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Table: 2, Figs: 1

Therapeutic Potentials of Medicinal Plants Anti-Inflammatory Properties

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ABSTRACT

Inflammation is an essential part of the body's cellular defence, triggered by pathogens, allergens, damaged cells, and toxic compounds. It signals the process of tissue repair and remodelling, typically causing redness, heat, swelling, pain, and loss of function. Conventional treatments for inflammatory conditions often have significant side effects. Conversely, herbal remedies are safer with fewer adverse effects. Based on traditional Ayurveda, these remedies offer a holistic approach to reduced inflammation. This review examines various phytoconstituents known for their anti-inflammatory properties and evaluates the effectiveness of herbal approaches in managing inflammation and aims to present herbal remedies as viable alternatives to conventional treatments.

Keywords: Herbal remedies, Inflammation, Medicinal Plants, phytoconstituents, Therapeutic Potentials,

1. INTRODUCTION

Inflammation serves as the body's defence to harmful stimuli like tissue injury or allergens. However, when inflammation becomes unregulated, it becomes the primary contributor to many disorders (allergies, cardiovascular issues, metabolic syndrome and autoimmune diseases). These conditions impose a significant economic burden on people (8). The initial phase of inflammation, termed acute inflammation, involves heightened movement of plasma and innate immune cells like neutrophils and macrophages from the

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bloodstream into the affected tissues. Chronic inflammation, on the other hand, involves a progressive alteration in the cellular composition at the site of inflammation and is characterized by simultaneous tissue destruction and healing. Despite the triggering factor, the mechanisms underlying the inflammatory process are consistent across all cases, with common signs including increased blood flow, elevated cellular metabolism, vasodilation, release of soluble mediators, leakage of fluids, and influx of cells into the affected area (20). When encountering the inflammatory agent, cell membranes initiate phospholipase A2 activation, leading to the release of arachidonic acid and inflammatory mediators like cytokines, serotonin, histamine, prostaglandin, and leukotrienes. These mediators enhance vascular permeability, thereby facilitating the migration of leukocytes to the inflammatory site.(16,19). Numerous medications are available to manage and alleviate inflammatory episodes, including steroids, nonsteroidal anti-inflammatory drugs, and immune-suppressants. However, these medications can often be linked to adverse effects. In practice, our objective is to administer the minimum effective dose that offers maximum efficacy while minimizing adverse effects. Therefore, integrating natural anti-inflammatory agents into medication becomes essential to enhance pharmacological response and minimize undesirable side effects (17,22). Though a number of synthetic anti-inflammatory drugs like steroids, nonsteroidal anti-inflammatory drugs (NSAIDs) and immunosuppressants are well-established for use in inflammatory disorders, their long term use is limited by the associated side effects.(23). Therefore, the need of safe, easily available and cost effective treatments of inflammatory disorders led to the exploration of plant based drugs. A number of medicinal plants are being used successfully in the treatment of inflammation since ancient times and are being successfully converted into their convenient, elegant .and effective dosage forms for use in the context of modern medicines.(26). The pathophysiology of inflammatory process involves activation of monocyte cells which further initiate cascade of pro-inflammatory signalling pathways leading to regulation of downstream transcriptional factors such as nuclear factor kappa B (NF-KB) and interferon regulatory factor 1 (IRF-1). These factors induce expression of proinflammatory cytokines such as interleukin (IL) including IL-1, IL-1b, IL-6 and tumor necrosis factor-a (TNF-a)(47).

2. HERBAL TREATMENT OF INFLAMMATION

Herbal remedies have a long history of use in combating inflammation (24). For centuries, different cultures around the world have relied on plants to treat swelling, pain and other inflammatory symptoms. From ancient Egyptian papyrus scrolls mentions the use of willow bark for pain relief to traditional Chinese medicine using ginger for arthritis, these plants have been used as natural anti-inflammatories (44). Modern science is now catching up this traditional wisdom. Research shows that many herbs possess bioactive compounds with potent anti-inflammatory properties (38). For instance curcumin, the active ingredient in turmeric effectively manages inflammation associated with arthritis (41). Similarly, ginger's anti-inflammatory effects reduces the production of inflammatory molecules in the body (11). These are a few examples, and ongoing research continues to unveil the potential of various herbs in providing natural relief from inflammation.

