



PHARMACOLOGICAL ACTIVITIES OF *PITHECELLOBIUM DULCE* LEAF AND SEED EXTRACTS IN TREATMENT OF INFLAMMATIONS & PAIN RELIEF

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ABSTRACT

Pithecellobium dulce is a species rich in phytochemicals that has medicinal uses, especially in the treatment of pain and inflammation. This review provides a comprehensive summary of the pharmacological effects of *P. dulce* leaf and seed extracts, particularly their analgesic and anti-inflammatory qualities, as well as distinguishable cellular and molecular mechanisms that could explain this reaction. Nevertheless, the number of studies is small, and they hardly ever prove causation. Following pathogenic stimuli, *P. dulce*'s bioactive constituents—such as flavonoids, alkaloids, and saponins—act as potent intermolecular agents towards inflammatory pathways, modifying T-cell and macrophage activity to concurrently upregulate cytokine profiles important to pain and inflammation. According to laboratory research, plant extracts from *P. dulce* are very effective in

treating pain, on par with traditional analgesics, and may even improve complementary therapies. In order to provide more insight into the advantages and disadvantages of *P. dulce* extracts, the study concludes by discussing comparison trials with conventional medications. The significance of clinical trials in verifying preclinical findings and formulation factors that might enhance pharmacodynamics and bioavailability are highlighted as future research objectives. As a natural source of analgesic and anti-inflammatory compounds, *P. dulce* shows promise and might be a creative way to address the growing need for plant-based pharmacotherapies, the research concludes.

KEYWORDS: *Anti-inflammatory agent, Analgesic agent, Bioactive compounds, Flavonoids, Macrophages, etc.*

1. INTRODUCTION

The tropical legume tree *Pithecellobium dulce*, often known as the Manila tamarind, is indigenous to Central and South America and belongs to the Fabaceae family. The tree has a well-established ethnomedical use and is currently found throughout Asia and Africa. *P. dulce*, which is valued for its therapeutic qualities, has been used extensively in traditional medicine to treat ailments like skin infections and stomach issues. The perspective for identifying therapeutic potentials for *P. dulce* from the folk medicinal system is sharpened by the examination of ethnomedicinal usage themselves.^[1]

Some of the traditional applications of *P. dulce* are supported by current pharmacological research. According to studies, its high phenolic content gives it antioxidant qualities that may help lessen illnesses linked to oxidative stress. Its historic usage in treating illnesses is validated by its antibacterial and antifungal properties, which have been shown in extracts from the bark and leaves. Furthermore, *P. dulce* extracts have been shown in antidiabetic tests to lower blood glucose levels, which is consistent with its long-standing use in the treatment of diabetes. Its use in the treatment of inflammatory diseases including arthritis and muscular soreness is supported by the presence of bioactive chemicals like flavonoids and tannins, which have also been demonstrated to have anti-inflammatory properties.^[2]

Inflammation and pain are important biological reactions to a variety of illnesses, injuries, and infections that are meant to defend the body and start the healing process. But when these reactions become excessive or persistent, they lead to a variety of inflammatory and pain-related disorders, from cardiovascular and autoimmune diseases to neuropathy and arthritis. Leukotrienes, prostaglandins, cytokines, and other signaling pathways govern intricate biochemical processes that coordinate the body's reaction to damaging stimuli. These systems underlie both pain and inflammation. Because these mechanisms are at the heart of the pathophysiology of many acute and chronic illnesses, patients' quality of life and the prevention of disease progression depend on the efficient treatment of pain and inflammation.

In the therapeutic arsenal, pharmacological substances' analgesic and anti-inflammatory qualities are essential for resolving these problems. Anti-inflammatory medications reduce symptoms and stop the progression of illness by lowering the immune response and focusing on important inflammatory mediators.^[3] Analgesics, on the other hand, mainly work on the neurological system to reduce pain by either blocking pain impulses or changing how the brain perceives pain. When combined, analgesic and anti-inflammatory drugs offer a two-

pronged strategy for treating pain and inflammation, addressing the root causes of pain-related illnesses as well as their symptoms. Corticosteroids, nonsteroidal anti-inflammatory medicines (NSAIDs), and more recent families of selective COX-2 inhibitors are well-known examples of anti-inflammatory medications that are often used in clinical settings. In chronic illnesses where pain continues even after inflammation is controlled, opioids and non-opioid analgesics like acetaminophen are equally essential for pain management.

