflammatory responses alongside fibroblast-related activity and wound-healing outcomes. The findings provide preliminary evidence that the seed oil-based preparation may influence inflammatory processes associated with wound repair [20].

Lai et al. subsequently investigated the biological activities of *S. mukorossi* seed hydrosol, including its potential for skincare applications and its effects in experimental wound models [21]. These findings are relevant to the broader investigation of Reetha-derived preparations; however, evidence obtained using seed hydrosol should not automatically be interpreted as confirmation of the anti-inflammatory effects of seed oil or other plant extracts.

The available studies provide a basis for further research, but the strength of the evidence depends on the endpoints measured and the experimental conditions. A change in wound closure or cell behaviour alone does not establish a specific anti-inflammatory mechanism. Direct measurements of inflammatory mediators and appropriate controls are needed to clarify the nature of the response.

4.2. Possible Role of Phytochemical Constituents

Triterpenoid saponins are among the characteristic constituents of Reetha, particularly its fruit pericarp. Other plant parts may contain different combinations of lipids and minor constituents. These chemical differences are important when interpreting pharmacological findings, as an effect observed with seed oil cannot necessarily be attributed to saponins commonly associated with the fruit pericarp [18, 20, 22].

The contribution of individual constituents to the anti-inflammatory activity of Reetha remains to be established. Studies using chemically characterized extracts, isolated compounds and suitable biological assays would help determine whether the observed responses are associated with a particular constituent or arise from the combined effects of several components. [18, 23, 24, 30, 31]

4.3. Relevance to Wound Repair

The relationship between inflammation and wound healing is complex. The early inflammatory response contributes to wound defence and tissue clearance, whereas its timely resolution allows subsequent stages of repair to proceed. Therefore, potentially useful wound-care preparation should support an appropriate inflammatory response rather than indiscriminately suppress inflammation.

The reported findings for selected *S. mukorossi* preparations justify further investigation of their effects on inflammatory responses during tissue repair [20, 21]. However, the evidence currently available is insufficient to conclude that Reetha consistently reduces inflammation in human wounds or that its anti-inflammatory activity is responsible for the wound-healing effects observed in experimental models.

4.4. Limitations and Future Research

The interpretation of the anti-inflammatory potential of Reetha is limited by differences in plant material, preparation methods and experimental models. More studies are needed to measure relevant inflammatory mediators, establish dose-dependent effects and investigate the relationship between anti-inflammatory responses and tissue repair. Researchers should also evaluate cytotoxicity and dermal safety, since biological activity at one concentration does not necessarily indicate safety at another.

Future research should compare standardized preparations and identify the constituents associated with observed effects. Well-designed clinical studies would eventually be required to determine whether findings from laboratory and animal experiments translate into meaningful benefits in human wound care.

Overall, the available evidence supports further investigation of the anti-inflammatory potential of selected Reetha preparations. However, the specific compounds involved, the molecular pathways affected and the clinical significance of these findings remain to be established.

5. Proposed Mechanisms of Action of Reetha (*Sapindus mukorossi* Gaertn.)

The biological activities of *Sapindus mukorossi* Gaertn. may involve interactions between its phytochemical constituents and cellular processes associated with inflammation and tissue repair. Experimental investigations of seed oil and seed hydrosol have reported effects on nitric oxide production, fibroblast-related responses, antimicrobial activity and wound closure [20, 21]. These findings provide preliminary evidence of biological activity; however, the specific molecular targets and intracellular signalling pathways responsible for these effects remain incompletely understood.

5.1. Modulation of Inflammatory Mediators

Nitric oxide (NO) is an important signalling molecule involved in inflammation, immune defence and tissue repair. Its production may increase in activated macrophages following stimulation by lipopolysaccharide (LPS). Chen et al. and Lai et al. reported reduced NO production in LPS-stimulated RAW 264.7 macrophages following treatment with *S. mukorossi* seed oil and seed hydrosol, respectively [20, 21]. These observations suggest that the tested preparations can influence an inflammatory response under laboratory conditions.

However, reduced NO production does not establish the precise molecular target responsible for this effect. Further investigation of inducible nitric oxide synthase (iNOS), nuclear factor kappa B (NF-κB) and other inflammatory mediators is necessary to determine whether these pathways contribute to the observed response.