Figure 1. Potential Medicinal plants having Anti-inflammatory properties

Natural products are being used from ancient times to treat various disorders and are considered safe as compared to synthetic drugs (51). Medicinal plants and their chemical constituents have been used to treat the inflammatory disorders (Table 1 and Table 2). A number of plant derived chemical constituents (Alkaloids, tannins, flavonoids, terpenoids, glycosides, carotenoids and saponins) possess anti-inflammatory properties. Some important medicinal plants and their bioactive principles used as anti-inflammatory agents are discussed (52).

Table 1. Plants used to treat inflammation and their mechanism of action.

Plant Name	Common Name	Plant Part	Mode of action	Ref
Achillea millefolium L.	Yarrow	Whole plant	Inhibits enzymes like cyclooxygenase (COX)	12,29
Adhatoda vasica L	Malabar Nut	Leaves	Inhibits the inflammatory molecules like cytokines and prostaglandins.	10,35
Lycopodium clavatum L.	Clubmoss	Aerial Parts	Inhibits the production of inflammatory molecules and enzymes, and down-regulate NF-κB and also have antioxidant property.	4,37
Lippia nodiflora L.	Jal Buti	Leaves	Inhibits the inflammatory molecules such as TNF-α, IL-6 and IL-1β, and. also interfere with cellular signalling pathways (MAPK, NF-κB) .	2,9
Tuberaria lignose Samp.	Rock-rose	Leaves	Suppresses the production of pro-inflammatory mediators like prostaglandins, cytokines , and leukotrienes.	32,39
Azardirachta indica A.Juss.	Neem tree	Leaves	Inhibits the activity of NF-κB	18,25
Thespesia populnea L.	Portia tree	Leaves and Bark	Inhibits the activation of NF-Kb	45,46

2.1 *Curcuma longa* L : *Curcuma longa* L. (Zingiberaceae) rhizomes are the source of curcumin (diferuloylmethane), which has been used as a spice since ancient times **(Table 2).** Many inflammatory conditions have been treated using curcumin as a protective agent, including hepatitis, depression, diabetes, Parkinson's disease, cancer, and cardiovascular illnesses (43). Curcumin's anti-inflammatory properties are ascribed to its inhibition of lipoxygenase (LOX), cyclooxygenase (COX), matrix metalloproteinase-9 (MMP-9) and IL-1b/TNF-a, which are all mediated by nuclear factor kappa beta (NF-kB). Curcumin stimulates intestinal T cells with a hyporesponsive phenotype via inducing dendritic cells. Additionally, the curcumin-treated dendritic cells reduces the antigen-presenting capacity, which decreased the degree of immunological activation (14).

2.2 *Zingiber officinale* Roscoe: Ginger (*Zingiber officinale* Roscoe; Family: Zingiberaceae) is well known for its anti-inflammatory property and is used to treat degenerative disorders (arthritis and rheumatism), digestive health (indigestion, constipation and ulcer), cardiovascular disorders (atherosclerosis and hypertension), vomiting, diabetes mellitus and cancer since ancient times (Table 2). The pharmacologically active phytoconstituents present in ginger includes 6,8,10-gingerol, 6,8,10-shagoal and zingiberine. The protective effect of 6- gingerol in chlorpyrifos induced oxidative damage and inflammation has proved its efficacy in treatment of inflammatory diseases. The anti-inflammatory activity of 6-gingerol is attributed to its potential to lower the levels of NO, TNF-a and caspase-3. It also improves activity of superoxide dismutase (SOD), catalase (38) and Glutathione

S-transferases (GST) (1). Clinical efficacy of 6- shagoal in gouty arthritis has been investigated in monosodium urate induced inflammation in mice. Administration of 6-shagoal reduced the levels of b-glucourinidase, TNF-a and lactate dehydrogenase and hence, can be considered useful to treat gouty arthritis (42).