The importance of these characteristics is further highlighted by the increasing incidence of disorders linked to pain and inflammation across the world. The chronic nature of many inflammatory illnesses, the aging of the population, and the rise in lifestyle-related diseases are all factors driving up demand for efficient therapies.^[4] Nevertheless, using these therapeutic medicines comes with risks, such as the development of drug tolerance, dependency, and negative consequences with continuous usage. Therefore, research is still being done to produce novel analgesic and anti-inflammatory molecules that are both efficacious and have a favourable safety profile.

2. Botanical Profiling of *Pithecellobium dulce*

The leguminous plant *Pithecellobium dulce*, also known as "Jungle Jalebi" or the Manila tamarind, is a member of the Fabaceae family. Dispersed over tropical and subtropical areas, this versatile plant is well known for its distinct phytochemical composition, conventional therapeutic uses, and environmental advantages.^[5] *Pithecellobium dulce's* taxonomy, morphology, environment, and phytoconstituents are all thoroughly examined as part of the botanical profiling process in order to clarify any possible medicinal uses. A plant with thorny branches, bipinnate leaves, and characteristic coiled pods, it has long been used to treat microbial infections, discomfort, and inflammation (*as shown in figure 1*). Expanding its role in contemporary medicine and investigating its pharmacological relevance are made possible by this profile.^[6]



Figure 1: Plant and fruit of *Pithecellobium dulce*.

Pithecellobium dulce, a versatile leguminous plant belonging to the family Fabaceae, is widely recognized by various synonyms and regional names due to its global distribution and cultural significance. The botanical name derives from the Greek words "pithekos" (ape) and "lobos" (pod), alluding to the curved, monkey-pod-like structure of its fruit.^[7] Additionally, its specific epithet *dulce* highlights the sweet pulp of its seed pods. This plant is commonly referred to as "Madras Thorn" in English, emphasizing its origins and thorns, and "Manila Tamarind", reflecting its resemblance to tamarind with a twist of geographical identity.^[8]

In India, it is known as "Jungle Jalebi" due to its coiled, pod-like fruits resembling the sweet jalebi. Across regions, names such as "Guamuchil" (Mexico), "Ganga Imli" (Hindi), "Seeme Hunase" (Kannada), and "Vilayati Chintakaya" (Telugu) illustrate its cultural and linguistic diversity (*as shown in table 1*). These synonyms not only reflect its physical characteristics but also highlight the plant's historical and traditional uses, positioning it as a species of ethnopharmacological importance.^[9]

Pithecellobium dulce is a multipurpose tropical plant known for its medicinal properties, nutritional value, and ecological benefits. It is a member of the Fabaceae family, widely recognized under various synonyms and regional names across the globe due to its extensive distribution.^[10]

Table 1: Synonyms of *Pithecellobium dulce* in different names.

Category	Names
Scientific Synonyms	<i>Inga dulcis</i> Willd.
	<i>Mimosa dulcis</i> Roxb.
	<i>Acacia obliquifolia</i> (DC.) Benth.
	<i>Zygia obliquifolia</i> (DC.) Britton & Rose
English Names	Manila Tamarind
	Madras Thorn
	Blackbead
Indian Regional Names	Hindi: Jungle Jalebi
	Bengali: Tentul-goda
	Tamil: Kodukkapuli
	Telugu: Seema Chintakaya
	Kannada: Seema Hunase
	Malayalam: Chakkarpaavu
Spanish/Latin American Names	Guamá Chino
	Huamúchil
	Chiminango
Filipino Names	Kamatsile
	Sampaloc na Bilog
Other Local Names	Thai: Makhham Thet
	Vietnamese: Me Tây
	Malay/Indonesian: Asam Jawa Belanda

3. Phytochemical Profile of *Pithecellobium dulce*

The increasing incidence of disorders linked to pain and inflammation throughout the world emphasizes the importance of these characteristics even more. The need for efficient therapies is growing as a result of an aging population, a rise in lifestyle-related illnesses, and the chronic nature of many inflammatory diseases. However, there are drawbacks to using these therapeutic drugs, such as the possibility of dependency, the development of drug tolerance, and negative consequences with continuous usage. Thus, research is being done to create novel analgesic and anti-inflammatory drugs that are both efficient and have a good safety record.^[11] Together, these phytochemicals as shown in figure 2 support *P. dulce*'s traditional medicinal usage in the treatment of a range of conditions, including as infections, inflammation, and metabolic problems, and provide a basis for future pharmacological studies.

