



# The Therapeutic Potential of *Borassus flabellifer* in Oral Mucosal Regeneration and Repair: A Review

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**Abstract:** The oral mucosa is a vital component of the human body, forming the moist lining of the oral cavity and acting as the first barrier against physical, chemical, and microbial insults. Oral mucosal injuries are among the most common conditions in dental practice and may result from mechanical trauma, infections, systemic diseases, or iatrogenic factors. In physically active individuals and athletes, the risk of orofacial injury is significantly higher due to repeated exposure to impact and mechanical stress. *Borassus flabellifer*, a tropical plant widely used in traditional medicine, has gained attention due to its rich phytochemical content, including flavonoids, polyphenols, and saponins. To evaluate the regenerative potential of *Borassus flabellifer* as a therapeutic agent for oral mucosal wound healing based on available scientific evidence. A structured literature search was conducted across PubMed, ScienceDirect, and Google Scholar using Boolean search strategies based on the PICO framework. Studies published between 2016 and 2026 were screened according to predefined inclusion criteria. Results: A total of 5 eligible studies were identified and included in this review. The findings consistently demonstrated that *Borassus flabellifer* exhibits anti-inflammatory and antioxidant properties, which are key mechanisms in promoting wound healing. These studies reported enhanced tissue regeneration, reduced inflammation, and improved healing outcomes associated with its phytochemical constituents. *Borassus flabellifer* shows promising potential as a natural therapeutic agent for oral mucosal wound healing. Its bioactive compounds support its development as a topical treatment; however, further clinical studies are needed to confirm its efficacy and safety.

**Keywords:** *Borassus Flabellifer*, Wound Healing, Oral Mucosa, Regeneration, Repair

## Introduction

The oral mucosa is an essential component of the human body, forming the moist lining of the oral cavity and serving as the first barrier against physical, chemical, and microbial insults (Şenel, 2021). This tissue plays a crucial role in maintaining local homeostasis, providing protection, sensation, and facilitating wound repair. It consists of stratified epithelial layers supported by connective tissue that safeguard underlying muscles, blood vessels, and nerves. An oral mucosal wound is defined as a disruption of the integrity and normal function of the mucosa, which can be caused by trauma, chemical irritation, infections, or surgical procedures (Chen et al., 2025). Although the oral mucosa demonstrates rapid regenerative capacity, wound healing remains a complex and tightly regulated biological process involving hemostasis, inflammation, proliferation, and remodeling (Toma et al., 2021).

Oral mucosal injuries are highly prevalent in dental practice and significantly affect oral function and patient quality of life (Phore & Panchal, 2018). The burden is particularly pronounced in physically active individuals and athletes, where repeated exposure to impact and mechanical stress increases the risk of orofacial injuries (de Oliveira et al., 2021). Sports-related oral mucosal injuries, including lacerations, abrasions, and ulcerations, can impair essential oral functions such as mastication and speech, and may delay return-to-play time (Bousché et al., 2026). Additionally, orofacial trauma represents a frequent condition among elite athletes, particularly in contact sports, with significant implications for their oral health and sports performance (Campana Zamudio et al., 2025).

Oral lesions are commonly associated with substantial pain and may disrupt normal oral activities such as mastication, speech, and swallowing. Although treatment strategies mainly focus on symptom control and the promotion of tissue healing, their effectiveness remains limited, and they may be associated with adverse effects (Albakri et al., 2024). Current treatment of oral mucosal wounds commonly includes the use of topical antiseptics, anti-inflammatory agents, and supportive therapies. Although these interventions are effective in controlling infection and alleviating symptoms, they present several limitations, such as mucosal irritation, inadequate stimulation of tissue regeneration, and potential adverse effects (Pan et al., 2024).

This limitation highlights a critical research gap, namely the lack of therapeutic agents that can simultaneously promote rapid tissue regeneration, reduce inflammation, and ensure biocompatibility. Natural extracts have been used for medicinal purposes throughout history, as they contain bioactive compounds capable of producing pharmacological effects. *Borassus flabellifer*, known as the Palmyrah palm, is prevalent in South Asia, with significant populations in northern Sri Lanka and the Tamil Nadu region of southern India (Thevamirtha et al., 2023). *Borassus flabellifer*, a tropical plant widely used in traditional medicine, has attracted interest due to its rich phytochemical composition, including flavonoids, polyphenols, and saponins. These bioactive constituents are associated with antioxidant, anti-inflammatory, and wound-healing activities, suggesting

its potential role in tissue regeneration. Various parts of the plant have been reported to contain bioactive constituents, including flavonoids, polyphenols, and saponins, which contribute to its antioxidant and anti-inflammatory effects (Tunit et al., 2022).

