Journal of Mines, Metals and Fuels, *71(11): 2095-2109; 2023. DOI: 10.18311/jmmf/2023/36273*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Mineral-associated Medicinal Plants: Uncovering their Anti-Inflammatory Potential Through Comprehensive Exploration of Bioactive Compounds and Pharmacological Activities

Jayant C. Thorat[1], Sonali V. Dhamal[2]* and Priyanka V. Dudheinamdar[1]

[1]BVDU Yashwantrao Mohite College of Arts, Science and Commerce, Kothrude, Pune – 411038, Maharashtra, India; jaythorat28@gmail.com, priyanka.dudheinamdar@gmail.com

[2]BVDU College of Engineering, Pune - 411043, Maharashtra, India; svdhamal@bvucoep.edu.in

Abstract

In recent years, there has been a growing interest in harnessing the potential of bioactive compounds sourced from specific wild plants with inherent natural anti-inflammatory properties. Inflammation is a complex physiological response crucial for defense against adverse stimuli. However, prolonged inflammation can give rise to a myriad of health issues, particularly when influenced by factors related to mineral exposure and processing. This review aims to provide an overview of the current status of knowledge regarding the anti-inflammatory plant-based drugs which have been derived from green tea, licorice, devil's claw, willow bark, chamomile, Salvia officinalis and Piper ovatum etc. Bioactive compounds such as catechins, glycyrrhizin, harpagoside, salicin, chamazulene, Lactones and alkaloids which are referred as secondary plant metabolites obtaining the pharmacological effects in human beings and animals. It has long been identified by the authors of various classical texts of Ayurveda and their properties, indications to inhibit the production of pro-inflammatory cytokines and enzymes which helps to modulate various signaling pathways involved in inflammation. This study delves into the assessment of the anti-inflammatory properties of select wild plants while taking into consideration their potential interactions with mineral and mineral-associated pollutants. Safety and potential side effects are discussed in the context of metal exposure scenarios. Additionally, it underscores the necessity for continued research to elucidate the action mechanisms of these plant-derived compounds, further unlocking their therapeutic potential and efficacy in addressing inflammation heightened by mineral-related factors.

Keywords: *Anti-inflammatory, Bioactive Compounds, Defense Mechanism, Mineral-associated Plants, Natural Remedies, Phytochemicals*

1.0 Introduction

This review emphasizes the significance of secondary metabolites derived from specific wild plants, which display anti-inflammatory activity[1]. Our study suggests that inflammation has a complex defense mechanism with our body to treat hazardous stimuli but uncontrolled inflammation could be associated with various health issues[2]. The use of natural anti-inflammatory agents from plant sources[3] has become a challenging pathway for preventing and treating inflammation-related diseases. It is crucial to enhance the presence of bioactive compounds in wild plants and prioritize the exploration of their valuable pharmacological activities. *Artemisia*

*Author for correspondence

annua exhibits potent action against malarial activity due to the presence of artemisinin, a bioactive compound in traditional Chinese medicine, and has been proven effective in clinical trials[4]. *Hypericum perforatum*, commonly known as St. John's wort, possesses hypericin and hyperforin with antidepressant properties[5]. The study of flavonoids and terpenoids from the *Ginkgo biloba* plant shows antioxidant and anti-inflammatory properties and has been used in clinical trials to treat dementia and other cognitive disorders[6]. *Echinacea purpurea* plant contains alkamides and polysaccharides with immune modulatory properties. Extraction from *Salvia miltiorrhiza* plant involves bioactive constituents like tanshinones and salvianolic acids, which have cardiovascular and anti-inflammatory properties[7].

Anti-inflammatory activities have been observed in the presence of listed secondary metabolites as various phenolic compounds, flavonoids[8], anthocyanins, and tannins[9], they suppress the production of pro-inflammatory cytokines and enzymes. It is observed that antioxidant, analgesic, and immunemodulatory activities could be effective with anti-inflammatory potential. Inflammation, a multifaceted biological process, has emerged as a pivotal mechanism in the body's immune response to infection and injury[10].

However, chronic inflammation can lead to various diseases such as cancer[11], cardiovascular disease, and neurodegenerative diseases[12]. Hence, anti-inflammatory drugs are widely used to control inflammation including arthritis, asthma, and inflammatory bowel disease and its associated disorders. However, the long-term use of synthetic anti-inflammatory drugs can cause adverse effects[13]. Therefore, there is a growing interest in finding natural sources of anti-inflammatory compounds. Wild plants have been used for centuries as traditional medicine for various ailments[14], focusing on inflammation. Recent studies have considered selective plants, enriched with bioactive components having interest in anti-inflammatory properties. A mineral overview of bioactive compounds is essential to understanding their significance in human health and the potential therapeutic benefits they offer. Bioactive compounds, which encompass a wide range of phytochemicals found in plants, are known for their various physiological effects on the human body. These compounds often contain minerals that play crucial roles in cellular processes and overall well-being.

2.0 Methodology

The main objective of this review is to conduct a comprehensive examination of wild plants, focusing on their potential as anti-inflammatory agents. The review aims to explore the bioactive compounds present in selected plants and their pharmacological activities. Traditional herbal medicines have been gaining wider acceptance as prospective alternative resources of remedial treatment for diverse ailments globally. This review addresses an extensive and updated overview of the current knowledge of wild plants with anti-inflammatory activities.

Table 1. Brief overview of mineral-associated plants

Plant	Minerals Associated	Reference
Green Tea (*Camellia sinensis*)	Potassium, Fluoride, Manganese, Aluminum, Zinc	15
Licorice (*Glycyrrhiza glabra*)	Potassium, Calcium, Magnesium, Phosphorus, Iron	16
Devil's Claw (*Harpagophytum procumbens*)	Calcium, Magnesium, Iron, Phosphorus, Silicon	17
Willow Bark (Salix spp.)	Calcium, Magnesium, Phosphorus, Potassium, Iron	18
Chamomile (*Matricaria chamomilla*)	Calcium, Magnesium, Potassium, Phosphorus, Iron	19
Salvia officinalis (Sage)	Calcium, Iron, Magnesium, Potassium, Phosphorus	20
Piper ovatum	Calcium, Magnesium, Iron, Potassium, Zinc	21

2.1 Mineral-associated Plants

The mineral-associated plants of green tea, licorice, devil's claw, willow bark, chamomile, *Salvia officinalis*, and *Piper ovatum* are rich sources of bioactive compounds known for their potential anti-inflammatory properties. These plants contain a variety of minerals and elements, such as magnesium, calcium, potassium, and others, that can contribute to their therapeutic effects. The specific mineral content can vary among these plants and may influence their anti-inflammatory properties (Table 1).