Table 2. Medicinal Plants with Anti-Inflammation Properties

Plant	Family	Phytoconstituent	Chemical Class	Target	Ref
Curcuma longa L.	Zingiberaceae	Curcumin	Diferuloylmethane	LOX, MMP-9, COX-2, IL-1b	43
Zingiber officinale Roscoe	Zingiberaceae	Shagoal and gingerol	Phenol	NO, TNF-α, caspase-3, SOD, GST, CAT	31
Boswellia serrate Roxb.	Burseraceae	Boswellic acid	Pentacyclic terpene	NO, LTC4, NF-kB of IL-1b, IL-2, IL-4, IL-6, IFN-γ, PGE2	7
Cannabis sativa L.	Cannabaceae	Cannabidiol	Chromone	IFN-γ, IL-6, TNF-α NF-kb	7
Borago officinalis L.	Boraginanceae	γ-Linoleic acid	Omega-6-fatty acid	TNF-α ,PGE	50
Rosmarinus officinalis L.	Lamiaceae	Rosmarinic acid	Polyphenol	TNF-α, NF-kB	5
Coptis chinensis Franch	Buttercups	Berberine	Isoquinoline	RhoA GTPase/NF-kB, TNF-α	15
Gymnema sylvestre Kutz.	Asclepidaceae	Gymnemic acid	Flavonoids	PGE2, NO, IL-1b, IL-6, TNF-a, TG, LDL, VLDL, SOD, CAT, GST	27
Aloe vera (L.) Burm	Liliaceae	Aloin	Anthraquinones	IL-8, PGE2, SOD, ROS	48
Ginkgo biloba L.	Ginkgoaceae	Ginkgolides	Flavonoids, glycosides	MPO, TNF-a, IL-1b, IL-6, GST	28
Elaeagnus angustifolia L.	Elaeagnaceae	Gallic acid	Tannin	TNFa, IL-10, IL-1b, MMP-1, MMP-13	36
Oenothera biennis L.	Onagraceae	Tetracosanol	Fatty alcohol	NO, TNF-a, IL-1b, TXB2, COX-2	34
Arctium lappa L.	Compositae	Arctigenin	Lignan	IL-6, TNF-a, MIP-2, MCP-1, MAdCAM-1, ICAM-1, Th1, Th17, MAPK and VCAM-1	30
Witahnia somnifera L. (Dunal)	Solanaceae	Withanolide	Steroidal lactone	NF-kB, a-CCP, a-CII, CRP	40

2.3 *Boswellia serrata* Roxb : *Boswellia serrata* Roxb. (Family Burseraceae) contains boswellic acid (BA), a pentacyclic terpene. B-boswellic acid, 3-acetyl-b-boswellic acid, 11-keto-b-boswellic acid and 3-acetyl-11-keto-b-boswellic acid. Anti-inflammatory, immunomodulatory, anticancer, anti-asthmatic, anti-ulcerative, antimicrobial, and antirheumatic effects are attributed to BA and its derivatives (Table 2). When compared to a

placebo, *B. serrata* Roxb. extract proved more beneficial in improving the disease in individuals with collagenous colitis. By lowering NO, LT-C4 and NF-kB, oral treatment of a combination of *B. serrata*, Roxb. *Glycyrrhiza glabra* L. and *C. longa* L. has been shown to be useful in the management of bronchial asthma. *B. serrata* extract is an anti-inflammatory agent as it slow down the progression of osteoarthritis in mice by preventing joint damage and blocking IL-1b and TNF-a when administered topically or orally. Additionally, BA and its derivatives have dose-dependent immunomodulatory action. The downregulation of PG, NF-kB, ILs, and TNF-a is thought to be responsible for BA's protective function (49).

2.4 *Cannabis sativa* L: The two main cannabinoid derivatives derived from *Cannabis sativa* L. (Cannabaceae) are tetrahydrocannabinol and cannabidiol (CBD) (Table 2). Because these compounds can inhibit toll-like receptor-4, they are used for neuroprotective, skin-homeostasis, and anti-inflammatory properties. Research has shown the effectiveness of cannabis in treating coronary artery disease, and it promotes immunomodulation in IL-6 and CRP. Cannabis can be used to treat IBD because clinical study has shown its beneficial effects on the gut and its capacity to lower discomfort, inflammation, and hypermotility. Cannabidiol pre-treatment reduced the production of TNF-a and interferon-g (IFN-g) in the knee synovial fluid in mice with collagen-induced arthritis, suggesting that it may be used to treat arthritic disorders (6).

2.5 *Borago officinalis* L : The primary ingredient of *Borago officinalis* L., Boraginanceae family, is g-linoleic acid (GLA). Prostaglandin E (PGE) level, which further reduces TNF-a level and hence has an anti-inflammatory effect in RA (Table 2). In comparison to primrose oil, borago seed oil was found more effective in clinical experiments to reduce inflammation. The higher GLA concentration of borago seed oil contributes to its superior therapeutic efficacy. Ghahremanitamadon investigated how an extract from *B. officinalis* L. (borage) affected memory impairment in male Wistar rats caused by amyloid b (Ab). It was discovered that the extract improved the symptoms of Alzheimer's, such as travelled distance and escape latency(21).