Therefore, the novelty of this study lies in providing a systematic and focused synthesis of the available evidence on the regenerative potential of *Borassus flabellifer* for oral mucosal wound healing. The significance of this study is to bridge the existing knowledge gap and support the development of safe, natural, and effective therapeutic strategies that may enhance healing outcomes, particularly in populations with a high risk of oral mucosal injury.

## Methodology

In this study, the researchers applied the Population, Concept, and Context (PCC) framework. The focused question was: 'What is the therapeutic potential of *Borassus flabellifer* in wound healing?'. A systematic search was conducted across electronic databases, including PubMed, ScienceDirect, and Google Scholar, using a Boolean operator approach to retrieve relevant articles. The search query used was (Borassus flabellifer) AND ((wound healing) OR (tissue repair) OR (regeneration) OR (healing acceleration)). In addition to the electronic search, a manual search was also conducted. Limitations were applied to the publication period and language. The inclusion criteria consisted of freely accessible full text articles in English, available through the Universitas Negeri Surabaya IP address, with publications restricted to the period from 2016 to 2026.

The review included articles that met the following criteria: original studies examining the methods of utilizing *Borassus flabellifer* as a therapeutic agent to promote the wound healing process. Review articles, short communications, editorial notes, protocols, and recommendations were excluded from the analysis. Only experimental and observational studies published in English were included. Additionally, duplicate studies were removed and not considered in the final analysis. Wound healing and *Borassus flabellifer* as well as any additional therapies involving tissue engineering, were included in the research as study factors or exposures. Restrictions were applied regarding both publication period and language. The inclusion criteria comprised freely available full-text articles in English that were accessible through Universitas Negeri Surabaya's IP address, with the publication timeframe limited to studies published between 2016 and 2026. The most recent search was conducted in March 2026.

Two reviewers (S.M.R and C.H) independently performed the electronic literature search and study selection. Any discrepancies were resolved through discussion or by involving additional reviewers (D.S.H and N.H). Both reviewers (S.M.R and C.H) also conducted duplicate screening, data extraction, and data summarization using a standardized and pre-validated form in Microsoft Excel. The reviewers (S.M.R and C.H) independently performed critical evaluations utilising JBI critical evaluation tools. Figure 1 depicts the flow diagram of the study selection process. Information related to study methodology, participant criteria, study duration, and types of investigations was extracted

from each article. The findings from all studies were then independently organized into tables using predetermined data collection forms by both investigators

## Result and Discussion

The initial search was conducted across PubMed, ScienceDirect, and Google Scholar, yielding 385 potentially relevant articles based on the selected keywords. Following the removal of duplicate records and screening for full-text eligibility in accordance with the inclusion criteria, 380 articles were excluded for specified reasons, leaving 5 studies for further evaluation and analysis. The included studies were summarized based on: (a) author(s) and year of publication, (b) study design and subject characteristics, (c) type of *Borassus flabellifer* material used, (d) methods and variables assessed, (e) outcomes (mean  $\pm$  SD), and (f) conclusions. A descriptive summary of the characteristics of the included articles is presented in Table 1.

The methodological quality of the included studies was generally moderate to high. None of the included studies reported the use of randomization or blinding procedures, indicating a potential risk of bias. However, most studies employed valid and standardized laboratory methods, including biochemical assays and instrumental analyses, ensuring the reliability of outcome measurements. Overall, the evidence was primarily derived from in vitro and experimental studies with limited methodological rigor in bias control. The assessment of the risk of bias and quality can be detailed in (Table 2).