3.0 Bioactive Compounds in Wild Plants

Wild plants have long been recognized as valuable sources of bioactive compounds with diverse pharmacological properties. These compounds, often found in various parts of these plants, play a crucial role in their adaptability and defense mechanisms against environmental stressors[22]. The following section provides an overview of key bioactive compounds commonly found in wild plants, discusses the major phytochemical categories they belong to, and presents examples of wild plants known for their richness in these compounds.

3.1 Overview of Key Bioactive Compounds

Wild plants are rich sources of a wide array of bioactive compounds[23], many of which have demonstrated anti-inflammatory properties. These compounds are typically secondary metabolites produced by plants to interact with their surroundings. Some of the key bioactive compounds found in wild plants include:

Polyphenols: Polyphenols are a class of compounds characterized by the presence of phenolic rings. They are known for their antioxidant properties and have been extensively studied for their anti-inflammatory effects. Common polyphenols found in wild plants include flavonoids, tannins, and lignans.

Flavonoids: Flavonoids are a diverse group of polyphenolic compounds found in a wide range of wild plants. They are known for their antioxidant and anti-inflammatory activities. Examples of flavonoids include quercetin, kaempferol, and apigenin.

Alkaloids: Alkaloids are nitrogen-containing compounds with a wide range of pharmacological activities. Some alkaloids found in wild plants exhibit anti-inflammatory effects. Notable examples include berberine, nicotine, and caffeine.

Terpenoids: Terpenoids, also known as terpenes, are aromatic compounds found in the essential oils of many wild plants. They have been investigated for their anti-inflammatory and analgesic properties. Limonene, pinene, and menthol are examples of terpenoids.

Saponins: Saponins are glycosides with surfactant properties. They are found in various wild plant species and have demonstrated anti-inflammatory and immunomodulatory effects. Ginsenosides and glycyrrhizin are examples of saponins.

4.0 Anti-inflammatory Potential of Wild Plants

4.1 Green Tea

Leaves of *Camellia sinensis* (Figure 1) have been widely consumed as Green Tea for centuries, particularly in Asia[24] which is enriched with numerous health benefits. Green Tea components have been effective in treating various types of cancer, including mouth, stomach, lung, colon, esophagus, kidney, mammary glands, small intestine, and pancreas. Bioactive compounds have been reported with anti-inflammatory activity such as catechins, flavonoids, and alkaloids Mentioned in Table 4. The intricate

Figure 1. *Camellia sinensis.*

biological process of inflammation has been implicated in the development of diverse chronic diseases, including cancer, diabetes, and cardiovascular conditions[25]. Further research will be necessary to focus on anti-inflammatory effects of green tea.

Multiple studies have contributed to our understanding of the anti-inflammatory properties of green tea, elucidating the involvement of its bioactive compounds through in vitro and in vivo pathways[26]. The bioactive component catechins found in green tea, particularly epigallocatechin gallate (EGCG), is associated with the inhibition of pro-inflammatory cytokines like interleukin-2 (IL-2), interleukin-10 (IL-10), and interferon-gamma (IFN-γ) by modulating the activity of nuclear factor kappa B[27]. Catechins from green tea show an inhibition effect towards the activation of Toll-Like Receptor 4 (TLR4), a key mediator of inflammation and responsible for reduce the production of inflammatory cytokines[28]. Limitation on the human clinical authentication has been responsible for preceding the future research with the actual magnitude of health care which will provide a safe range of tea consumption and reveal the potential behind the mechanisms of action.

Green tea is an active source for the production of Nitric Oxide (NO) which acts as a potent mediator of inflammation and regulates the activity of inducible Nitric Oxide Synthase (iNOS)[29]. Catechins have been detected as an inhibitor in the activity of cyclooxygenase-2 (COX-2). This enzyme plays a key role in the secretion of prostaglandins which are well known to promote inflammation[30]. The pharmacological study of green tea with its bioactive components reported in various diseases such as anticancer, ant-diabetic, and cardioprotective properties[31].

4.2 Licorice

Licorice (Glycyrrhiza glabra) is a widely recognized medicinal plant that has been traditionally employed in the treatment of various inflammatory conditions. The

Figure 2. *Glycyrrhiza glabra.*

Table 2. Some drug interaction due to consumption of licorice and its Potential Interaction

Drug	Potential Interaction
Warfarin	Licorice may inhibit the breakdown of warfarin in the body, leading to increase blood-thinning effects and get converted in the risk of bleeding[37].
Digoxin	Licorice decreases the excretion of digoxin, leading to increased levels of the drug in the body. This could be responsible for increasing the risk of digoxin toxicity[38].
Corticosteroids (e.g., prednisone)	Licorice triggers the effects of corticosteroids with the risk of side effects such as fluid retention, high blood pressure, and potassium depletion[39].
Diuretics (e.g., furosemide)	In the presence of licorice, effectiveness of diuretics reduces their ability to lower blood pressure and remove excess fluid from the body[39,40].
Potassium-sparing diuretics (e.g., spironolactone)	Licorice enhances potassium levels in the body when combined with potassium-sparing diuretics and may lead to dangerously high potassium levels[41].
Antihypertensive medications	Licorice affects blood pressure and counteract the side effects of antihypertensive drugs which has potential to reduce efficacy in managing high blood pressure[42].

The consumption of licorice and its drug interactions with various medications.