5.2. Effects on Cellular Processes Involved in Wound Repair

Fibroblast migration and proliferation are important for granulation tissue formation and extracellular matrix development during wound healing. Experimental studies of *S. mukorossi* seed oil and seed hydrosol have reported effects on fibroblast-related responses and wound closure [20, 21]. These findings suggest that selected preparations may influence cellular processes involved in tissue repair.

Nevertheless, the receptors, enzymes and intracellular signalling pathways responsible for these responses have not been conclusively identified. The involvement of pathways associated with cell survival, migration or extracellular matrix production should therefore be investigated rather than presented as an established mechanism of Reetha.

5.3. Possible Contribution of Phytochemical Constituents

The phytochemical composition of S. mukorossi varies according to the plant part and preparation method. Its fruit pericarp is known for triterpenoid saponins, whereas seed oil contains fatty acids and minor lipid-associated constituents, including tocopherols and phytosterols [18, 20, 22]. These compounds provide potential directions for investigating the biological activity of different Reetha preparations.

Although some of these constituents have biological activities reported in other experimental systems, their individual contributions to the wound-healing and anti-inflammatory effects of *S. mukorossi* remain uncertain. Studies using isolated compounds, chemically characterized extracts and appropriate controls are needed to identify the active constituents and their molecular targets.

5.4. Potential Role of Antimicrobial Activity

Microbial contamination can complicate wound repair and contribute to persistent inflammation. Antimicrobial activity reported for selected *S. mukorossi* preparations may therefore be relevant to their investigation as potential topical ingredients [20, 21]. However, the molecular basis of this activity and its contribution to wound closure have not been fully established. In particular, membrane disruption or other specific antimicrobial mechanisms should not be attributed to Reetha without direct experimental evidence. [26, 30, 32-38]

5.5. Overall Mechanistic Interpretation

The available findings support a preliminary model in which selected *S. mukorossi* preparations influence inflammatory mediator production and cellular responses associated with wound repair, with antimicrobial activity representing a possible additional contribution. These effects may collectively help explain the outcomes reported in experimental wound models. However, this interpretation remains provisional because the molecular targets, active constituents and relationships between individual biological effects have not been fully established.

Further research should investigate relevant inflammatory signalling pathways, fibroblast-associated molecular targets, dose-dependent effects and the contribution of individual phytochemicals. Such studies, together with standardized formulations and appropriate safety assessments, are necessary to establish the mechanism of action of *S. mukorossi* more definitively.