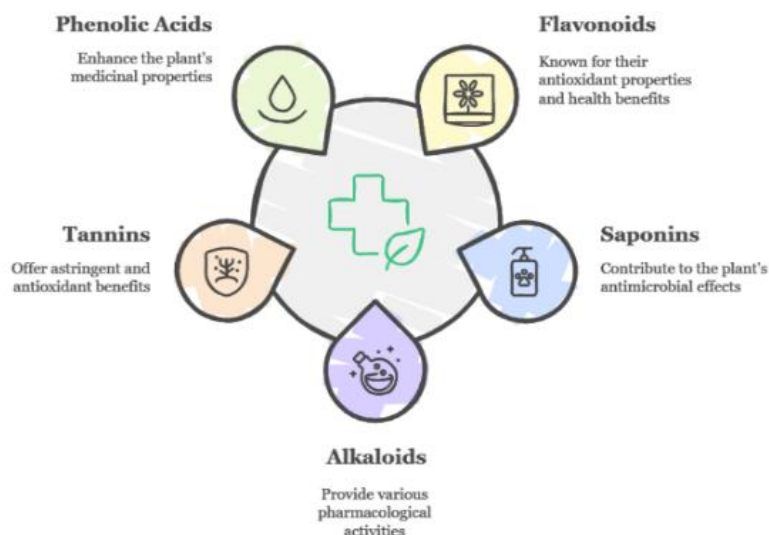


Figure 2: Bioactive compounds of *P. dulce* used as medicine.

3.1. Bioactive Components in Plant Extracts

Many plant extracts include bioactive substances, including alkaloids, flavonoids, tannins, saponins, and phenolics, which are crucial for achieving medicinal benefits like analgesic and anti-inflammatory properties (as shown in table 2). The different profiles in leaf and seed extracts are compared after discussing the bioactive components and how they support biological activity.

Table 2: Phytochemical constituents of *P. dulce* plant parts.

Plant Part	Chemical Name	Plant Part	Chemical Name
Bark	Catechol	Fruits	Gallic acid
Wood	Campesterol	Fruits	Mandelic acid
Wood	Melacacidin	Fruits	Ferulic acid
Seeds	Hederagenin	Fruits	Vanillic acid
Seeds	Pitheduloside A	Fruits	Coumaric acid
Seeds	Pitheduloside B	Fruits	Rutin
Seeds	Pitheduloside D	Fruits	Naringin
Seeds	Pitheduloside F	Peel, Leaves	Quercetin
Seeds	Pitheduloside H	Peel, Leaves	Stigmastrol
Seeds	Pitheduloside I	Fruits, Peel	Pinitol
Seeds	Pitheduloside K	Seeds	Oleanolic acid
Leaves	Octacosanol	Seeds	Echinocystic acid
Leaves	Kaempferol	Leaves	Dulcitol
Seeds	Pathogenic	Stem	Prenylapigenine
Fruits	Ellagic acid	Fruits	Daidzein

3.1.1. Alkaloids

Medicinal plants frequently contain large amounts of alkaloids, which are nitrogen-containing chemicals. The analgesic actions of these substances stem from their capacity to interact with pain circuits. The alkaloid morphine, for example, is widely recognized for its potent analgesic properties. By blocking the cyclooxygenase (COX) and lipoxygenase (LOX) pathways, among other inflammatory enzymes and pathways, alkaloids can also have anti-inflammatory effects.^[12]

3.1.2. Flavonoids

Polyphenolic chemicals called flavonoids are often present in plant-based diets. Because of their capacity to scavenge free radicals, they are well-known for their anti-inflammatory and antioxidant characteristics. This antioxidant effect is essential for lowering oxidative stress, which frequently precedes inflammation. Flavonoids such as quercetin and kaempferol have demonstrated analgesic qualities via altering neurotransmitters that indicate pain in addition to their anti-inflammatory activities.^[13]