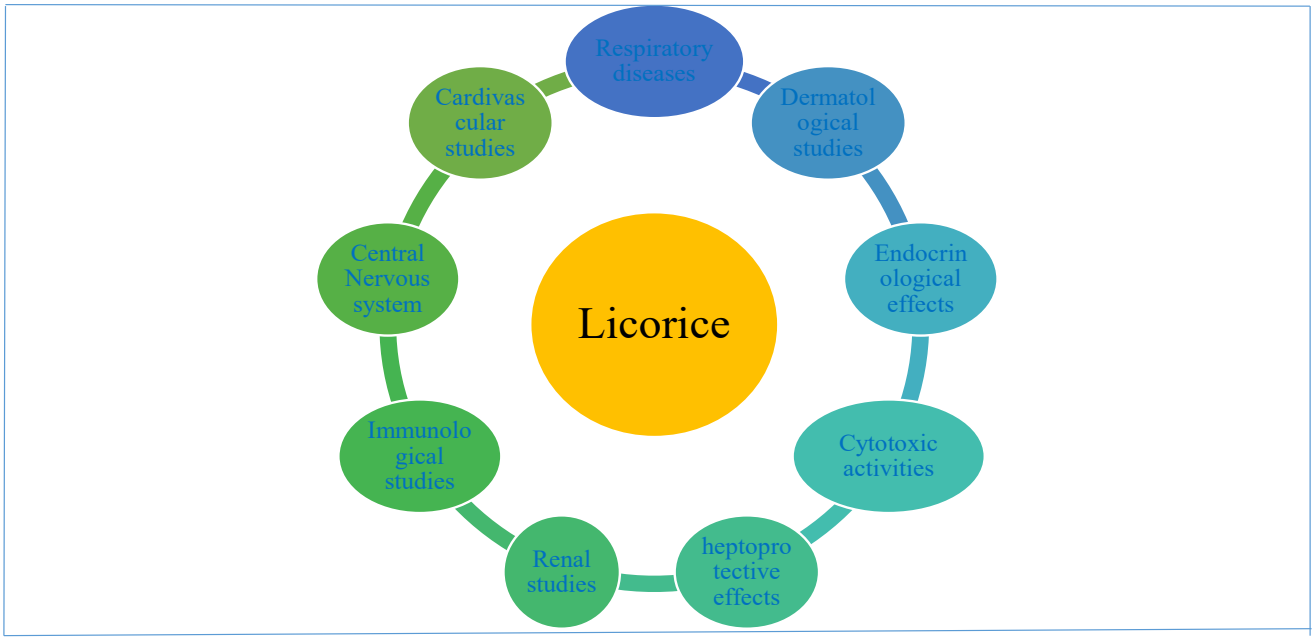

Figure 3. Block diagram of licorice in medicinal application of Licorice.

roots and rhizomes of *Glycyrrhiza* species, depicted in Figure 2, have a long-standing history of use as a natural sweetener and as an integral component of traditional medicine. Licorice root is effective against skin diseases, peptic ulcer, hepatitis C and pulmonary with magical pharmacological properties such as antimicrobial, anti-inflammatory, anticancer activities, immunomodulatory, antiviral, antioxidative, cardioprotective, and, hepatoprotective effects. A diagrammatic representation of the use of licorice is given in Figure 3.

Glycyrrhizin, a significant bioactive compound found in Licorice, demonstrates potent anti-inflammatory properties by inhibiting the production of specific inflammatory molecules, such as interleukin-2 (IL-2), interleukin-12 (IL-12), and interferon-gamma (IFN-γ), thereby preventing the activation of the key molecule NF-κB in the context of inflammation[32,33].

Licorice also detected by the presence of bioactive compounds such as liquiritin, isoliquiritin, liquiritigenin, and, isoliquiritigenin which were reported with anti-inflammatory properties. These compounds are responsible for inhibiting the production of pro-inflammatory cytokines and chemokines by reducing the expression of adhesion molecules and suppressing the activation of NF-κB[23-34]. Several pharmacological components isolated from *licorice* were investigated for their anti-inflammatory effects[35]. They suppress adverse effects such as hypertension and hypokalemia[29], due to the presence of glycyrrhizin. Hence medicinal application of licorice has limitations[36].

4.3 Devil's Claw

Harpagophytum procumbens subsp. *procumbens* (Burch.) selected from Sesame seed Family-Pedaliaceae which is a famous traditional herbal plant known as Devil's claw

Figure 4. *Harpagophytum procumbens.*

(Figure 4). *Devil's claw (Harpagophytum procumbens)* is a native plant to Southern Africa and is effective against arthritis and rheumatism. The root extract was analyzed with various secondary metabolites, which have therapeutic effects. Inflammation means a multifaceted bio-physiological host defense mechanism towards harmful signals such as toxic substances, tissue damage, and unwanted pathogens

4.3.1 Harpagoside

This is the primary bioactive compound investigated in *Devil's claw*, which has inhibition properties against inflammatory due to presence of cytokines and other supportive enzymes[43].

This study focused on the reduction of inflammatory cytokines and inhibition of the activated pathway for the NF-κB signaling in human. With osteoarthritic chondrocytes, potential of anti-inflammatory effects enhanced in osteoarthritis[44]. Health benefits, and potential side effects are mentioned in Table 4.

4.3.2 Proanthocyanidins

Proanthocyanidins [PACs], which are secondary metabolites found in fruits, vegetables, and herbs, offer health benefits by combatting inflammation[43], protecting cells from damage, and even potentially preventing cancer.

4.3.2.1 Anti-inflammatory Effects of Cranberry Proanthocyanidins

Cranberry proanthocyanidins investigated as an agent to terminate the production of inflammatory substances in human colon cells[45].

4.3.2.2. Antioxidant and Anti-Inflammatory Effects of Grape Seed Proanthocyanidins

Literature review concerned with Grape seed proanthocyanidins which includes potent antioxidant and anti-inflammatory effects about *in vitro* and *in vivo* pathways[46].

4.3.2.3. Anticancer Effects of Cocoa Proanthocyanidins

Cocoa proanthocyanidins (PACs) have potential anticancer effects. They possess antioxidant and anti-inflammatory properties. Cocoa PACs can inhibit cancer cell proliferation. They may hinder angiogenesis, the formation of new blood vessels. Cocoa PACs can suppress cancer cell migration and invasion[46-49].

4.3.2.4. Iridoid Glycosides

Devil's claw contains several iridoid glycosides, which is reducing pain and inflammation by modulating the activity of various receptors in the body[47].

4.3.3 Flavonoids

This plant contains several flavonoids, which are potent antioxidants that help protect cells from oxidative damage.

4.3.3.1 Anti-inflammatory Effects of Flavonoids

In vitro process of *Devil's claw* and its active derivatives analyzed importance of anti-inflammatory activities with flavonoids such as kaempferol and luteolin[48].

4.3.3.2 Blood Flow and Swelling by Flavonoids:

Flavonoids present in *Devil's claw* have potential benefits for improving blood flow and reducing swelling, based on both *in vitro* and *in vivo* studies.