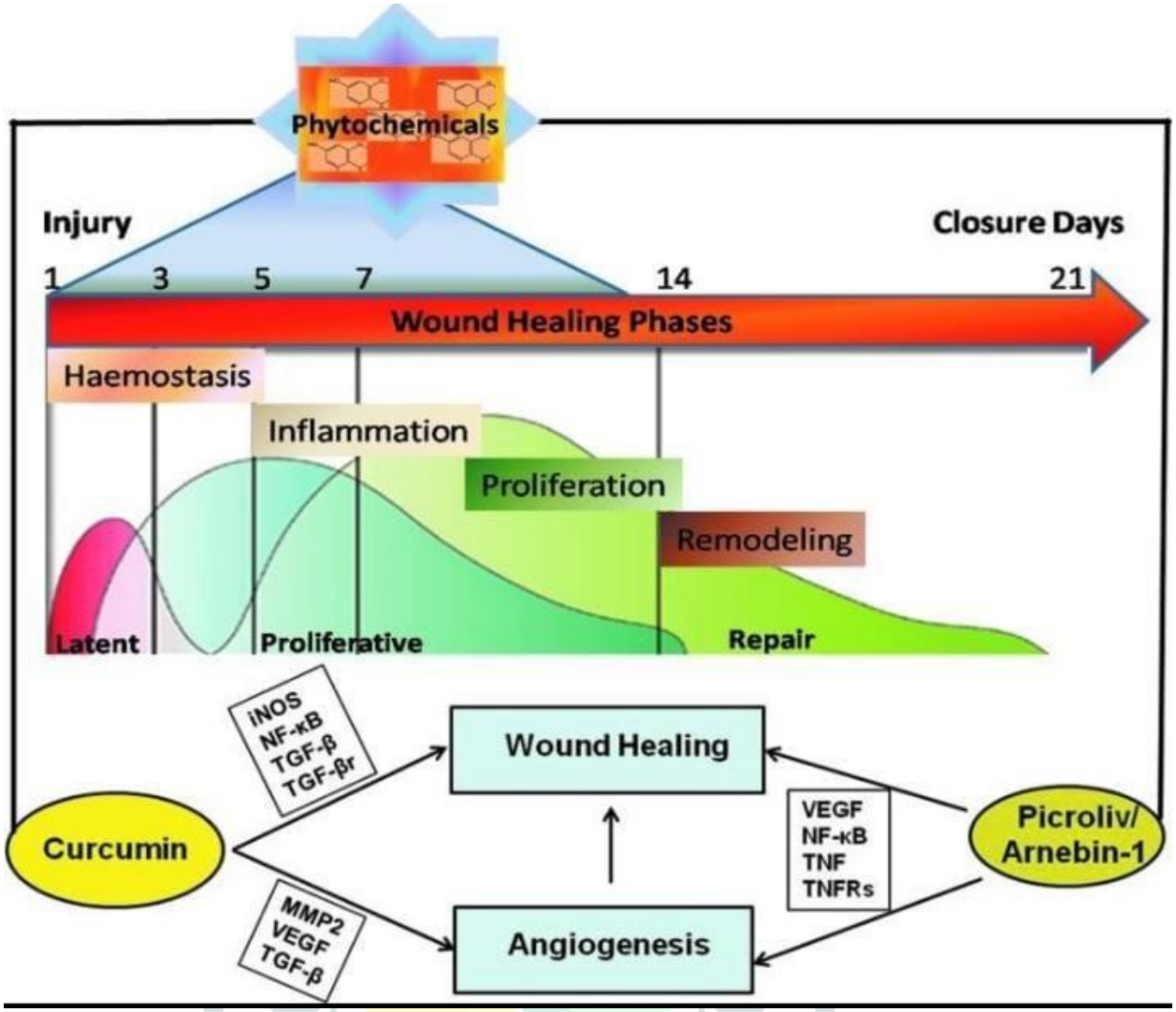

Figure 3: Proposed relationship between reported biological activities of selected Reetha preparations and wound repair. (Rajesh L. Thangapazham, Advances in Wound Care, 2016)

6. Safety and Limitations of Current Evidence

Although experimental studies have reported promising wound-healing and anti-inflammatory effects for selected preparations of *Sapindus mukorossi* Gaertn., their safety and therapeutic potential require further evaluation. The available findings are primarily derived from laboratory experiments and animal models, and evidence supporting their use in human wound care remains limited.

6.1. Safety Considerations

The safety of Reetha preparations may vary according to the plant part, extraction method, concentration and formulation. Triterpenoid saponins, which are characteristic constituents of the fruit pericarp, possess surface-active properties. Their biological effects and potential to irritate skin may depend on the specific compounds and their concentrations. Consequently, the traditional use of Reetha or its presence in cosmetic preparations should not be considered sufficient evidence of safety when applied to damaged skin. [18, 29, 39, 40]

Furthermore, results obtained using seed oil or seed hydrosol cannot automatically be generalized to fruit extracts, concentrated saponin preparations or other formulations. Assessment of skin irritation, sensitization, cytotoxicity and appropriate concentrations is necessary before any preparation can be considered suitable for wound-care applications.

6.2. Limitations of Experimental Evidence

The principal limitation of the current literature is the lack of adequate clinical evidence. In vitro studies can identify effects on particular cell types or biological endpoints, but they do not reproduce the complex environment of a human wound. Similarly, animal studies

provide preliminary information about wound closure and tissue repair but cannot independently establish clinical effectiveness. [15, 41-44]

The studies discussed in this review also use different plant-derived preparations and experimental methods. Differences in chemical composition, formulation, concentration, treatment duration and outcome measurements make direct comparisons difficult. In addition, the small sample size of some animal experiments limits the strength and generalizability of their findings.

6.3. Limitations in Phytochemical and Mechanistic Understanding

Although several phytochemical constituents of *S. mukorossi* have been reported, the compounds directly responsible for its observed wound-healing and anti-inflammatory effects remain incompletely characterized. The presence of a biologically active compound in a plant preparation does not establish that it accounts for the effects observed in an experimental model.

