

Pongamia Pinnata (Karanj): A Natural Ally In The Management of Acne.

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ABSTRACT

Acne Vulgaris is one of the most prevalent dermatological conditions affecting adolescents and adults, often associated with physical discomfort, scarring and a significant psychosocial burden. Despite the availability of conventional treatments such as antibiotics, retinoids and hormonal therapies, long – term use is frequently limited by side effects, resistance development and recurrence. This has generated growing interest in safe, plant-based alternatives with multifunctional benefits. *Pongamia pinnata* (also known as Karanj) is a well-documented medicinal plant in Ayurveda and traditional medicine, valued for its diverse therapeutic properties. The seeds, leaves and oil of Karanj are rich in bioactive compounds such as karanjin, pongamol, flavonoids and fixed oils, which have demonstrated antimicrobial, anti-inflammatory, antioxidant and wound-healing activities – mechanisms directly relevant to acne pathogenesis. Recent pharmacological investigations highlight the ability of Karanj extracts and isolated phyto-constituents to inhibit acne-causing microorganisms, reduce oxidative stress and modulated inflammatory pathways, thereby providing a natural, multi-targeted approach. Additionally, formulation advancements, including nanoemulgels, cream and soaps incorporating karanj oil or extracts, have been explored to enhance stability, skin penetration and patient compliance. These formulations show promise as effective and safer alternatives to conventional therapies, especially in an era where consumers increasingly prefer herbal-based cosmetics and cosmeceuticals. This review consolidates current knowledge on the phyto-chemistry, pharmacological activities and anti-acne potential of *Pongamia pinnata*, while also discussing formulation strategies, comparative efficacy with standard drugs and safety considerations. It further identifies research gaps such as limited clinical trials and the need for standardized formulation, which must be addressed for successful translation into commercial products. Overall, Karanj emerges as a scientifically supported, sustainable and promising candidate in the development of novel anti-acne therapies..

Keywords: Acne Vulgaris, *Pongamia pinnata*, Karanj oil, Phytoconstituents, Antimicrobial activity.

INTRODUCTION

Acne vulgaris is among the most common dermatological disorders worldwide, particularly affecting adolescents and young adults. Globally, it is estimated that nearly 85% of individuals between the ages of 12 and 25 years experience some form of acne [1]. According to the Global Burden of Disease Study, the age-standardized prevalence of acne in the 10–24 years group increased from approximately 8,560 per 100,000 in 1990 to about 9,790 per 100,000 in 2021 [2]. Importantly, acne is not confined to adolescence. A considerable proportion of adults—especially women—continue to experience either persistent or late-onset acne, which can significantly affect quality of life and mental health [3]. Regional variations have

also been noted, with higher prevalence reported in Western Europe, East Asia, Latin America, and the Middle East, while some developing regions show rising trends in recent decades [4].

The impact of acne extends beyond the skin. Visible lesions, scarring, and chronicity contribute to psychosocial stress, including anxiety, depression, and reduced self-esteem [5]. Furthermore, delayed or inadequate treatment can worsen disease outcomes, increasing both personal and healthcare system burdens. Hence, understanding its prevalence underscores the need for effective, safe, and sustainable treatment strategies.

Causes and Current Treatments of Acne

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Acne vulgaris is a multifactorial skin disorder involving a complex interplay of biological, hormonal, and environmental factors. At its core, acne develops due to four primary pathogenic mechanisms: excess sebum production, abnormal follicular keratinization, colonization by *Cutibacterium acnes* (formerly *Propionibacterium acnes*), and inflammation of the pilosebaceous unit [6]. Sebum, an oily secretion of sebaceous glands, plays a critical role in skin lubrication, but its overproduction—often triggered by androgens—creates an ideal environment for follicular blockage and microbial growth [7].

Hormonal fluctuations are a major contributor, particularly during puberty and in adult women. Elevated androgen activity stimulates sebaceous glands, while hormonal imbalance related to polycystic ovarian syndrome (PCOS) or menstrual cycles often aggravates acne [8]. Genetic predisposition also plays a role, with studies indicating that individuals with a family history of acne are more likely to develop the condition [9]. Additionally, lifestyle factors such as high-glycemic diets, stress, and the use of certain cosmetic or pharmaceutical products may exacerbate the disease [10]. The microbial factor, especially *C. acnes*, is central to acne pathogenesis. This bacterium thrives in the lipid-rich environment of clogged follicles and promotes inflammation by releasing pro-inflammatory mediators. The resulting immune response contributes to papules, pustules, and nodules, leading to the visible lesions associated with acne [11].