4.4 Willow Bark

Salix alba is commonly known as *willow bark*[50], with application history in traditional medicine for analgesic and anti-inflammatory effects[51] (Figure 5). It contains *salicin* can help reduce inflammation by inhibiting the production of prostaglandins[52], which are chemical messengers that cause inflammation in the body it is

Figure 5. *Salix alba.*

natural compound that is similar in structure to aspirin, and is believed to be responsible for its therapeutic effects. The isolation and synthesis of salicin from *willow bark* in the form of aspirin in the late 1800s have been showing a significant role in pain relief. Willow bark's anti-inflammatory and analgesic effects concern with salicin content which is a natural salicylic acid precursor[53]. *Willow bark* may be a safe and effective alternative to Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) for the treatment of pain and inflammation. Plant extract and salicylic acid have been acting as prohibitant for inflammation rate by blocking key signals like NF- kB and AP-1 in the body[54].

4.5 Chamomile

Scientifically *Chamomile* is also known as *Matricaria chamomilla* or *Chamaemelum nobile*[55] (Figure 6). This herb is reported with versatile medicinal applications which are part of tea, capsules, and essential oil, for managing varied ailments[56]. *Chamomile* was reported in the complex array of bioactive constituents with terpenoids (such as bisabolol and chamazulene), flavonoids (such as quercetin and apigenin)[57], and coumarins. It is administrated for therapeutic use. A literature survey has explored the anti-inflammatory, anxiolytic, and somnolent properties of *chamomile.* suppresses the secretion of substances that generate support for inflammation in skin cells[58]. It flourishes the skin tone as it could reduce inflammation and improve wound healing rate by preventing stress damage[59]. It can potentially interact with certain medications shown in Table 3.

Figure 6. *Chamomile.*

Table 3. Medication of drug interactions that may occur with chamomile

Medication	Interaction with Chammomile	Potential side effect
Warfarin	Increased risk of bleeding	Excessive bleeding[59].
Benzodiazepines	Enhanced sedative effects	Excessive drowsiness, impaired coordination
Aspirin	Increased risk of bleeding	Excessive bleeding[59].
Clopidogrel	Increased risk of bleeding	Excessive bleeding[59].
Barbiturates	Enhanced sedative effects	Excessive drowsiness, impaired coordination[56].
Blood pressure medications	Possible hypotensive effect	Excessive lowering of blood pressure
Diabetes medications	Possible hypoglycemic effect	Excessive lowering of blood sugar[56].
Insulin	Possible hypoglycemic effect	Excessive lowering of blood sugar[56].
Allergy medications	Increased risk of allergic reactions	Allergic reactions in individuals with plant allergies (e.g., ragweed, chrysanthemums) [59].

4.6 *Salvia officinalis*

Sage, scientifically referred to as *Salvia officinalis* revealed a rich history of medicinal and culinary uses[60]. This medicinal plant has a long application history in traditional drugs. It has been used for a variety of health issues, including anti-inflammatories. The anti-inflammatory activity was investigated by selected essential oils from *Salvia officinalis*[61]. The in vivo and in vitro anti-inflammatory potential was evaluated to identify the active components among key compounds such as β-myrcene, borneol, and limonene[62], *Sage (Salvia officinalis)* with its derivatives like triterpenoids, specifically ursolic and oleanolic acids are administrated in neurodegenerative diseases like Alzheimer by neuroprotective benefits[63]. Rosmarinic acid in sage could be studied as an effective therapy for inflammation and oxidative stress-related illnesses and numerous drugs formed in common sage interaction with inflammation in Table 4. The pharmacological properties of these plants reported bioactive compounds such as rosmarinic acid, carnosic, acid and ursolic acid. *Salvia officinalis* was examined with therapeutic potential in the treatment of inflammatory diseases[64].

Figure 7. Sage.

4.7 *Piper ovatum*

Piper ovatum, commonly referred to as "*matico*",[68] is a botanical species belonging to the *Piperaceae* family and indigenous to the South American region. This plant has been conventionally utilized in herbal medicine due to its efficacious anti-inflammatory and antiseptic attributes[69]. The anti-inflammatory and anti-cancer properties of the bioactive components lactones and aristolactams have been extensively studied (Figure 7).

Table 4. Interaction of *Salvia officinalis* (common sage) with inflammation

Medication	Interaction with *Salvia officinalis*	Potential Effects
Nonsteroidal Anti-Inflammatory Drugs (NSAIDs)	Possible additive effects	Increased anti-inflammatory activity, potential risk of gastrointestinal bleeding[65].
Corticosteroids	Possible additive effects	Increased anti-inflammatory activity, potential risk of corticosteroid side effects[66].
Immuno suppressants	Possible interaction	Potential modulation of immune response and effects on immunosuppressive therapy[67].
Antiplatelet drugs	Possible interaction	Potential modulation of platelet function and increased risk of bleeding.
Anticoagulant drugs	Possible interaction	Potential modulation of coagulation and increased risk of bleeding[57].
Herbal supplements with anti-inflammatory properties	Possible additive effects	Increased anti-inflammatory activity, potential risk of excessive suppression of inflammation[59].

Figure 8. *matico.*

***Anti-inflammatory Effects*:** Extracts of *Piper ovatum* assigned with significant anti-inflammatory effects, attributed to the involvement of bioactive compounds such as alkaloids, flavonoids, and terpenoids. The anti-inflammatory effects of *Piper ovatum* extracts could be attributed to the existence of secondary metabolites, which are alkaloids, flavonoids, and terpenoids (Table 5).

Wound Healing: The botanical species are classified as *matico* which is concerned with Anti-Inflammatory effects. Experimental analysis has authenticated the intake of *matico* extract in the topical form which can

Table 5. Plant having Anti-inflammatory potentials

Herb/Plant	Active Compounds	Health Benefits	Potential Side Effects	References
Green Tea	Catechins, caffeine	Antioxidant, may boost metabolism, may reduce risk of chronic diseases	Can cause stomach upset, insomnia, or nervousness if consumed in excess	72-73
Licorice	Glycyrrhizin	May help soothe sore throat and cough, may have anti-inflammatory effects.	Can cause high blood pressure, low potassium levels, and hormonal imbalances if consumed in large amounts over a prolonged period	73-74
Devil's Claw	Harpagosides	May help reduce pain and inflammation, may improve joint function.	Can cause stomach upset, may interact with certain medications	44,75
Willow Bark	Salicin	May help reduce pain and fever, may have anti-inflammatory effects	Can cause stomach upset, may interact with certain medications	76
Chamomile	Apigenin, chamazulene	May help reduce anxiety, promote sleep, and soothe upset stomach	Can cause allergic reactions in some individuals.	77
Salvia officinalis	Triterpenoids	anti-inflammatory, antioxidant, antimicrobial, and antidiabetic	Sage has a wide range of potential therapeutic applications due to its diverse range of bioactive compounds and its various beneficial effects on health.	78-79, 81
Piper ovatum	safrole, myristicin, and elemicin	The essential oils and other compounds in *Piper ovatum* have demonstrated anti-inflammatory effects in animal studies, which may have potential applications in treating inflammatory conditions in humans.	Despite some evidence to the contrary, some sources claim that excessive *Piper ovatum* use may harm the liver.	80, 82