3.1.3. Tannins

The astringent qualities of tannins, which are polyphenolic chemicals, aid in the healing of wounds and have anti-inflammatory effects. As mediators of pain and inflammation, tannins decrease the production of prostaglandins and inhibit pro-inflammatory enzymes. Tannins astringent properties are also good for mucosal health and can reduce inflammation by having modest analgesic effects.^[14]

3.1.4. Saponins

Glycosides having surface-active qualities, saponins might perhaps reduce inflammation by modifying immune responses and building complexes with cholesterol. Nitric oxide and other pro-inflammatory cytokines are inhibited by saponins, which has been shown to lessen inflammation. Additionally, their capacity to inhibit pain signals by acting on nociceptors or pain receptors gives them the potential to be analgesics.^[15]

3.1.5. Phenolics

It is well-known that phenolic compounds, which include simple phenols, polyphenols, and other related substances, have strong antioxidant capabilities. They combat inflammation by scavenging reactive oxygen species (ROS), which may injure cells and initiate inflammatory

responses. Their pain-relieving abilities stem from their capacity to alter pain pathways, perhaps via blocking enzymes such as COX and LOX.^[16]

3.2. Preparation of plant extracts from leaves & seeds

The leaves were thoroughly checked, and any old, diseased, or fungus-damaged leaves were removed. The extracts were made from both dried and fresh leaves. Healthy leaves were spread out, dried at room temperature for about ten days, and processed into a fine powder with an electric blender. The leaves were chopped into small pieces, dried, and crushed into coarse powder for the maceration procedure with methanol at room temperature. After thorough extraction, the methanol extract was concentrated under lowered 338 pressure at 50-54°C and kept in a vacuum desiccator. The extract suspension was produced in 2% gum acacia and utilized throughout the experimental study.^[17]

The seeds were obtained from the *Pithecellobium dulce* tree and cleaned with sterile distilled water. Approximately 400 grams of *P. dulce* seed were crushed to a coarse powder using an electronic grinding mill before being extracted via cold maceration in 80% methanol at room temperature. It was then let to stand for 3-4 days with intermittent shaking to generate the crude extract. Later, the crude extract was filtered using Whatman filter paper (1.45 mm grade). The filtered product was then concentrated with a rotating vacuum evaporator at low pressure (45 rpm) and temperature (40°C). Following drying, approximately 6 grams of powder extract were generated and kept at 4°C.^[18]

The composition of bioactive components in leaves and seeds often varies significantly, resulting in distinct pharmacological properties (as shown in figure 3).

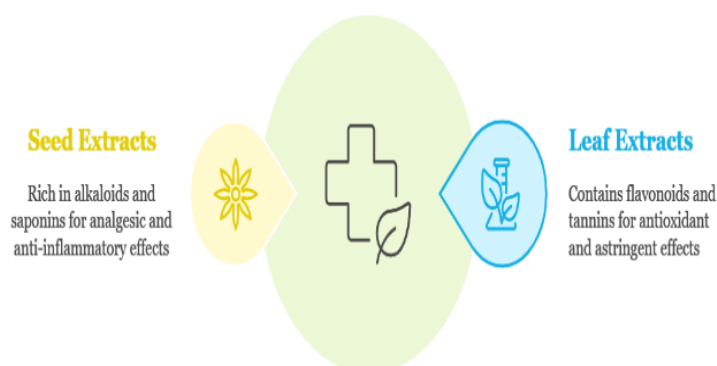


Figure 3: Pharmacological activity of *P. dulce* plant extracts.