Similarly, the molecular mechanisms underlying the reported biological activities have not been fully elucidated. More research is required to identify relevant molecular targets, clarify dose-dependent responses and determine whether different preparations act through similar or distinct mechanisms.

6.4. Need for Standardization and Clinical Evaluation

Future studies should use authenticated plant material and standardized preparation methods, supported by detailed phytochemical characterization. Appropriate dose-response studies, dermal safety testing and adequately powered experimental designs are also needed. Comparative studies could help determine whether seed oil, seed hydrosol and fruit-derived preparations differ in their biological activities and safety profiles. [24, 45-49]

Once sufficient preclinical evidence is available, well-designed clinical studies will be necessary to evaluate tolerability, safety and effectiveness in humans. Until then, the reported wound-healing and anti-inflammatory activities of Reetha should be regarded as preliminary experimental findings rather than established therapeutic benefits.

7. Research Gaps and Future Perspectives

The available experimental evidence suggests that selected preparations of *Sapindus mukorossi* Gaertn. may have potential for further investigation in wound management. However, several research gaps must be addressed before their therapeutic value can be established. Future work should focus on phytochemical standardization, validation of biological activity, clarification of molecular mechanisms, safety assessment and clinical evaluation.

7.1. Phytochemical Standardization

The chemical composition of *S. mukorossi* varies according to the plant part, geographical origin, maturity and preparation method. Future studies should establish reproducible extraction procedures and characterize the major constituents of seed oil, seed hydrosol and fruit-derived preparations. Such standardization would improve comparability between studies and help identify compounds associated with specific biological effects.

7.2. Investigation of Molecular Mechanisms

Although experimental studies have reported effects on nitric oxide production and fibroblast-related responses, the molecular targets responsible for these findings remain incompletely understood. Further investigations should examine relevant inflammatory mediators, cellular signalling pathways and molecular targets using validated assays. Studies of isolated compounds and standardized extracts would also help distinguish the effects of individual constituents from those of complex plant preparations.

7.3. Validation of Wound-Healing Activity

The wound-healing potential of Reetha requires confirmation through reproducible experiments with appropriate controls, adequate sample sizes and clearly defined outcomes. Future studies should evaluate wound closure, re-epithelialization, granulation tissue

formation, collagen organization and relevant inflammatory responses. Where appropriate, different wound models should be used to determine whether observed effects are consistent across experimental conditions. [25, 27, 43, 44, 49, 50]

7.4. Formulation Development and Safety Assessment

The development of topical formulations may improve the stability, application and delivery of selected Reetha preparations. However, formulation studies should consider chemical stability, concentration, release characteristics and compatibility with skin cells. Comprehensive safety testing should include cytotoxicity, skin irritation and sensitization, particularly when preparations are intended for application to damaged skin. [45-49]

7.5. Need for Clinical Studies

Most current findings are based on laboratory experiments and animal models. Well-designed clinical studies are therefore needed to establish whether the reported biological effects translate into meaningful benefits for people with wounds. Such studies should use standardized formulations, appropriate comparison groups, predefined outcome measures and systematic safety monitoring. [41, 47]

Overall, further research integrating phytochemistry, mechanistic biology, formulation science and clinical evaluation is necessary to determine the potential role of *S. mukorossi* in evidence-based wound management. Addressing these gaps would help distinguish promising experimental observations from effects that are reproducible, safe and clinically meaningful.

Review approach: This article is a narrative review of published literature on Reetha phytochemistry, experimental wound-healing and anti-inflammatory activity, antimicrobial findings, and safety. A formal systematic-review protocol was not undertaken; conclusions are therefore limited to the studies discussed and their reported methods and outcomes.

8. OBSERVATIONS AND FINDINGS

The literature reviewed indicates that evidence directly relevant to wound healing is concentrated in two experimental studies of seed-derived preparations: seed oil and seed hydrosol. Other studies provide supporting context on phytochemistry, antimicrobial activity, anti-inflammatory effects and toxicity, but they use different plant parts, extracts, biological systems or endpoints. The findings should therefore be interpreted as preparation-specific and preclinical.

9. RECOMMENDATIONS

Future investigations should authenticate plant material, standardize extraction and formulation, report chemical profiles and dose-response relationships, and assess cytocompatibility, irritation, sensitization and systemic exposure where appropriate. Mechanistic studies should measure relevant inflammatory and repair endpoints directly. Clinical evaluation should proceed only after adequate reproducibility and dermal safety have been established.