Plant having Anti-inflammatory effect on the basis of selected plant

Table 6. Defense mechanisms of the human body

Defense Mechanism	Description	References
Immune System Response	The immune system includes innate (e.g., macrophages, neutrophils) and adaptive (e.g., T and B cells) components that work together to recognize and combat foreign invaders, including pathogens and inflammatory triggers. The mineral-associated medicinal plants can potentially modulate immune responses.	83
Inflammation Regulation	Inflammation is a key component of the body's defense mechanism against infections and injuries. However, chronic inflammation can be detrimental. Medicinal plants with anti-inflammatory bioactive compounds may help regulate inflammation by targeting cytokines, enzymes, and signaling pathways.	84
Oxidative Stress Defense	Oxidative stress arises from an imbalance between the production of Reactive Oxygen Species (ROS) and the body's antioxidant defenses. Medicinal plants rich in minerals like manganese and zinc can enhance antioxidant capacity, reducing oxidative damage associated with inflammation.	85
Tissue Repair and Regeneration	Tissue repair is essential for restoring damaged structures after inflammation. Some medicinal plants may contain minerals like calcium, required for bone health, and magnesium, important for muscle function, which aid in tissue repair and regeneration.	86
Detoxification and Metal Chelation	The body's detoxification mechanisms, particularly involving minerals like selenium and sulfur, can help remove harmful metals and toxins. Medicinal plants with metal-chelating properties may assist in reducing the impact of metal-associated inflammation.	87
Microbiota and Gut Health	A healthy gut microbiota plays a role in immune regulation and inflammation. Certain medicinal plants, like licorice, may impact gut health through their mineral content, influencing the balance of beneficial and harmful bacteria.	88

Defense mechanisms work together or independently to protect organisms from various harmful agents and maintain their overall well-being and survival.

lead to enhanced wound closure rates and ameliorated inflammatory inflammation in animal models[70] (Table 6).

Antioxidant Effects: A High content of polyphenolic compounds could be acting as cell shield from damage caused by oxidative stress, associated with chronic inflammation and diseases[71].

5.0 Future Directions

The exploration of mineral-associated medicinal plants and their anti-inflammatory potential through an in-depth investigation of bioactive compounds and pharmacological activities has yielded valuable insights into the therapeutic applications of these natural remedies. However, as we delve deeper into this fascinating field, it becomes evident that there is a pressing need for further research. Firstly, while we have identified minerals associated with these plants and their potential contributions to anti-inflammatory effects, more comprehensive studies are required to elucidate the precise mechanisms of action. Understanding how these minerals interact with bioactive compounds and the pathways they modulate is crucial for optimizing their therapeutic potential. Secondly, the safety and

potential side effects of mineral-associated medicinal plants deserve closer scrutiny. Depending on factors such as dosage, duration of use, and individual variations, these plants may have adverse effects or interactions with other medications. Robust clinical trials and toxicological assessments are essential to establish clear guidelines for safe consumption.

Moreover, investigating the synergistic effects of minerals and bioactive compounds within these plants can provide a deeper understanding of their holistic healing properties. Research into the combined action of these elements may unlock novel therapeutic approaches and enhance the efficacy of traditional remedies. Additionally, considering the potential impact of environmental factors, such as soil composition and pollution levels, on the mineral content of these plants is vital. Studying variations in mineral profiles across different geographical regions can help us better harness the medicinal potential of these plants while accounting for regional differences.

6.0 Conclusion

Traditional herbs have low adverse effects and enriched with a wide range of bioactive compounds since the ancient times. This review article supported with some herbal plants which could be overcome the effect of anti-inflammatory agents. Natural anti-inflammatory plant-based drugs being vital part and increases attention as therapeutic agents for various inflammatory disorders. The secondary metabolites derived from selected plants such as *Green tea, Licorice, Devil's claw, Willow bark, Chamomile, Salvia officinalis,* and *Piper ovatum* which were proven to be anti-inflammatory properties by reducing pro-inflammatory cytokines and enzymes. Reported bioactive compounds may offer promising benefits for future drugs, hence it is important to note their potential side effects and interactions with other medications. Further research will be needed to better understand their defense mechanism and therapeutic properties. Overall, the use of natural anti-inflammatory plant-based drugs offers a promising approach for managing inflammation and associated health problems which will enhance efficacy and safety applications in Global market.

7.0 References

1. Amin MU, Khattak MB, Khan MA, *et al*., The role of flavonoids in the treatment of inflammatory disorders. Biomedicine and Pharmacotherapy. 2021; 138:111525.
2. Chen L, Deng H, Cui H, *et al*., Inflammatory responses and inflammation-associated diseases in organs. 2018. Doi: 10.18632/oncotarget.23208
3. Kayabas M. *et al*., Protective effect of hydrogen-rich saline on spinal cord damage in rats. 2023; *16*(4):527. https://doi.org/10.3390/ph16040527
4. Tu Y. *et al*. The discovery of artemisinin (qinghaosu) and gifts from Chinese medicine. Nature Medicine. 2011; 17(10):1217-1220.
5. Kholghi G, *et al*. St. John's wort (*Hypericum perforatum*) and depression: What happens to the neurotransmitter systems? Naunyn-Schmiedeberg's Archives of Pharmacology. 2022; 395(6):629-642. https://doi.org/10.1007/s00210-022-02229-z
6. Hou J, *et al*. *Ginkgo biloba* extracts improve choroidal circulation leading to suppression of myopia in mice. Scientific Reports. 2023; 13(1):3772. https://doi.org/10.1038/s41598-023-30908-1
7. Naveed R, Hussain I, Tawab A, *et al*. A review on biological, nutraceutical and clinical aspects of French maritime pine bark extract. Journal of Ethnopharmacology. 2016; 190:224-236. doi: 10.1016/j.jep.2016.06.045
8. Mendes, *et al*. Tannins and flavonoids from plants used in the treatment of gastrointestinal diseases as anti-inflammatory agents. Molecules. 2020; 25(15):3533.
9. Kim YJ, *et al*. Anti-inflammatory effects of phenolic compounds isolated from the bark of Cinnamomum Cassia. Molecules. 2018; 23(11):2927.
10. Ciaunica A, Shmeleva EV, Levin M. The brain is not mental! coupling neuronal and immune cellular processing in human organisms. Front Integr Neurosci. 2023 May 17; 17:1057622. doi: 10.3389/fnint.2023.1057622. eCollection 2023.
11. Hou K, Wu ZX, Chen XY, *et al*. Signal transduct target ther. microbiota in health and diseases. 2022 Apr 23; 7(1):135. doi: 10.1038/s41392-022-00974-4.
12. Diab A, Dastmalchi LN, Gulati M, *et al*., A heart-healthy diet for cardiovascular disease prevention: where are we now? Vasc Health Risk Manag. 2023 Apr; 21; 19:237-253. doi: 10.2147/VHRM.S379874. eCollection 2023.
13. Alamil JMR, Paudel KR, Chan Y, *et al*., Rediscovering the therapeutic potential of agarwood in the management of