2.6 *Rosmarinus officinalis* L: One of the polyphenolic compounds found in *Rosmarinus officinalis* L. (Lamiaceae) is rosmarinic acid (Table 2). RE reduced the amount of inflammatory proteins and pro-inflammatory ytokines in macrophages. Furthermore, by reducing paw edema and volume, RE was beneficial in treating colitis brought on by DSS. Therefore, RE has been suggested as a dietary supplement for inflammatory bowel diseases. It also suppressed the DSS-induced activation of p38, extracellular regulated kinase (ERK) and c-Jun N-terminal kinase (JNK), mitogen-activated protein kinase (MAPKs), COX-2 and iNOS expressions, and decreased the levels of TNF-a and IL-6 cytokines and the myeloperoxidase activity in the colon tissue. RE reduced the amount of inflammatory proteins and pro-inflammatory cytokines in macrophages. Furthermore, by reducing paw edema and volume, RE proved beneficial in treating colitis brought on by DSS. Therefore, RE has been suggested as a dietary supplement for inflammatory bowel diseases. It also suppressed the DSS-induced activation of p38, extracellular regulated kinase (ERK) and c-Jun N-terminal kinase (JNK), mitogen-activated protein kinase (MAPKs), COX-2 and iNOS expressions, and decreased the levels of TNF-a and IL-6 cytokines and the myeloperoxidase activity in the colon tissue (33).

2.7 *Coptis chinensis* Franch: *Coptis chinensis* Franch is the source of the quaternary ammonium alkaloid berberine (Isoquinoline) **(**Table 2). Additional sources of berberine are: *Berberis aristata* Roxb, *Berberis vulgaris* L. and *Berberis aquifolium* Pursh. In addition to reducing LPS-induced pro-inflammatory cytokines (NO, iNOS, TNF-a, and IL-6), CM markedly increased macrophage proliferation. CM can be used to prevent and cure inflammation-mediated disorders, as it lowered ear and paw edema in mice *in-vivo* (15).

3. QUERCETIN CONTAINING PLANTS

3.1 *Camellia sinensis* (L.) Kuntze

Tea, or *Camellia sinensis* (L.) Kuntze, Theaceae family is the most widely consumed beverage worldwide. It is primary source of numerous active ingredients, including those with anti-inflammatory, anti-oxidant, anti-ulcer, anti-atherosclerotic, hepatoprotective, anti-microbial, and anti-cancer properties. Gallic acid, caffeine, (-)-epigallocatechin gallate, (-) -epicatechin gallate, (-)-epicatechin, (+)-catechin, and polyphenol are among the bioactive ingredients in tea. To find how quercetin affected markers of chronic systemic inflammation in individuals with stable coronary artery disease (CAD), a clinical investigation was done. Quercetin has no effect on IL-10, however, it decreased TNF-a and IL-1b levels (13).

3.2 *Gymnema sylvestre* Retz

Gurmur, another name for Gymnemic acid (GA, *Gymnema sylvestre* Retz, Asclepidaceae), is a native of India and also found in tropical woods in Africa, Australia, and Indonesia (3). Therapeutic applications for GA and its derivatives include the management of infections, inflammations, and diabetes. Moreover, pro-inflammatory cytokines PGE2, NO, IL-1b, IL-6, and TNF-a were all brought back to normal (3).

4. CONCLUSIONS

Herbal products, used as alternative medicines for various ailments, are generally safer compared to synthetic drugs. Plants have long been valued for their medicinal properties, and traditional herbal remedies continue to inspire new drug discoveries. Inflammation-related disorders affect a large portion of the global population and natural compounds derived from medicinal plants present promising alternatives. Phytoconstituents from plants demonstrate anti-inflammatory properties and interact with various inflammation-related pathways. Utilizing the diversity of natural sources in drug discovery opens new possibilities for developing safer and more effective treatments for inflammatory conditions.

AUTHOR'S CONTRIBUTION

In this review, Bobby Tyagi significantly contributed to the conceptualization of the article on Inflammation and its herbal and allopathy treatments. Monika, Avijit Mazumder and Rupa Mazumder conducted the systematic evaluation and articulated the conclusion. All authors have reviewed and approved the final manuscript.

DECLARATION

We affirm that all authors of this manuscript has significantly contributed to its creation. No author who made substantial contributions has been excluded. We adhered to the ethical guidelines set by our respective institutions.

CONFLICT OF INTEREST

The authors announce that they have no conflict of interest.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct.

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