In terms of management, acne treatment typically follows a stepwise approach based on severity. Mild cases are often managed with topical agents such as benzoyl peroxide, retinoids, and topical antibiotics. These help in reducing bacterial colonization, normalizing keratinization, and preventing comedone formation [12]. For moderate to severe cases, systemic therapies such as oral antibiotics (e.g., doxycycline, minocycline) or hormonal agents (e.g., oral contraceptives, anti-androgens like spironolactone) are employed to target both microbial and hormonal contributors [13].

For the most severe and treatment-resistant cases, isotretinoin remains the gold standard. It significantly

reduces sebaceous gland activity and has the potential for long-term remission. However, its use is limited by teratogenicity and other adverse effects [14]. Beyond pharmacotherapy, procedural interventions like chemical peels, photodynamic therapy, and laser treatments are increasingly integrated into management strategies. Despite these advances, issues such as antibiotic resistance, side effects, and recurrence highlight the need for safer and sustainable alternatives, including plant-based remedies like *Pongamia pinnata* [15].

Need for Herbal/Alternative Therapies

Despite the wide range of conventional options available for acne management, many patients struggle with side effects, resistance, or recurrence. Long-term use of antibiotics, for example, has led to rising concerns about antimicrobial resistance, reducing their overall effectiveness. Similarly, agents like isotretinoin, while highly effective, are often associated with severe adverse effects including teratogenicity, mucocutaneous dryness, and mood alterations. These limitations highlight a gap in current therapeutic approaches, creating demand for safer and more sustainable alternatives [16].

Patient preference also plays a role in this growing demand. With increasing awareness about lifestyle diseases and chemical-related toxicities, individuals often lean towards herbal remedies, perceiving them as “gentle” and more compatible with the body. Herbal preparations are also readily available over the counter, frequently marketed as cosmeceuticals, and tend to appeal to those seeking holistic or natural healthcare solutions [17].

From a scientific standpoint, herbal medicines bring in multi-targeted benefits. Unlike single-molecule synthetic drugs, plant extracts often contain a wide spectrum of bioactive compounds that can act synergistically. In the case of acne, plants that combine antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties hold special promise. This polypharmacological approach could potentially improve efficacy while lowering the risk of resistance and side effects [18].

Finally, the move towards herbal-based therapies aligns with global healthcare trends. The World



Health Organization (WHO) has consistently emphasized the integration of traditional and complementary medicines into mainstream healthcare, especially for chronic and lifestyle-related conditions. Within dermatology, this integration has opened avenues for herbs like *Pongamia pinnata*, which combine a history of traditional use with emerging scientific validation [19].

Overview of *Pongamia pinnata* (Karanj)

Botanical Description

Pongamia pinnata (commonly called Karanj in Hindi, Indian Beech in English) is a medium-sized, glabrous tree belonging to the family Fabaceae. It usually grows up to 15–25 meters in height and is widely distributed across tropical and subtropical regions of India, Southeast Asia, and Australia. The tree is easily recognized by its glossy green, pinnate leaves, clusters of pinkish-white to lilac flowers, and flat brown pods containing a single seed [20].

The seeds are particularly important as they yield a non-edible fixed oil (Karanj oil), which is thick, yellow to reddish-brown in color, and rich in flavonoids such as karanjin and pongamol. These phytoconstituents have been linked to antimicrobial, anti-inflammatory, and insecticidal activities. Besides seeds, other parts of the plant such as leaves, bark, and roots also contain bioactive compounds that contribute to its diverse medicinal applications [21].

Traditional Uses

In Ayurveda and Siddha systems of medicine, *Pongamia pinnata* has been used for centuries to treat a variety of ailments. The oil is traditionally applied topically for skin diseases such as eczema, leprosy, scabies, and ulcers. Its antiseptic and wound-healing properties made it a common household remedy for cuts, boils, and skin eruptions [22].