chronic inflammatory diseases. Molecules. 2022 May; 9; 27(9):3038. doi: 10.3390/molecules27093038.
14. Fabricant DS, Farnsworth NR. The value of plants used in traditional medicine for drug discovery. Environmental Health Perspectives. 2001; 109(Suppl 1):69-75. doi: 10.1289/ehp.01109s169.
15. Prasanth MI, Sivamaruthi BS, Chaiyasut C, Tencomnao T. A review of the role of green tea (*Camellia sinensis*) in antiphotoaging, stress resistance, neuroprotection, and autophagy. Nutrients. 2019; 11(2):474. https://doi.org/10.3390/nu11020474
16. Pastorino G, Cornara L, Soares S, Rodrigues F, Oliveira MBP. Liquorice (*Glycyrrhiza glabra*): A phytochemical and pharmacological review. Phytotherapy Research. 2018; 32(12):2323–2339. https://doi.org/10.1002/ptr.6178.
17. Brendler T. From bush medicine to modern phytopharmaceutical: a bibliographic review of Devil's claw (Harpagophytum spp.). Pharmaceuticals. 2021; 14(8):726. https://doi.org/10.3390/ph14080726
18. Warmiński K, Stolarski M, Gil L and Krzyżaniak M. Willow bark and wood as a source of bioactive compounds and bioenergy feedstock. Industrial Crops and Products. 2021; 171:113976. https://doi.org/10.1016/j.indcrop.2021.113976
19. Singh, O, Khanam Z, Misra N, Srivastava M. Chamomile (*Matricaria chamomilla* L.): An overview. Pharmacognosy Reviews. 2011; 5(9):82. https://doi.org/10.4103/0973-7847.79103
20. Khedher MRB, Khedher SB, Chaieb I, Tounsi S, Hammami M. Chemical composition and biological activities of Salvia officinalis essential oil from Tunisia. PubMed, 2017; 16:160–173. https://doi.org/10.17179/excli2016-832
21. Silva DR, Endo EH, Filho BP, *et al*., Chemical composition and antimicrobial properties of *Piper ovatum* Vahl. Molecules. 2009; 14(3):1171–1182. https://doi.org/10.3390/molecules14031171
22. Samtiya M, Aluko RE, Dhewa T, Moreno-Rojas JM. Potential health benefits of plant food-derived bioactive components: an overview. Foods. 2021; 10(4):839. https://doi.org/10.3390/foods10040839
23. Liu RH. Dietary bioactive compounds and their health implications. Journal of Food Science. 2013; 78(s1):A18–A25. https://doi.org/10.1111/1750-3841.12101
24. Chacko SM, *et al*., Beneficial effects of green tea: a literature review. Chinese Medicine. 2010; 5(1):13. doi: 10.1186/1749-8546-5-13.
25. Cabrera C, Artacho R, Giménez R. Beneficial effects of green tea—a review. Journal of the American College of Nutrition. 2006; 25(2):79-99. doi: 10.1080/07315724.2006.10719518.
26. Bhattacharya S, Rana T. *In vitro* and *in vivo* evaluation of green tea extract against the inflammation associated with cardiovascular disease. Journal of Functional Foods. 2020; 73:104151. doi: 10.1016/j.jff.2020.104151.
27. Kim H, *et al*., Epigallocatechin-3-Gallate (EGCG) suppresses lipopolysaccharide-induced Toll-Like Receptor 4 (TLR4) Activity via 67-kDa Laminin Receptor (67LR) in Human Gingival Fibroblasts. Molecules. 2018; 23(5):1045.
28. Tian F, *et al*., Epigallocatechin-3-gallate (EGCG) attenuates high glucose-induced insulin signal defects in human umbilical vein endothelial cells. Journal of Functional Foods. 2018; 47:234-242.
29. Nam D, *et al*., Green tea catechins suppress NO-induced iNOS expression via a p38 MAPK-dependent pathway in human dental pulp cells. Archives of Oral Biology. 2018; 85:62-68.
30. Feng R, *et al*., Epigallocatechingallate inhibits the expression of cyclooxygenase-2 in peripheral blood mononuclear cells of patients with cervical cancer. Oncology Letters. 2018; 16(3):2923-2928.
31. Khan N, Mukhtar H. Tea and health: studies in humans. Current Pharmaceutical Design. 2018; 24(19):2141-2147.
32. Hosseinzadeh H, Nassiri-Asl M. Pharmacological effects of Glycyrrhiza spp. and its bioactive constituents: update and review. Phytother Res. 2015; 29(12):1868-1886. doi: 10.1002/ptr.5487.
33. Chen W, Liu Y, Li Y, *et al*., Traditional uses, phytochemistry, pharmacology, pharmacokinetics and toxicology of Glycyrrhizaglabra L.: a review. J Ethnopharmacol. 2021; 267:113546. doi: 10.1016/j.jep.2020.113546.
34. Zhang X, Wang L, Peng Y, *et al*., Glycyrrhizin, a potential drug candidate, inhibits inflammation-mediated colorectal carcinogenesis and chemoresistance. Cancer Cell Int. 2019; 19:324. doi: 10.1186/s12935-019-1015-7.
35. Kim SJ, Kim SY, Kim JK, *et al*., Anti-inflammatory effects of liquiritigenin as a consequence of the inhibition of NF-κB-dependent iNOS and proinflammatory cytokines production. Br J Pharmacol. 2018; 154(1):165-173. doi: 10.1038/bjp.2008.65.
36. Li W, Li Y, Li J, *et al*., Hypertension and related cardiovascular disease burden in China. Ann Transl Med. 2019; 7(9):192. Doi: 10.21037/atm.2019.03.56.

