https://doi.org/10.48047/AFJBS.6.5.2024. 10126-10158

AfricanJournalofBiological Sciences

A Review of Ethnopharmacology, Phytochemistry, and Anti-Inflammatory Properties of Selected Medicinal Plants

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Article History
Volume 6, Issue 5, 2024
Received: 22 May 2024
Accepted: 03 Jun 2024
doi:*10.48047/AFJBS.6.5.2024. 10126-10158*

Abstract:

For millennia, the foundation of traditional medicine has been the therapeutic potential of medicinal plants, which provide an abundant supply of natural substances with noteworthy health advantages. With an emphasis on plant characteristics and morphology, ethnopharmacological usage, phytochemical profiles, and anti-inflammatory qualities, this paper offers a thorough examination of twenty well-known medicinal plants. Ginger (Zingiberofficinale), Turmeric (Curcuma longa), Garlic (Allium sativum), Long Pepper (Piper longum), Clove (Syzygiumaromaticum), Kalonji (Nigella sativa), Green Tea (Camellia sinensis), Neem (Azadirachtaindica), Tulsi (Ocimum sanctum), Ashwagandha (Withaniasomnifera), Sarpagandha (Rauvolfiaserpentina), Aloe Vera (Aloe barbadensis), Rosemary (Rosmarinus officinalis), Bamboo (Bambusoideae spp.), Isabgol (Plantagoerosa), Paan (Piper betle), Gandhali (Paederiafoetida), Nirgundi (Vitex negundo), and Boswellia serrata (Indian Frankincense).

To provide a basic understanding of each plant's physical and biological qualities, the botanical description and morphological characteristics are evaluated first. The section on ethnopharmacology delves into the traditional use and cultural significance of these plants, showcasing their use in many medicinal systems worldwide. The section on phytochemistry explores the main bioactive substances found in each plant, clarifying its molecular makeup and biological functions. The section on anti-inflammatory activity summarises research results and describes the processes by which these plants reduce inflammation.

In order to provide a comprehensive understanding of the medicinal benefits of these plants, this thorough assessment attempts to combine traditional knowledge with contemporary scientific research. This paper aims to promote the development of novel therapeutic agents derived from natural sources and to improve knowledge of these plants' roles in health and disease management by offering comprehensive insights into their morphology, ethnopharmacology, phytochemistry, and anti-inflammatory properties.

Keywords:

Bioactive chemicals, Traditional medicine, phytochemistry, ethnopharmacology, medicinal plants, and natural therapeutic agents. Anti-inflammatory properties.

1. Introduction

When bacteria, viruses, or fungi enter the body, lodge in specific tissues, or circulate through the bloodstream, they usually result in inflammation. Events such as degeneration, ischemia, cancer, tissue damage, and cell death can also result in inflammation. The innate immune system, which is made up of mast cells, dendritic cells, and macrophages, is the main defence system against invasive microorganisms and cancer cells. The adaptive immune system is made up of more specialised cells like B and T cells, which use specific antibodies and receptors to fight invasive infections and cancer cells [1]. Inflamed tissues accumulate cells and secretions as a pattern of response to insult, offering protection against further damage. Scientists have studied inflammation for millennia in an attempt to mitigate its impact on the

body. Celsius recorded the first descriptions of the four classic signs of inflammation in AD 30: tumour, rubor, calor, and dolor, or redness, heat, pain, and swelling.

Acute inflammation is commonly accompanied by discomfort, fever, erythema, edoema, and—most importantly—loss of function. White blood cells, or leucocytes, and serum enter the tissues to start the conventional signs. Chronic inflammation leads to a progressive alteration in the type of cells seen at the site of inflammation. It is identified by the simultaneous inflammatory event-induced destruction and healing of the injured tissue.[3]