3.2.1. Leaf Extracts: Leaves often have greater levels of flavonoids and tannins. This high flavonoid concentration can result in a strong antioxidant profile, making leaf extracts particularly beneficial for anti-inflammatory and oxidative stress disorders. Tannins in leaf extracts boost their astringent and wound-healing effects.^[19]

3.2.2. Seed Extracts: Seeds, on the other hand, frequently contain larger levels of alkaloids and saponins. Alkaloid-rich seed extracts are often stronger in analgesic action, making them useful for pain relief. Saponins in seeds also help to reduce inflammation, particularly through immunological regulation. Furthermore, seeds may possess a greater phenolic content, which contributes to their antioxidant and anti-inflammatory properties.^[20]

4. Mechanisms of Anti-Inflammatory Activity

Anti-inflammatory activity refers to a substance's ability to suppress inflammation, a biological response that the immune system initiates in response to infections, injuries, or adverse stimuli. While inflammation is beneficial, it can also cause tissue harm if it is persistent or severe. Anti-inflammatory drugs function by blocking inflammatory pathways, particularly cyclooxygenase (COX) and lipoxygenase (LOX), enzymes involved in the creation of pro-inflammatory mediators such as prostaglandins and leukotrienes.^[21]

Anti-inflammatory medications are classified into two categories: nonsteroidal anti-inflammatory medicines (NSAIDs) and corticosteroids. NSAIDs like ibuprofen and aspirin inhibit COX enzymes, lowering prostaglandin production and relieving pain and swelling. Corticosteroids, such as prednisone, dampen immunological responses and decrease the synthesis of inflammatory cytokines.^[22] In addition, there is a rising interest in natural anti-inflammatory medicines, such as phytochemicals from plants (e.g., curcumin from turmeric, resveratrol from grapes), which have shown promise with fewer side effects.

4.1. Inhibition of Pro-Inflammatory Mediators

Pithecellobium dulce, often known as Manila tamarind, has anti-inflammatory characteristics that make it a viable treatment for inflammation-related illnesses. It significantly decreases pro-inflammatory cytokines, including TNF- α and IL-6, and inhibits enzymes such as COX and LOX. Chronic inflammation is driven by TNF- α and IL-6, while COX and LOX enzymes create inflammatory mediators such as prostaglandins and leukotrienes.^[23] *Pithecellobium dulce*'s bioactive components, including flavonoids, saponins, and alkaloids, target cytokine production pathways such as NF- κ B and JAK/STAT. They also inhibit COX-

2 and LOX, lowering pain, swelling, and allergic reactions. This comprehensive inhibition decreases inflammation while potentially lessening the adverse effects of standard anti-inflammatory medications. It is a valuable source for creating natural anti-inflammatory medicines, but further clinical trials are required to completely prove its therapeutic potential and safety.^[24]

4.2. Antioxidant Action

Pithecellobium dulce's antioxidant activity is significant, owing to its ability to reduce oxidative stress by scavenging free radicals. Oxidative stress, which is caused by an imbalance between reactive oxygen species (ROS) generation and antioxidant defenses, is a major contributor to the pathogenesis of many chronic illnesses, including inflammatory ailments, cardiovascular problems, cancer, and neurodegenerative diseases.^[25]

Pithecellobium dulce has showed potential in combating oxidative stress because to its diverse phytochemical makeup, which comprises flavonoids, polyphenols, tannins, and other bioactive components with high antioxidant activity.

Pithecellobium dulce's antioxidant mechanism involves the donation of hydrogen atoms or electrons by its bioactive ingredients, which neutralizes free radicals and converts them to more stable, nonreactive forms. This mechanism aids in the reduction of ROS and reactive nitrogen species (RNS) in the body.^[26] The phenolic compounds of *Pithecellobium dulce* efficiently scavenge superoxide anions, hydroxyl radicals, and hydrogen peroxide, preventing lipid peroxidation and preserving cell membranes from oxidative damage.

Pithecellobium dulce extracts have been shown in studies to have significant activity in common antioxidant assays, such as DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging, ABTS (2,2'-azinobis-3-ethylbenzothiazoline-6-sulfonic acid) radical scavenging, and ferric reducing antioxidant power (FRAP) assays. These tests assess the plant's ability to donate protons or electrons, which is an important property of effective antioxidants.^[27]

Pithecellobium dulce indirectly helps to reduce inflammation by lowering oxidative stress levels. Free radicals and oxidative stress activate nuclear factor-kappa B (NF- κ B), which produces pro-inflammatory cytokines such as TNF- α , IL-1, and IL-6. *Pithecellobium dulce* antioxidants can reduce activation, lowering pro-inflammatory mediator synthesis and

inflammation. This anti-inflammatory action has the potential to help manage arthritis, colitis, and other chronic inflammatory illnesses.^[28]