37. Tavakkoli-Kakhki M, Motavasselian M, Talasaz AH, *et al.* Iran J Basic Med Sci. 2018; 21(2):91-99. doi: 10.22038/ijbms.2018.23148.5853.
38. Alkherat AM, Alkhalidi DK. Assessment of knowledge and counseling practice of warfarin among pharmacists in UAE: A cross-sectional study. Pharm Pract (Granada), 2022; 20(4):2741. https://doi.org/10.18549/PharmPract.2022.4.2741
39. Wahab S, *et al*., Glycyrrhizaglabra (Licorice): a comprehensive review on its phytochemistry, biological activities, clinical evidence and toxicology. Plants (Basel). 2021; 10(12):2751. https://doi.org/10.3390/plants10122751
40. Khan Tahir M, Patel R, Siddiqui AH. Furosemide**.** 2023 Jan. PMID: 29763096 Bookshelf ID: NBK499921
41. Felker GM, *et al*., Diuretic strategies in patients with acute decompensated heart failure. The New England Journal of Medicine. 2011; 364(9):797-805.
42. Ferreira JP, *et al*., Proteomic and mechanistic analysis of spironolactone in patients at risk for HF. JACC Heart Failure. 2021; 9(4):268-277. https://doi.org/10.1016/j.jchf.2020.11.010
43. Mishima E, Abe T. Role of the microbiota in hypertension and antihypertensive drug metabolism. Hypertens Res. Feb 2022; 45(2):246-253. doi: 10.1038/s41440-021-00804-0. Epub 2021 Dec 9.PMID: 34887530
44. Ju-Young K, *et al*., Harpagoside attenuates local bone Erosion and systemic osteoporosis in collagen-induced arthritis in mice. BMC Complement Med Ther. 2022 Aug 10; 22(1):214. doi: 10.1186/s12906-022-03694-y.
45. Gxaba N, Manganyi MC. The fight against infection and pain: Devil's Claw (*Harpagophytum procumbens*) a Rich Source of Anti-Inflammatory Activity. Molecules. 2022 Jun; 6:27(11):3637. doi: 10.3390/molecules27113637.
46. Kaur R, Shekhar S, Prasad K. Secondary metabolites of fruits and vegetables with antioxidant potential. 2022 Feb 14; doi: 10.5772/intechopen.103707
47. Gudoityte E. *et al*., Ursolic and oleanolic acids: plant metabolites with neuroprotective potential. Int J Mol Sci. 2021; 22:4599. doi: 10.3390/ijms22094599
48. Sheng K, *et al*., Alleviation effects of grape seed proanthocyanidin extract on inflammation and oxidative stress in a D-galactose-induced aging mouse model by modulating the gut microbiota. Food Funct. 2022 Feb 7; 13(3):1348-1359. doi: 10.1039/d1fo03396d.
49. Gxaba N, Manganyi MC. The fight against infection and pain: Devil's Claw (*Harpagophytum procumbens*) a Rich Source of Anti-Inflammatory Activity. Molecules. 2022 Jun 6; 27(11):3637. doi: 10.3390/molecules27113637.
50. Ewelina P, Dybowska M, *et al*., Identification and accumulation of phenolic compounds in the leaves and bark of *Salix alba* (L.) and their biological. Biomolecules. 2020; 10(10):1391; https://doi.org/10.3390/biom10101391
51. Chrubasik S, *et al*., Treatment of low back pain exacerbations with willow bark extract: a randomized double-blind study. Am J Med. 2000; 109(1):9-14. doi: 10.1016/s0002-9343(00)00461-1.
52. Nora T, Mahmoud MF, *et al*. Phytochemistry, pharmacology and medicinal uses of plants of the genus salix: an updated review. Front Pharmacol. 2021. https://doi.org/10.3389/fphar.2021.593856
53. Antoniadou K, *et al*., Identification of salicylates in willow bark (salix cortex) for targeting peripheral inflammation. Int J Mol Sci. 2021 October 15; 22(20):11138. doi: 10.3390/ijms222011138.
54. Sinniah A, Yazid S, Flower RJ. From NSAIDs to glucocorticoids and beyond. Cells. 2021 Dec 14; 10(12):3524. doi: 10.3390/cells10123524
55. Sah A, Naseef PP, Kuruniyan *et al*. A comprehensive study of therapeutic applications of chamomile. Pharmaceuticals (Basel). 2022 Oct 19; 15(10):1284. doi: 10.3390/ph15101284.
56. Amel B, *et al*., Chemical composition and biological activities of essential oils of *Matricaria chamomilla* L. from Tunisia. Chemistry and Biodiversity. 2020. doi: 10.1002/cbdv.201900619.
57. Srivastava JK, Shankar E, Gupta S. Inhibitory effects of chamomile extract on tumor necrosis factor alpha-induced activation of NF-kappaB in keratinocytes. Molecular and Cellular Biochemistry. 2010; doi: 10.1007/s11010-009-0305-x
58. Bako E, Fehervari P, Garami A, *et al*., Efficacy of topical essential oils in musculoskeletal disorders: systematic review and meta-analysis of randomized controlled trials. Pharmaceuticals. 2023 Jan 19; 16(2):144. doi: 10.3390/ph16020144.
59. Garbuio DC, Leite MN, Figueiredo SA, *et al*. Topical formulation containing chitosan-chamomile microparticles in cutaneous wound healing in rats. J Wound Care. 2023 Mar 2; 32(Sup3a):xxii-xxx. doi: 10.12968/jowc.2023.32.Sup3a.xxii.
60. Tan CSS, *et al*., Warfarin and food, herbal or dietary supplement interactions: A systematic review. Br J Clin Pharmacol. 2021 Feb; 87(2):352-374. doi: 10.1111/bcp.14404.
61. Wu SJ, Liou CJ, Chen YL, *et al*., Fucoxanthin ameliorates oxidative stress and airway inflammation in tracheal epi-