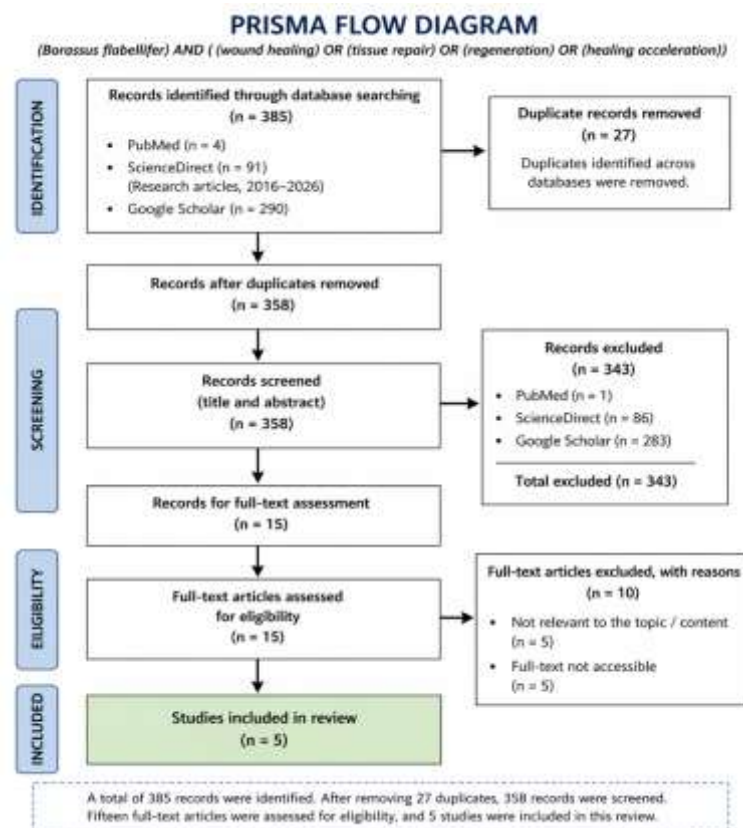


Figure 1. PRISMA 2020 flow diagram illustrating the study selection process.

**Table 1.** Summary of descriptive characteristic of articles included in the present study

Author, Year.	Type of Study and Subject	Type of <i>Borassus flabellifer</i> materials	Examination and Variables	Outcome (Mean±SD)	Conclusion
(Malayil et al., 2022)	True experimental ( <i>In vitro</i> ), Murine macrophages (Raw 264.7)	<i>Borassus flabellifer</i> haustorium extract (10, 25, and 50 mg/mL)	Inflammatory marker : IL-1 $\beta$ , IL-6, and TNF- $\alpha$ , and NO	IL-1 $\beta$ (pg/mg protein): 371.0 $\pm$ 46.4 (10 mg/mL); 284.1 $\pm$ 51.5 (25 mg/mL); 219.5 $\pm$ 44.6 (50 mg/mL) IL-6 (pg/mg protein): 1237.6 $\pm$ 117.8 (10 mg/mL); 1063.2 $\pm$ 112.9 (25 mg/mL); 956.8 $\pm$ 107.0 (50 mg/mL) TNF- $\alpha$ (pg/mg protein): 11514.0 $\pm$ 143.2 (10 mg/mL); 1374.5 $\pm$ 138.6 (25 mg/mL); 1218.6 $\pm$ 106.5 (50 mg/mL) NO (mM/mg protein) : 89.7 $\pm$ 7.2 (10 mg/mL); 76.3 $\pm$ 9.5 (25 mg/mL); 61.0 $\pm$ 7.2 (50 mg/mL)	The <i>Borassus flabellifer</i> extract modulates inflammatory pathways by inhibiting cytokine production and reducing nitric oxide synthesis.
(Tunit et al., 2022)	True experimental ( <i>In vitro</i> ), 0.2 mL of egg albumin	<i>Borassus flabellifer</i> male flower ethanolic extract (0.25, 0.5, 1, 2, and 4 mg/mL)	Albumin denaturation assay : % inhibition	The <i>Borassus flabellifer</i> male flower ethanolic extract at 250, 500, and 1000 $\mu$ g/mL inhibited albumin denaturation of 47.55 $\pm$ 1.30, 47.79 $\pm$ 3.53, and 27.40 $\pm$ 5.08%, respectively.	At concentrations of 250 and 500 $\mu$ g/mL, the <i>Borassus flabellifer</i> extract exhibited anti-inflammatory effects by inhibiting albumin denaturation.
(Mariselvam et al., 2021)	Quasi experimental ( <i>In vivo</i> ), Rabbit, 15-mm full thickness portion of skin from dorsal thoracic central region of the back	<i>Borassus flabellifer</i> leaf extract and Cetrimide 0.5% (Control)	Wound area (mm)	Wound area in day 1: 15 mm ( <i>Borassus flabellifer</i> leaf extract and Cetrimide 0.5%) Wound area in day 5: 13 mm ( <i>Borassus flabellifer</i> leaf extract); and 12 mm (Cetrimide 0.5%) Wound area in day 10: 2 mm ( <i>Borassus flabellifer</i> leaf extract); and 3 mm (Cetrimide 0.5%) Wound area in day 12: 0 mm ( <i>Borassus</i>	The extract derived from palm leaf secretions demonstrated significantly greater wound-healing effects in the treated group compared to the untreated control group.