Beyond dermatology, Karanj has also been valued for its use in treating gastrointestinal disorders, rheumatism, and as an antiparasitic agent. In folk practices, leaves were often applied as poultices to reduce inflammation, while decoctions of bark were used as febrifuges. This long history of traditional use provides a strong foundation for modern scientific

exploration, especially in dermatological conditions like acne where antimicrobial and anti-inflammatory actions are crucial [23].

Phytochemistry of *Pongamia pinnata*

The medicinal potential of *Pongamia pinnata* largely stems from its diverse array of phytochemicals. Seeds, which are the most studied part, contain a thick fixed oil rich in furanoflavonoids, flavones, sterols, and fatty acids. Among these, **karanjin** and **pongamol** are considered the signature bioactive molecules, showing strong antimicrobial, antioxidant, and insecticidal activities [24]. In addition to these, seeds also contain sitosterol, stigmasterol, and various glycerides that contribute to their therapeutic properties.

Leaves of the plant are another important source of phytochemicals. They are rich in flavonoids such as glabrin, pinnatin, and kanjone, as well as tannins and glycosides. These compounds are known for their anti-inflammatory, antimicrobial, and free-radical scavenging effects, which explain the traditional use of leaf poultices in wound care and skin infections [25]. The bark, meanwhile, contains alkaloids and tannins with astringent properties, supporting its use in fever and digestive disorders.

Phytochemical studies also highlight the presence of fixed oils in seeds, primarily consisting of oleic, linoleic, palmitic, and stearic acids. These fatty acids provide emollient and skin-conditioning effects, making Karanj oil a useful base for topical formulations. Moreover, the synergistic presence of flavonoids and fatty acids may enhance skin penetration and bioavailability of active compounds, which is particularly relevant for anti-acne applications [26].

Recent analytical advancements have enabled deeper characterization of these compounds. High-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and nuclear magnetic resonance (NMR) studies have confirmed the presence of diverse bioactive molecules, supporting their potential role in pharmacological activities. Such detailed profiling is essential to standardize herbal formulations and ensure reproducible efficacy in clinical applications



[27]. Apart from the major flavonoids and fixed oils, *Pongamia pinnata* is also rich in minor constituents such as tannins, triterpenoids, and sterols. These compounds contribute to its overall pharmacological profile by enhancing antioxidant activity and stabilizing cell membranes. The presence of tannins, in particular, supports wound-healing and antimicrobial actions, making them relevant in acne management where tissue repair and bacterial control are equally important.

Another noteworthy group of phytochemicals present in *P. pinnata* are the alkaloids and glycosides. Though present in relatively small quantities, they play synergistic roles with flavonoids and fatty acids in exerting antimicrobial and anti-inflammatory effects. This synergism is an important feature of herbal medicines, where multiple compounds act together to achieve therapeutic benefits, unlike single-target synthetic drugs.

Recent phytochemical analyses have also revealed that the seed oil of *P. pinnata* contains a balanced mix of saturated and unsaturated fatty acids, such as oleic acid, linoleic acid, and palmitic acid. These fatty acids not only provide emollient properties but also possess inherent antimicrobial activity, helping reduce the growth of acne-causing bacteria like *Cutibacterium acnes*. Additionally, their antioxidant potential helps reduce oxidative stress within sebaceous glands, thereby minimizing acne flare-ups [28].

Pharmacological Activities Relevant to Acne

Antimicrobial Activity

One of the most important mechanisms by which *Pongamia pinnata* helps in acne management is its antimicrobial potential. Extracts of the plant, especially the seed oil, have been shown to inhibit the growth of common skin pathogens, including *Staphylococcus aureus* and *Cutibacterium acnes*. These bacteria are strongly associated with acne formation, as they colonize sebaceous follicles and trigger inflammation. The flavonoids and fatty acids present in *P. pinnata* disrupt bacterial cell membranes, making the plant an effective natural antimicrobial agent [29].

Anti-inflammatory Activity

Inflammation is a hallmark of acne, responsible for the redness, swelling, and discomfort associated with lesions. Studies have highlighted that *P. pinnata* contains bioactive compounds such as karanjin and pongamol, which possess strong anti-inflammatory effects. These phytochemicals reduce the production of inflammatory mediators like prostaglandins and cytokines, helping to calm irritated skin and prevent the progression of papules and pustules [30].