5. Analgesic Properties of *Pithecellobium dulce*

Analgesic characteristics relate to a substance's capacity to reduce pain without producing unconsciousness. Analgesics function via a variety of methods and are classed as either non-opioid or opioid analgesics. Non-opioid analgesics, such as NSAIDs (e.g., ibuprofen and aspirin), decrease inflammation and pain at the site of tissue damage by inhibiting prostaglandin formation via the enzyme cyclooxygenase. Opioid analgesics, such as morphine, attach to opioid receptors in the central nervous system, affecting pain perception and emotional reaction.^[29] Furthermore, several natural substances, such as turmeric (curcumin) and willow bark, have analgesic properties via lowering inflammation or regulating pain pathways, making them potential candidates for safer, more accessible pain management treatments.

5.1. Pain Modulation Mechanisms

Pithecellobium dulce's analgesic qualities have received more attention in recent research, with an emphasis on its interaction with cerebral and peripheral pain pathways. *P. dulce* contains a variety of phytoconstituents, including flavonoids, alkaloids, tannins, and saponins, which are thought to work together to modulate pain responses.

Flavonoids such as quercetin and kaempferol have been discovered as important modulators due to their anti-inflammatory effects and inhibition of the COX and LOX pathways. This inhibits the creation of prostaglandins and leukotrienes, both of which are important in the peripheral nociceptive response.^[30]

Alkaloids discovered in *P. dulce* have been demonstrated to interact with opioid receptors in the central nervous system, perhaps mimicking the effect of endogenous opioids and producing central analgesia. These chemicals also work on the descending inhibitory pathways, perhaps increasing serotonin and noradrenaline levels, which aid in pain alleviation.

Saponins reduce the release of pro-inflammatory cytokines including TNF- α and IL-6, leading to anti-inflammatory actions. This immunomodulatory activity at the peripheral locations reduces inflammatory pain signals before they reach the central nervous system.^[31]

According to research, the combination of these chemicals may result in a balanced interaction with both brain and peripheral pain pathways, making *P. dulce* a promising choice for pain management via several mechanisms.

Recent comparative studies in animal models highlight the potential efficacy of *P. dulce* extracts when benchmarked against conventional analgesics like ibuprofen and morphine. For instance.

In mouse tests, *P. dulce* extracts were found to be as effective as ibuprofen in inflammatory pain models (for example, the carrageenan-induced paw edema test). The reduction in paw swelling and behavioral reactions to pain stimuli was similar in the *P. dulce*-treated and ibuprofen-treated groups, indicating that *P. dulce* may have COX-inhibitory effects similar to nonsteroidal anti-inflammatory medications (NSAID).^[32]

Further investigation comparing *P. dulce* to morphine in neuropathic pain models revealed that *P. dulce*, particularly its alkaloid-rich fraction, gave considerable pain relief while avoiding morphine-like adverse effects such as tolerance and dependency. *P. dulce*'s fewer side effects indicate that it may be a safer choice, particularly for chronic pain treatment.^[33]

6. Potential Therapeutic Applications

Jungle jalebi, or *Pithecellobium dulce* (PD), is attracting a lot of interest due to its possible medical uses in a number of chronic illnesses. A well-known phytoconstituent profile, PD has been researched for its antibacterial, antioxidant, analgesic, and anti-inflammatory properties. The use of PD in pain treatment, especially for chronic conditions like rheumatoid arthritis, is covered in this review along with its benefits, drawbacks, and current clinical evidence issues.^[34]

The long-term negative consequences of synthetic analgesics and anti-inflammatory medications make managing pain in chronic disorders, especially inflammatory ones like rheumatoid arthritis (RA), difficult. A natural substitute with possibly fewer adverse effects is provided by plant-based medicines, and PD has showed promise in this field.