Author, Year.	Type of Study and Subject	Type of <i>Borassus flabellifer</i> materials	Examination and Variables	Outcome (Mean±SD)	Conclusion
(Jamkhande et al., 2016)	True experimental ( <i>In vitro</i> )	<i>Borassus flabellifer</i> leaf extract (20, 40, 60, 80, 100 µg/ml)	DPPH radical scavenging activity : % inhibition and IC50 (µg/ml)	<i>flabellifer</i> leaf extract); and 1 mm (Cetrimide 0.5% ) % inhibition : 42.01 ± 0.58 (20 µg/ml), 47.92 ± 0.00 (40 µg/ml), 59.76 ± 0.00 (60 µg/ml), 68.04 ± 0.02 (80 µg/ml), and 72.18 ± 0.57 (100 µg/ml) IC50 : 40.19 µg/ml	The methanol extract of <i>Borassus flabellifer</i> leaf possesses an interesting antioxidant activity
(Basava Prasad et al., 2022)	True experimental ( <i>In vitro</i> )	Palmyra haustorium powder (PHP), Palmyra haustorium milk (PHM), and powder derived from the extracted cake of Palmyra haustorium milk (PHMCP).	DPPH radical scavenging activity : % inhibition	PHP sample : 72.86% PHM sample : 53.55% PHMCP sample : 68.95%,	The phenolic constituents present in the PH samples are capable of neutralizing free radicals and exhibit enhanced antioxidant activity.

Table 2. Risk of bias assessment according to JBI critical appraisal

Author, Year.	Study Design	Randomization	Binding	Sample Adequate	Outcome Measurement Valid	Statistical Analysis	Risk of Bias
(Malayil et al., 2022)	<i>In vitro</i>	No	No	Yes	Yes	Yes	Moderate-High
(Tunit et al., 2022)	<i>In vitro</i>	No.	No.	Yes	Yes	Yes	Moderate-High
(Mariselvam et al., 2021)	<i>In vivo</i>	No.	No.	Unclear	Yes	Unclear	Moderate
(Jamkhande et al., 2016)	<i>In vitro</i>	No.	No.	Yes	Yes	Yes	Moderate-High
(Basava Prasad et al., 2022)	Experimental	No.	No.	Yes	Yes	Yes	Moderate-High

## Discussion

This review aimed to provide a summary of existing research on the regeneration possibility of *Borassus flabellifer* as biomaterial to stimulate the regeneration of oral mucosa wound healing. Overall, this comprehensive analysis suggests that *Borassus flabellifer* has potential in promoting the regeneration and healing of oral mucosal wounds.

The included studies consistently demonstrate that *Borassus flabellifer* exhibits significant biological activities relevant to tissue repair, particularly through its antioxidant and anti-inflammatory properties. Across the in vitro studies, extracts derived from different plant parts—including haustorium, male flower, leaves, and palmyra seed derivatives—showed a consistent ability to modulate key inflammatory and oxidative pathways. For instance, haustorium extract significantly reduced pro-inflammatory mediators such as IL-1 $\beta$ , IL-6, TNF- $\alpha$ , and nitric oxide in macrophage cells, indicating a strong anti-inflammatory effect (Malayil et al., 2022). Similarly, male flower extract demonstrated dose-dependent inhibition of albumin denaturation, supporting its anti-inflammatory potential (Tunit et al., 2022). In addition, antioxidant activity was consistently observed across studies using DPPH assays, with high radical scavenging activity reported in both leaf extracts and palmyra haustorium-derived products (Jamkhande et al., 2016 ; (Basava Prasad et al., 2022)

Despite these consistent patterns, notable differences exist among the included studies in terms of experimental design, plant part used, and outcome measures. The majority of studies employed in vitro models focusing on biochemical and molecular assays, whereas only one study utilized an in vivo model to directly assess wound healing outcomes (Mariselvam et al., 2021). This in vivo study demonstrated accelerated wound closure in rabbits treated with *Borassus flabellifer* leaf extract compared to controls, providing more direct evidence of its regenerative potential. Furthermore, variations in extract type and concentration influenced the magnitude of biological effects, with higher concentrations generally associated with enhanced anti-inflammatory and antioxidant responses (Tunit et al., 2022; Jamkhande et al., 2016). The heterogeneity in methodologies and outcome measures limits direct comparability across studies.