Many different compounds that are found in plants and combine to alter particular parts of complex biological pathways are the source of herbal remedies. Biologically active compounds have been identified in plant species since prehistoric times. Herbal therapies are being used more frequently these days due to the toxicity and negative side effects of allopathic medications [1]. The mechanism of anti-inflammatory effect demonstrates that this plant has been used in traditional medicines from Southeast Asia and Greece. Rhizomes are also grown for medical uses in Brazil, Australia, Africa, China, India, Bangladesh, Taiwan, Mexico, Japan, Jamaica, the Middle East, and some parts of the United States. The protein appears to have a limited role in the process of inflammatory reactions, as evidenced by molecular research showing that COX-1 mRNA and protein expression remain unchanged in inflammatory settings. TNFα, lipopolysaccharide (LPS), interleukin-1, and other stimuli can activate the inducible enzyme COX-2 when they cause tissue damage. Research indicates that both isotypes can be constitutive and induced depending on the physiological circumstances. [1,4]

Our primary focus is on the carefully chosen botanicals that are readily available and exhibit strong anti-inflammatory properties. The ability to supply new pharmacological compounds or lead molecules for drug development can be extremely beneficial to the pharmaceutical business and the scientific community as a whole.

This review aims to provide a thorough analysis of traditional medicinal plants. By fusing empirical research with the corpus of existing information, our goal is to shed light on the variety, accessibility, and therapeutic uses of these plant resources. In addition to being crucial for conservation efforts, knowing which plants in this area have anti-inflammatory qualities holds enormous promise for drug development and other medicinal improvements.

2. Plant Morphology and Descriptions:

1. Ginger (Zingiber officinale): A perennial herb, ginger has tall, reed-like stems that can grow up to 1.5 metres in height. Its underground rhizomes, which are utilised in traditional medicine and cuisine, have a distinctive spicy flavour and perfume, and its lance-shaped leaves can reach a length of 20 to 30 cm [5].

2. Turmeric (Curcuma longa): Curcuma longa, or turmeric, is a perennial herbaceous plant that grows up to one metre tall on upright, tufted stems. Its subterranean rhizomes, which are dried and powdered into a powder for use in cooking and medicine, have a vivid orange-yellow hue, and its long, lance-shaped leaves can grow up to 45 centimetres in length [6].

3.Garlic (Allium sativum): Allium sativum, often known as garlic, is a perennial bulbous plant that reaches a height of 60 to 90 cm on slender, upright stems. It produces underground bulbs made up of several cloves, each encased in a papery sheath, and its linear leaves can reach lengths of 30 to 60 centimetres [7].

4. Long Pepper (Piper longum): Long pepper is a perennial climbing vine bearing small, greenish blooms in thin, cylindrical spikes. Its fruits can reach a length of 5 to 15 cm and are shaped like elongated catkins. Inside are many tiny, scented, black seeds [8].

5. Clove (Syzygiumaromaticum): Syzygiumaromaticum, or clove, is an evergreen tree with glossy, elliptical leaves and a pyramidal crown. It grows to a height of 10–20 metres, and its fragrant reddish-brown flower buds, known as cloves, are formed from the clusters of blooms it produces [9].

6. Kalonji (Nigella sativa): Nigella sativa, often known as kalonji, is an annual herbaceous plant that reaches a height of 20 to 30 centimetres on slender, upright stems. It contains tiny, black seeds that are used as a spice and in traditional medicine, and its finely split leaves are distributed alternatingly along the stems [10].

7. Green Tea (Camellia sinensis): Camellia sinensis, also known as green tea, is a tiny tree or evergreen shrub with glossy, elliptical leaves that may reach a length of 5 to 10 cm. It yields spherical seed pods with several seeds and tiny, white blooms with yellow stamens [11].

8. Indian Gooseberry (Emblica officinalis): The Indian Gooseberry, or Emblica officinalis, is a medium-sized deciduous tree with delicate, light green leaves and spreading branches. It grows to a height of 8–18 metres, and its spherical, greenish-yellow fruits are widely valued for their high vitamin C content and sour flavour [12].

9. Neem (Azadirachtaindica): Azadirachtaindica, or neem, is a fast-growing evergreen tree with complex leaves that have nine to fifteen leaflets each. Its little white blooms are fragrant and borne in thick clusters; it can grow to a height of fifteen to twenty metres [13].

10.Tulsi (Ocimum sanctum): The intensely aromatic, upright plant tulsi (Ocimum sanctum) has square stems and fragrant, green or purple leaves. Its tiny purple flowers are placed in spikes at the tops of the branches, and it can reach a height of 30 to 60 cm [14].