10. CONCLUSION

Sapindus mukorossi Gaertn. (Reetha) is a medicinal plant containing diverse phytochemical constituents that have attracted interest in their potential biological activities. Experimental studies of selected seed-derived preparations have reported effects on fibroblast-related responses, inflammatory mediator production, antimicrobial activity and wound closure. These findings suggest that certain Reetha preparations may influence biological processes associated with wound repair.

However, the available evidence is predominantly based on in vitro experiments and animal models. The active constituents, precise molecular mechanisms, appropriate formulations and safety profiles require further investigation. The effects observed with one plant part or preparation should not be generalized to all Reetha products, and clinical effectiveness in human wound management has not yet been established.

Further research involving standardized preparations, detailed mechanistic studies, comprehensive dermal safety assessment and well-designed clinical trials is necessary to determine the therapeutic potential of Reetha. Such evidence would help establish whether selected *S. mukorossi* preparations can contribute to safe, reproducible and evidence-based herbal approaches to wound management.

REFERENCES

[1] Broughton G 2nd, Janis JE, Attinger CE. The basic science of wound healing. Plast Reconstr Surg. 2006;117(7 Suppl):12S-34S. doi:10.1097/01.prs.0000225430.42531.c2.

[2] Gurtner GC, Werner S, Barrandon Y, Longaker MT. Wound repair and regeneration. Nature. 2008;453(7193):314-321. doi:10.1038/nature07039.

[3] Guo S, DiPietro LA. Factors affecting wound healing. J Dent Res. 2010;89(3):219-229. doi:10.1177/0022034509359125.

[4] Martin P. Wound healing—aiming for perfect skin regeneration. Science. 1997;276(5309):75-81. doi:10.1038/s41580-024-00715-1

[5] Peña OA, Martin P. Cellular and molecular mechanisms of skin wound healing. Nat Rev Mol Cell Biol. 2024;25(8):599-616. doi:10.1038/s41580-024-00715-1.

[6] Rittié L. Cellular mechanisms of skin repair in humans and other mammals. J Cell Commun Signal. 2016;10(2):103-120. doi:10.1007/s12079-016-0330-1.

[7] Rodrigues M, Kosaric N, Bonham CA, Gurtner GC. Wound healing: a cellular perspective. Physiol Rev. 2019;99(1):665-706. doi:10.1152/physrev.00067.2017.

[8] Velnar T, Bailey T, Smrkolj V. The wound healing process: an overview of the cellular and molecular mechanisms. J Int Med Res. 2009;37(5):1528-1542. doi:10.1177/147323000903700531.

[9] Wallace HA, Basehore BM, Zito PM. Wound healing phases. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470443/.

[10] Winter GD. Formation of the scab and the rate of epithelialization of superficial wounds in the skin of the young domestic pig. Nature. 1962;193:293-294. doi:10.1038/193293a0.

[11] Witte MB, Barbul A. General principles of wound healing. Surg Clin North Am. 1997;77(3):509-528. doi:10.1016/S0039-6109(05)70566-1.

[12] Barrientos S, Stojadinovic O, Golinko MS, Brem H, Tomic-Canic M. Growth factors and cytokines in wound healing. Wound Repair Regen. 2008;16(5):585-601. doi:10.1111/j.1524-475X.2008.00410.x.

[13] Eming SA, Martin P, Tomic-Canic M. Wound repair and regeneration: mechanisms, signaling, and translation. Sci Transl Med. 2014;6(265):265sr6. doi:10.1126/scitranslmed.3009337.

[14] Landén NX, Li D, Ståhle M. Transition from inflammation to proliferation: a critical step during wound healing. Cell Mol Life Sci. 2016;73(20):3861-3885. doi:10.1007/s00018-016-2268-0.

[15] Sen CK, Gordillo GM, Roy S, Kirsner R, Lambert L, Hunt TK, et al. Human skin wounds: a major and snowballing threat to public health and the economy. Wound Repair Regen. 2009;17(6):763-771. doi:10.1111/j.1524-475X.2009.00543.x.

[16] Sorg H, Tilkorn DJ, Hager S, Hauser J, Mirastschijski U. Skin wound healing: an update on the current knowledge and concepts. Eur Surg Res. 2017;58(1-2):81-94. doi:10.1159/000454919.