From a clinical perspective, these findings suggest that *Borassus flabellifer* holds promise as a natural therapeutic agent for wound healing, particularly in oral mucosal applications. Its combined antioxidant and anti-inflammatory properties may contribute to enhanced tissue regeneration, reduced inflammatory response, and improved healing outcomes (Mariselvam et al., 2021). However, the predominance of in vitro evidence and the limited availability of in vivo studies indicate that current findings remain preliminary. Further well-designed in vivo and clinical studies are required to validate its efficacy, determine optimal formulations, and ensure safety for clinical application.

Palm plants are important sources of edible items and other nutritious value-added compounds; various parts of these plants include fruit, kernel juice, tender water, and haustorium (E et al., 2024). *Borassus flabellifer* contains a range of bioactive compounds such as flavonoids, phenolic compounds, tannins, and saponins, which have been consistently

identified through phytochemical screening of different plant parts such as fruit pulp, seed coat, and other extracts (Basava Prasad et al., 2022). *Borassus flabellifer* contains bioactive phenolic compounds, including gallic acid, chlorogenic acid, caffeic acid, and rutin, which are known to exhibit strong biological activities associated with the wound-healing process (Basava Prasad et al., 2022). These compounds are well-recognized for their potent biological activities, including antioxidative and anti-inflammatory effects (Tunit et al., 2022).

Gallic acid acts as a potent free radical scavenger, reducing oxidative stress and upregulating the expression of antioxidant genes such as SOD2, CAT, and GPx1. In addition, gallic acid promotes fibroblast migration and angiogenesis, thereby accelerating granulation tissue formation and wound closure (Liu et al., 2022). Caffeic acid exhibits similar effects, with the added antimicrobial activity that can protect wounds from infection. This compound suppresses inflammatory mediators, maintains nitric oxide balance, and supports collagen synthesis as well as fibroblast migration, which are essential for new tissue formation (Zhang et al., 2024). Rutin, a flavonoid glycoside, reduces oxidative stress through activation of the Nrf2 pathway, suppresses pro-inflammatory cytokines and MMP expression, and enhances collagen production and epithelialization (Naseeb et al., 2023).

Uncontrolled inflammation is a major factor that delays oral mucosal wound healing (Chuhuaicura et al., 2025). Uncontrolled inflammation in the oral cavity arises when the normal immune response to microbial and mechanical challenges fails to resolve and instead persists, leading to chronic tissue damage. One of the primary triggers is biofilm accumulation and plaque-induced gingival inflammation, where bacterial dysbiosis at the gingival margin continually stimulates inflammatory mediators, preventing resolution of the inflammatory response and promoting conditions such as gingivitis and periodontitis in athletes (plaque biofilm dysbiosis and host immune imbalance). In elite athletes, high prevalence rates of gingival and periodontal inflammation have been documented, partly due to insufficient oral hygiene behaviors, frequent intake of carbohydrate-rich sports nutrition, and reduced protective salivary flow from mouth breathing and fluid loss during intense exercise, all of which exacerbate local inflammation and microbial challenge (Merle et al., 2022). Moreover, physical stress from intensive training can influence systemic and local immune responses: competitive exercise transiently increases pro-inflammatory cytokines such as CRP, IL-1 $\beta$ , and IL-6, and reduces salivary IgA, which together may delay resolution of inflammation in oral tissues and contribute to uncontrolled inflammatory states (inflammatory markers elevated up to 72 hours after loading) (Tripodi et al., 2021). Additionally, oxidative stress, a condition of excessive reactive oxygen species relative to antioxidant defenses, has been associated with periodontal inflammation in athletes, indicating that systemic metabolic stress can further perpetuate inflammatory burden in the periodontium (Schulze & Busse, 2024).