Antioxidant Properties

Oxidative stress plays a key role in acne pathogenesis by damaging skin cells and worsening inflammation. *P. pinnata* is rich in flavonoids and phenolic compounds that act as natural antioxidants. These compounds neutralize free radicals, protect the skin from lipid peroxidation, and maintain the health of sebaceous glands. By controlling oxidative stress, *P. pinnata* not only helps reduce acne breakouts but also minimizes post-acne hyperpigmentation and scarring [31].

Wound Healing

Acne lesions often leave behind small wounds that need to heal quickly to prevent secondary infections and scarring. *P. pinnata* seed oil and extracts have demonstrated wound-healing activity by promoting collagen synthesis and tissue regeneration. The presence of fatty acids also helps maintain skin hydration, creating an environment conducive to faster healing. This property makes *P. pinnata* particularly valuable in acne care, where quick resolution of lesions is essential for cosmetic and psychological well-being [32].

Evidence on Anti-Acne Potential

In-vitro Studies

Several in-vitro studies have confirmed the antimicrobial role of *Pongamia pinnata* extracts against acne-causing pathogens. Ethanolic and methanolic extracts of seeds and leaves have demonstrated strong inhibitory effects on *Staphylococcus aureus* and *Cutibacterium acnes*. These findings suggest that the bioactive compounds—flavonoids, karanjin, and fatty acids—disrupt bacterial cell membranes and hinder their



metabolic processes. Such results provide a strong foundation for considering *P. pinnata* as an anti-acne agent at the laboratory level [33].

In-vivo Studies

Animal studies have provided additional support to the anti-acne potential of *P. pinnata*. Topical application of seed oil and extracts has been shown to reduce experimentally induced skin inflammation and bacterial infection in rodent models. These studies highlight not just antimicrobial but also anti-inflammatory and wound-healing properties, reflecting the multifactorial nature of acne treatment. The ability to reduce lesion size and redness in vivo suggests its promising role as a topical herbal formulation [34].

Clinical Studies

Clinical evidence on *Pongamia pinnata* specifically for acne is still limited. However, small-scale trials and traditional medicine practices report improvement in acne severity when topical formulations containing *P. pinnata* oil are applied. In Ayurveda and folk practices, it is used in ointments and pastes to soothe inflamed skin and control pustules. While encouraging, more controlled, large-scale clinical trials are required to validate these claims and establish standardized dosages and formulations for acne management [35].

Safety, Toxicity & Regulatory Aspects

The safety of *Pongamia pinnata* has been an important subject of investigation, particularly because it is widely used in both traditional medicine and modern herbal formulations. Traditionally, its seed oil and leaf extracts have been applied topically for skin conditions, with very few reports of adverse effects. Most topical preparations are well tolerated, though rare cases of mild skin irritation or allergic reactions have been documented. These observations suggest that while the plant is generally safe, individual sensitivity should not be overlooked.

Toxicity studies in animal models have provided further insight. Oral administration of seed extracts in high doses has occasionally been associated with hepatotoxic effects, largely due to certain bioactive

constituents like karanjin. However, these effects are dose-dependent and usually observed at concentrations much higher than those used for topical or therapeutic applications. Such findings highlight the importance of carefully optimizing dosage and formulation to ensure safe use in humans.

From a regulatory perspective, *P. pinnata* faces similar challenges as many other medicinal plants. Standardization of extracts, identification of marker compounds, and ensuring batch-to-batch consistency are crucial steps before clinical acceptance. Regulatory authorities emphasize the need for toxicological profiling and safety testing before approving plant-based products for dermatological use. Without such data, herbal preparations risk being dismissed as unreliable or unsafe despite their therapeutic promise [36].

Another important aspect is the lack of harmonized global regulations. While *P. pinnata* is widely accepted in Ayurveda and traditional medicine, its use in Europe or the United States would require rigorous evaluation under guidelines set by EMA or FDA. This includes not only safety testing but also clinical efficacy trials. Therefore, much of its potential remains underutilized in mainstream dermatology due to regulatory hurdles rather than lack of therapeutic value.