[17] Wilkinson HN, Hardman MJ. Wound healing: cellular mechanisms and pathological outcomes. Open Biol. 2020;10(9):200223. doi:10.1098/rsob.200223.

[18] Sochacki M, Vogt O. Triterpenoid saponins from washnut (Sapindus mukorossi Gaertn.)—a source of natural surfactants and other active components. Plants (Basel). 2022;11(18):2355. doi:10.3390/plants11182355.

[19] Upadhyay A, Singh DK. Pharmacological effects of Sapindus mukorossi. Rev Inst Med Trop Sao Paulo. 2012;54(5):273-280. doi:10.1590/S0036-46652012000500007.

[20] Chen CC, Nien CJ, Chen LG, Huang KY, Chang WJ, Huang HM. Effects of Sapindus mukorossi seed oil on skin wound healing: in vivo and in vitro testing. Int J Mol Sci. 2019;20(10):2579. doi:10.3390/ijms20102579.

[21] Lai HY, Lu YCC, Fan KH, Virgirinia RP, Prasetyaningrum N, Nugraeni Y, et al. Investigating the biological activities of Sapindus mukorossi seed hydrosol and its potential as a skincare ingredient. Sci Rep. 2025;15:42801. doi:10.1038/s41598-025-27030-9.

[22] Huang HC, Wu MD, Tsai WJ, Liao SC, Liaw CC, Hsu LC, et al. Triterpenoid saponins from the fruits and galls of Sapindus mukorossi. Phytochemistry. 2008;69(7):1609-1616. doi:10.1016/j.phytochem.2007.10.033.

[23] Kuo YH, Huang HC, Kuo LM, et al. New dammarane-type saponins from the galls of Sapindus mukorossi. J Agric Food Chem. 2005;53(12):4722-4727. doi:10.1021/jf047963s.

[24] Wei MP, Qiu JD, Li L, Xie YF, Yu H, Guo YH, Yao WR. Saponin fraction from Sapindus mukorossi Gaertn as a novel cosmetic additive: extraction, biological evaluation, analysis of anti-acne mechanism and toxicity prediction. J Ethnopharmacol. 2021;268:113552. doi:10.1016/j.jep.2020.113552.

[25] Caley MP, Martins VL, O'Toole EA. Metalloproteinases and wound healing. Adv Wound Care (New Rochelle). 2015;4(4):225-234. doi:10.1089/wound.2014.0581.

[26] Edwards R, Harding KG. Bacteria and wound healing. Curr Opin Infect Dis. 2004;17(2):91-96. doi:10.1097/00001432-200404000-00004.

[27] Xue M, Jackson CJ. Extracellular matrix reorganization during wound healing and its impact on abnormal scarring. Adv Wound Care (New Rochelle). 2015;4(3):119-136. doi:10.1089/wound.2013.0485.

[28] Shah M, Parveen Z, Khan MR. Evaluation of antioxidant, anti-inflammatory, analgesic and antipyretic activities of the stem bark of Sapindus mukorossi. BMC Complement Altern Med. 2017;17:526. doi:10.1186/s12906-017-2042-3.

[29] Takagi K, Park EH, Kato H. Anti-inflammatory activities of hederagenin and crude saponin isolated from Sapindus mukorossi Gaertn. Chem Pharm Bull (Tokyo). 1980;28(4):1183-1188. doi:10.1248/cpb.28.1183.

[30] Kora AJ. Antibacterial and antioxidant activities of aqueous extract of soapnuts (Sapindus mukorossi). Curr Trends Biotechnol Pharm. 2020;14(4):388-395. doi:10.5530/ctbp.2020.4.40.

[31] Singh R, Kumari N. Comparative determination of phytochemicals and antioxidant activity from leaf and fruit of Sapindus mukorossi Gaertn.—a valuable medicinal tree. Ind Crops Prod. 2015;73:1-8. doi:10.1016/j.indcrop.2015.04.012.

[32] Bowler PG, Duerden BI, Armstrong DG. Wound microbiology and associated approaches to wound management. Clin Microbiol Rev. 2001;14(2):244-269. doi:10.1128/CMR.14.2.244-269.2001.