Extracts of *Borassus flabellifer* have been reported to suppress inflammatory mediators such as nitric oxide and pro-inflammatory cytokines, thereby facilitating a faster transition from the inflammatory phase to the proliferative phase of healing. This mechanism is

particularly important in the context of oral mucosal wounds, where mechanical irritation and microbial exposure often prolong the inflammatory condition beyond its normal course (Chen et al., 2025). As reported by Malayil *et al.*, *Borassus flabellifer* extract interferes with inflammatory cascades by inhibiting cytokine production and nitric oxide synthesis (Malayil et al., 2022). In the context of wound healing, the inflammatory phase is a critical initial stage. However, excessive or prolonged inflammation can delay the transition to the proliferative phase, primarily because elevated pro-inflammatory cytokines inhibit the proliferation and migration of fibroblasts and keratinocytes required for tissue regeneration (Landén et al., 2016; Mahmoud et al., 2024). By effectively suppressing the inflammatory response, *Borassus flabellifer* extract promotes faster resolution of inflammation, allowing the wound to enter the proliferative phase sooner, thereby enhancing angiogenesis, granulation tissue formation, and epithelialization, which accelerate wound closure (Esad et al., 2025; Tunit et al., 2022).

Oxidative stress in wound tissue can damage cell membranes, proteins, and the DNA of epithelial cells as well as fibroblasts (Gonçalves et al., 2022). The antioxidant content of *Borassus flabellifer* helps maintain the stability of the wound microenvironment by reducing oxidative damage (Comino-Sanz et al., 2021). This condition supports the viability of cells involved in re-epithelialization and the formation of new connective tissue in the oral mucosa (Ukaegbu et al., 2025). Jamkhande *et al.* demonstrated that methanolic leaf extracts exhibit significant antibacterial, antifungal, and antioxidant activities, supported by phytochemical screening that identified flavonoids, phenolic compounds, tannins, and saponins as major constituents. The strong free-radical scavenging capacity observed in DPPH assays, together with broad antimicrobial effects against tested pathogens, indicates that the leaf extract can modulate two critical factors that influence wound healing, namely microbial burden and oxidative stress (Jamkhande et al., 2016). In addition, Basava Prasad *et al.* analyzed the haustorium of the same plant and identified specific bioactive phenolic compounds, including gallic acid, chlorogenic acid, caffeic acid, and rutin, using chromatographic techniques, alongside notable antioxidant activity correlated with these phenolics. The study also highlighted the rich nutritional profile of the haustorium, suggesting an additional supportive role in cellular protection against oxidative damage (Basava Prasad et al., 2022). Collectively, these findings establish a phytochemical and biological basis for considering *Borassus flabellifer* as a promising natural source of antioxidant and antimicrobial agents relevant to tissue repair and mucosal wound healing.

## Conclusion

Despite the promising biological activities of *Borassus flabellifer*, several limitations should be acknowledged. First, the majority of included studies were conducted using in vitro experimental models, which may not fully represent the complex physiological conditions of human tissues. Only one study employed an in vivo model to evaluate wound healing, thereby limiting the generalizability of the findings to clinical settings (Mariselvam et al., 2021). Additionally, none of the included studies reported the use of randomization

or blinded outcome assessment, indicating a potential risk of bias in the experimental procedures. Furthermore, considerable heterogeneity was observed across studies in terms of plant parts used, extraction methods, concentrations, and outcome measurements, making direct comparison challenging. The lack of standardized protocols also limits the ability to determine optimal dosages and formulations. Another limitation is the absence of clinical studies evaluating the efficacy and safety of *Borassus flabellifer* in human subjects. As a result, current evidence remains largely preclinical and exploratory in nature (Malayil et al., 2022; Tunit et al., 2022).

Future research should focus on addressing these limitations by conducting well-designed in vivo and clinical studies to validate the therapeutic potential of *Borassus flabellifer*. In particular, randomized controlled trials (RCTs) are needed to evaluate its efficacy and safety in oral mucosal wound healing and other clinical applications. Standardization of extraction methods, dosage, and formulation is also essential to ensure reproducibility and facilitate clinical translation. Moreover, future studies should incorporate rigorous methodological approaches, including randomization and blinded outcome assessment, to minimize bias and improve the quality of evidence. Investigations into the underlying molecular mechanisms of action, such as modulation of inflammatory pathways and oxidative stress markers, would further strengthen the scientific basis of its therapeutic use. Additionally, the development of novel delivery systems, such as hydrogels or topical formulations, may enhance its bioavailability and clinical applicability (Tunit et al., 2022).

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