In recent years, researchers have been exploring nano-formulations and standardized extracts of *P. pinnata* to enhance safety and efficacy. Encapsulation of karanj oil into stable delivery systems has been suggested as a way to reduce irritation potential while ensuring controlled release of active compounds. Such innovations may bridge the gap between traditional use and modern regulatory requirements, paving the way for safer, globally accepted formulations.

Finally, patient perception plays a critical role in safety considerations. Herbal remedies are often perceived as inherently safe, but this can lead to misuse or overuse. Educating patients on the correct use, dosage, and possible side effects of *P. pinnata* is just as important as scientific validation. With proper guidelines, regulatory approval, and standardized products, *P. pinnata* can emerge as a reliable and safe alternative for acne management worldwide [37].



Future Perspectives & Research Gaps

Although *Pongamia pinnata* has shown promising antimicrobial, anti-inflammatory, and wound-healing activities relevant to acne, research in this area is still at a preliminary stage. Most existing studies are confined to in-vitro or in-vivo models, while well-structured clinical trials are largely lacking. Without such trials, it is difficult to establish standardized dosages, long-term safety, and comparative efficacy with conventional therapies. Future work must focus on translating laboratory findings into controlled human studies to confirm its real-world potential.

Another major gap lies in the standardization of extracts. The phytochemical profile of *P. pinnata* can vary depending on geographical location, soil conditions, and extraction methods. Such variability directly impacts the consistency and reproducibility of therapeutic outcomes. Development of standardized extracts, along with validated quality control markers, will be essential to ensure both safety and efficacy for acne management.

Advances in formulation science offer new directions for *P. pinnata*. Nanoformulations such as nanoemulsions, liposomes, and hydrogels could help improve the solubility, stability, and targeted delivery of bioactive compounds like karanjin and pongamol. This not only reduces the risk of irritation but also enhances therapeutic activity at the site of acne lesions. Further exploration of such novel delivery systems may help bridge the gap between traditional herbal remedies and modern dermatological treatments.

Finally, there is a need for interdisciplinary collaboration between botanists, pharmacologists, dermatologists, and regulatory scientists. Such collaborations can help unlock the full potential of *P. pinnata* by integrating traditional knowledge with evidence-based medicine. With growing global interest in plant-based skincare, *P. pinnata* has the potential to emerge as a leading candidate for herbal anti-acne formulations—provided that current research gaps are systematically addressed [37].

CONCLUSION

Acne continues to be one of the most common and distressing skin conditions worldwide, affecting individuals not only physically but also emotionally and socially. While modern therapies have brought significant progress, issues such as antibiotic resistance, side effects, and high costs limit their long-term use. This has paved the way for renewed interest in herbal alternatives that can offer safe, affordable, and effective solutions.

Among the many medicinal plants explored, *Pongamia pinnata* stands out as a promising candidate due to its rich phytochemical composition and diverse pharmacological activities. The plant contains bioactive compounds such as karanjin, pongamol, flavonoids, and fatty acids, which together contribute to antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties. These mechanisms align perfectly with the multifactorial nature of acne, addressing not just one but multiple pathways involved in its development and progression. The available evidence, though limited, highlights the potential of *P. pinnata* in acne care. In-vitro and in-vivo studies strongly support its ability to combat acne-causing bacteria and reduce inflammation. Traditional usage and small-scale clinical observations further validate its relevance in skincare. However, the lack of standardized extracts, controlled clinical trials, and harmonized regulatory guidelines remains a barrier to its mainstream acceptance.

Future research should focus on bridging these gaps by conducting well-designed clinical trials, developing standardized formulations, and exploring novel delivery systems such as nanoemulsions and gels. These advancements can enhance bioavailability, minimize side effects, and ensure consistent therapeutic outcomes, thereby making *P. pinnata* a reliable option for dermatologists and patients alike. Importantly, the integration of *P. pinnata* into acne management should be approached with balance—valuing both the wisdom of traditional medicine and the rigor of modern scientific validation. With the right scientific backing, this plant has the potential not only to serve as an alternative but



also as a complementary therapy alongside conventional treatments.

In conclusion, *Pongamia pinnata* offers a unique blend of traditional credibility and modern pharmacological promise. By addressing safety, standardization, and clinical validation, it could become a valuable herbal asset in the global fight against acne, meeting the growing demand for natural, effective, and patient-friendly skincare solutions

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