thelial cells and asthmatic mice. Cells. 2021; 10(6):1311. doi: 10.3390/cells10061311.
62. Farzaei MH, Abbasabadi Z, Ardekani MRS, *et al*., A review on the composition, properties, and therapeutic applications of *Salvia officinalis*. Journal of Acupuncture and Meridian Studies. 2019; doi: 10.1016/j.jams.2019.01.004
63. Jalalipour M, Yegdaneh A, Talebi A, *et al*. *Salvia officinalis* leaf extracts protect against acute colitis in rats. Res Pharm Sci. 2022 Jul 14; 17(4):350-359. doi: 10.4103/1735-5362.350236. eCollection 2022 Aug.
64. Masyita A, Sari R, Astuti AD, *et al*., Terpenes and terpenoids as main bioactive compounds of essential oils, their roles in human health. 2022 March 30; 13:100217. doi: 10.1016/j.fochx.2022.100217.
65. Kim M, Jung J, Jeong NY, *et al*., The natural plant flavonoid apigenin is a strong antioxidant that effectively delays peripheral neurodegenerative processes. AnatSciInt, 2019; 94(4):285-294. doi: 10.1007/s12565-019-00486-2.
66. Ladio TA, Lozada M. Comparison of wild edible plant diversity and foraging strategies in two aboriginal communities of northwestern Patagonia, Argentina. 2004. doi: 10.2993/0278-0771(2004)24[239:COWEPD]2.0.CO;2
67. Banerjee S, Butcher R. Pharmacological interventions for chronic pain in pediatric patients: a review of guidelines. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health. 2020 May 5; PMID: 33119240.
68. Lasheen RA, El Tohamy A, Salaheldin EO. MIS-C frenzy: The importance of considering a broad differential diagnosis. SAGE Open Med Case Rep. 2022 March 30. doi: 10.1177/2050313X221088397. eCollection 2022. PMID: 35371489
69. Bhat R, Kamath NS, Rao R, Sneha S. Varicella pneumonia masquerading as interstitial lung disease: Non-specific interstitial pneumonitis. SAGE Open Med Case Rep. 2021 November 19; 9:2050313X211059293. doi: 10.1177/2050313X211059293.eCollection 2021.
70. Monteiro SS, *et al*., Chemical composition and antimicrobial activity of essential oil of Piper ovatumVahl. Journal of Essential Oil Research. 2010. doi: 10.1080/10412905.2010.9700256
71. Carvalho Lima L. de, *et al*., Aristolactams and other chemical constituents from the leaves of *Piper ovatum* Vahl (Piperaceae) and their cytotoxicity. Molecules. 2021. doi: 10.3390/molecules26185828
72. Rojas JA, Bermúdez CO, Hernández JM, *et al*., Evaluation of the wound healing properties of Piper marginatum and Piper tuberculatum extracts in guinea pigs. Journal of Ethnopharmacology. 2010. doi: 10.1016/j.jep.2010.04.004
73. Gutiérrez-Grijalva AB, et al., Phenolic composition, antioxidant capacity and in vitro anti-inflammatory activity of infusions from Matico (*Piper aduncum*) Leaves. 2018. doi: 10.1007/s11130-018-0675-5
74. Farhan M. *et al*., Green tea catechins: nature's way of preventing and treating cancer. International Journal of Molecular Sciences. 2022; 23(18):10713. doi: 10.3390/ijms231810713.
75. Musial C, Kuban-Jankowska A, Gorska-Ponikowska M. Beneficial properties of green tea catechins. International Journal of Molecular Sciences. 2020; 21(5):1744. doi: 10.3390/ijms21051744.
76. Lin C, Tsai SH, Che L, Hung, Y. Willow Bark (Salix spp.) used for pain relief in arthritis: a meta-analysis of randomized controlled trials. Life. 2023: 13(10):2058. https://doi.org/10.3390/life13102058
77. Hattori T, Wada Y, Yamada K, *et al*. Glycyrrhetinic acid inhibits angiogenic activity of endothelial cells and stimulates cell death by activating the unfolded protein response. Biochemical and Biophysical Research Communications. 2017; 493(1):120-126.
78. Brendler T. From bush medicine to modern phytopharmaceutical: a bibliographic review of Devil's Claw (*Harpagophytum* spp.). Pharmaceuticals (Basel). 2021 Jul 27; 14(8):726. doi: 10.3390/ph14080726.
79. Shara M, Stohs SJ, Mukattash TL. Cardiovascular safety of herbal medicines: a review of human and animal toxicological data. Drug safety. 2015; 38(9):809-828.
80. Lord C, Charman T, Havdahl A, *et al*., The Lancet Commission on the future of care and clinical research in autism. 2022 Jan 15; 399(10321):271-334. doi: 10.1016/S0140-6736(21)01541-5. Epub 2021 Dec 6.
81. Barros M, Poppe SC, Bondan EF. *Salvia officinalis* and its main tanshinones: potential in the treatment of Alzheimer's disease and other neurodegenerative disorders. 2018. doi: 10.4103/1673-5374.230273
82. Yépez-Silva LD, et.al. Anti-inflammatory activity of ethanolic extract from *Piper ovatum* Vahl. Journal of Ethnopharmacology. 2020. doi: 10.1016/j.jep.2020.112896
83. Oguntibeju OO. Medicinal plants with anti-inflammatory activities from selected countries and regions of Africa. Journal of Inflammation Research. 2018; 11:307–317. https://doi.org/10.2147/jir.s167789
84. Barnes PJ. Targeting the epigenome in the treatment of asthma and chronic obstructive pulmonary disease.

Proc Am Thorac Soc. 2009; 6(8):693–696. [PubMed] [Google Scholar]
85. Ahmed AU. An overview of inflammation: mechanism and consequences. Frontiers in Biology. 2011; 6(4). https://doi.org/10.1007/s11515-011-1123-9
86. Chen L, Deng H, Cui H, Fang J, Zuo Z, Deng J, Li Y, Wang X, Zhao L. Inflammatory responses and inflammation-associated diseases in organs. Oncotarget. 2017; 9(6):7204–7218. https://doi.org/10.18632/oncotarget.23208
87. Singh V. Medicinal plants and bone healing. National Journal of Maxillofacial Surgery. 2017; 8(1):4. https://doi.org/10.4103/0975-5950.208972
88. Staples JE, Breiman RF, Powers AM. Chikungunya fever: An epidemiological review of a re-emerging infectious disease. Clin Infect Dis. 2009; 49:942-948. [Google Scholar]