Studies reveal that the bioactive substances in *P. dulce* (PD), including flavonoids, tannins, and alkaloids, are involved in regulating pain perception and inflammatory reactions. These substances block the cyclooxygenase (COX) pathway, which is linked to the processes behind inflammatory pain.^[35] According to a study that was published in Pharmaceutical

Biology, for instance, PD leaf extract dramatically decreased paw edema and pain sensitivity in animal models of inflammation. This suggests that it could be used to treat rheumatoid arthritis and other inflammatory diseases.

Oxidative stress also leads to nerve sensitization in neuropathic components of chronic pain disorders. The antioxidant qualities of *P. dulce* may help control oxidative damage and the neuropathic pain elements frequently seen in RA. A dual mechanism of anti-inflammatory and neuroprotective activities is suggested by research published in the Journal of Ethnopharmacology, which found that the antioxidant activity of PD extract showed promise in lowering oxidative stress indicators.^[36]

6.1. Advantages of PD in Pain Management

Low Toxicity and Minimal Side Effects: Even at greater dosages, preclinical research has demonstrated that PD extract is not as hazardous as synthetic painkillers. In the treatment of chronic diseases, where prolonged use of synthetic medications frequently results in negative side effects, such as cardiovascular and gastrointestinal problems, this is an important benefit.^[37]

Natural Anti-Inflammatory Properties: As mentioned in *Planta Medica*, PD has the potential to be used as an adjuvant treatment since it can lower inflammation without compromising immune function. In chronic illnesses, it can be used in conjunction with traditional therapy to decrease inflammation. This might reduce the amount of synthetic medicine needed and minimize adverse effects.^[38]

Multifaceted Mechanisms of Action: Multiple bioactive chemicals found in *P. dulce* allow it to influence several biological pathways linked to inflammation and pain. This multifaceted strategy is beneficial for managing chronic diseases since it targets underlying inflammatory pathways as well as symptom treatment.^[39]

6.2. Limitations in Clinical Evidence and Potential Drawbacks

The promising results from preclinical studies, there are limitations in the clinical evidence supporting PD's therapeutic applications in humans. Most studies to date have been conducted on animal models, and clinical trials on human subjects are limited. Key limitations include:

Lack of Large-Scale Human Trials: While animal studies demonstrate PD's potential for pain management, there is a scarcity of large-scale, randomized controlled trials in humans to confirm efficacy, dosing, and safety. Further clinical studies are essential to establish standardized dosages and evaluate long-term effects.^[40]

Variability in Bioactive Composition: The concentration of active compounds in PD can vary depending on factors such as plant origin, cultivation conditions, and extraction methods. This variability poses challenges for standardizing its use as a therapeutic agent.^[41]

Limited Mechanistic Studies: While some studies elucidate the anti-inflammatory and analgesic mechanisms of PD, more research is needed to fully understand the pathways involved. Mechanistic studies would aid in optimizing extraction and formulation methods for maximum therapeutic benefit.^[42]

With its low toxicity, minimal side effects, and multifaceted mechanism of action, PD provides a natural alternative or complement to synthetic drugs, making it a promising adjunctive therapy for managing chronic pain conditions, particularly inflammatory diseases like rheumatoid arthritis.^[36] However, the limitations in clinical evidence highlight the need for more extensive research, particularly human clinical trials, to fully understand its potential.^[43] As a result, it could significantly contribute to pain management strategies in chronic disease settings once these research gaps are addressed.

7. CONCLUSION

Pithecellobium dulce has a lot of potential for increasing health, avoiding disease, and extending life, and many of these effects are confirmed by recent study. Notwithstanding the advancements, there are still gaps in our understanding of the precise bioactive substances causing these advantageous outcomes. The capacity to fully use *P. dulce*'s potential is limited by our incomplete understanding of certain of its modes of action. In order to establish a clear structure-activity link and get a greater understanding of how these components exert their effects, it is imperative that these compounds be isolated and identified using a bioassay-guided method. To ascertain the stability, safety, and effectiveness of these molecules for possible medicinal uses, more research is also necessary. Developing commercial formulations and therapeutic agents based on *P. dulce* may be made possible by more study in this field, particularly for the markets for natural and herbal medicines. Increased attention to pharmacokinetics, toxicity profiles, and ideal doses would pave the way for the transition

from early research to real-world uses, bringing *P. dulce*'s encouraging benefits closer to wider medical use.

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