[33] Church D, Elsayed S, Reid O, Winston B, Lindsay R. Burn wound infections. Clin Microbiol Rev. 2006;19(2):403-434. doi:10.1128/CMR.19.2.403-434.2006.

[34] Mert Eren M, Dikmen B, Vatansever C, Servi H, Caner Yegin H, Ozan G. Antimicrobial activity of Sapindus mukorossi and Saponaria officinalis extracts on Streptococcus mutans and Enterococcus faecalis. Ann Med Res. 2021;28(3):516-519.

[35] Percival SL, McCarty SM, Lipsky B. Biofilms and wounds: an overview of the evidence. Adv Wound Care (New Rochelle). 2015;4(7):373-381. doi:10.1089/wound.2014.0557.

[36] Porsche FM, Molitor D, Beyer M, Charton S, André C, Kollar A. Antifungal activity of saponins from the fruit pericarp of Sapindus mukorossi against Venturia inaequalis and Botrytis cinerea. Plant Dis. 2018;102(5):991-1000. doi:10.1094/PDIS-06-17-0906-RE.

[37] Reddy DRS, Mallika D, Reddy GD, Murthy YLN. Phytochemical and antimicrobial activities of the soapnut saponin and its derivatives from Sapindus mukurossi. Asian J Chem. 2010;22(7):5399-5403.

[38] Singh R, Kumari N, Nath G. Free radical scavenging activity and antimicrobial potential of leaf and fruit extracts of Sapindus mukorossi Gaertn. against clinical pathogens. Int J Phytomedicine. 2016;8(1):22-28. doi:10.5138/ijpm.v8i1.1770.

[39] Park EH. Toxicity and hemolytic activity of saponin isolated from Sapindus mukorossi. Yakhak Hoeji. 1995;39(2):137-140.

[40] Singh R, Sharma R, Mal G, Varshney R. A comparative analysis of saponin-enriched fraction from Silene vulgaris, Sapindus mukorossi and Chlorophytum borivilianum: an in vitro hemolytic and cytotoxicity evaluation. Anim Biotechnol. 2022;33(1):193-199. doi:10.1080/10495398.2020.1775627.

[41] Ahmed LA, Hussain A, Barbhuiya PA, Zaman S, Laskar AM, Pathak MP, et al. Herbal medicine for the management of wounds: a systematic review of clinical studies. Infect Disord Drug Targets. 2025;25(5):e18715265320593. doi:10.2174/0118715265320593241007095952.

[42] Falanga V. Wound healing and its impairment in the diabetic foot. Lancet. 2005;366(9498):1736-1743. doi:10.1016/S0140-6736(05)67700-8.

[43] Frykberg RG, Banks J. Challenges in the treatment of chronic wounds. Adv Wound Care (New Rochelle). 2015;4(9):560-582. doi:10.1089/wound.2015.0635

[44] Singer AJ. Healing mechanisms in cutaneous wounds: tipping the balance. Tissue Eng Part B Rev. 2022;28(5):1151-1167. doi:10.1089/ten.TEB.2021.0114

[45] Boateng JS, Matthews KH, Stevens HNE, Eccleston GM. Wound healing dressings and drug delivery systems: a review. J Pharm Sci. 2008;97(8):2892-2923. doi:10.1002/jps.21210

[46] Dhivya S, Padma VV, Santhini E. Wound dressings—a review. Biomedicine (Taipei). 2015;5(4):22. doi:10.7603/s40819-015-0022-9

[47] Pereira RF, Bártolo PJ. Traditional therapies for skin wound healing. Adv Wound Care (New Rochelle). 2016;5(5):208-229. doi:10.1089/wound.2013.0506

[48] Schultz GS, Sibbald RG, Falanga V, Ayello EA, Dowsett C, Harding K, et al. Wound bed preparation: a systematic approach to wound management. Wound Repair Regen. 2003;11 Suppl 1:S1-S28. doi:10.1046/j.1524-475X.11.s2.1.x

[49] Tottoli EM, Dorati R, Genta I, Chiesa E, Pisani S, Conti B. Skin wound healing process and new emerging technologies for skin wound care and regeneration. Pharmaceutics. 2020;12(8):735. doi:10.3390/pharmaceutics12080735

[50] Al Mamun AA. Recent advances in molecular mechanisms of skin wound healing and its treatments. Front Immunol. 2024;15:1395479. doi:10.3389/fimmu.2024.1395479