11.Ashwagandha (Withaniasomnifera): Withaniasomnifera, often known as ashwagandha, is a small shrub with ovate leaves and tiny, yellowish-green flowers. The woody roots of this plant are utilised in traditional medicine due to their adaptogenic qualities. The plant can grow up to 150 cm (30 inches) tall [15].

12.Sarpagandha (Rauvolfiaserpentina): Rauvolfia serpentina, often known as sarpagandha, is a thorny shrub that bears small, white flowers along with glossy, elliptical leaves. Alkaloids having antihypertensive qualities are found in its roots. The plant has a maximum height of 60–150 cm [16].

13.Aloe Vera (Aloe barbadensis): The succulent plant known as aloe vera (Aloe barbadensis) has thick, lance-shaped leaves that are grouped in rosettes. The leaves have a gel-like material that has calming effects and is used in traditional medicine. Aloe vera has a maximum height of 60–100 cm [17].

14.Rosemary (Rosmarinus officinalis): Rosemary (Rosmarinus officinalis) is a fragrant evergreen shrub with tiny, blue blooms and leaves that resemble needles. It is used as a culinary herb, either fresh or dried, and in traditional medicine. It can reach a height of 1-2 metres [18].

15. Bamboo (Bambusoideae spp.): Bamboo, also known as Bamboooideae spp., is a tall, woody grass with long, linear leaves and jointed stems, or culms. Its height varies greatly; some species can grow to heights of more than thirty metres. Traditional medicine makes use of several bamboo species because they offer therapeutic qualities [19].

16. Isabgol (Plantagoerosa): Plantagoerosa, often known as Isabgol, is an annual herbaceous plant with small, inconspicuous blooms and basal rosettes of lanceolate leaves. Its seeds are wrapped in a mucilage that resembles gel and are used as a natural laxative. It can grow to a height of 30 to 60 cm [20].

17. Paan (Piper betle): Paan is a heart-shaped-leafed perennial vine that has tiny white blooms. Cultivated for its leaves, which are chewed with areca nut and other components as a stimulant and digestive aid, it can reach heights of 2-4 metres [21].

18.Gandhali (Paederiafoetida): The gandhali, or Paederiafoetida, is a creeping herbaceous plant that has tiny, tubular blooms and opposite, elliptical leaves. When crushed, it releases an offensive stench that can travel across wide areas. Traditional medicine uses gingkhali to treat a variety of illnesses [22].

19.Nirgundi (Vitex negundo): Vitex negundo, often known as niggundi, is a small tree or shrub with palmately complex leaves and tiny, lavender to white flowers. Because of its analgesic and anti-inflammatory qualities, it is utilised in traditional medicine and can grow to a height of 2 to 8 metres [23].

20.Indian Frankincense (Boswellia serrata): Boswellia serrata, often known as Indian Frankincense, is a deciduous tree that has small, white flowers in addition to pinnate leaves. It can reach a height of 6 to 8 metres and yields frankincense resin, which is used in traditional medicine and has anti-inflammatory qualities [24].

3. The study of ethnopharmacology:

Since ginger (Zingiber officinale) has anti-inflammatory, anti-nausea, and digestive qualities, it is widely utilised in traditional Asian medicine, especially in China and India. It is frequently used in treatments for gastrointestinal issues, arthritis, and colds [26]. Because of its strong anti-inflammatory and antioxidant qualities, turmeric (Curcuma longa) has been used for a very long time in Ayurvedic and traditional Chinese medicine to heal wounds, skin conditions, and joint discomfort. It is frequently used as a powder in teas, topical pastes, and cookery [27]. The medical benefits of garlic (Allium sativum) have been widely acknowledged, particularly in Indian and Chinese medicine, where it is used to treat infections, improve cardiovascular health, and strengthen the immune system. Cloves can be eaten fresh, roasted, or as an extract [28].

An important herb in Ayurvedic medicine, long pepper (Piper longum) is used to treat infections, digestive problems, and respiratory ailments. The dried fruit, called pippali, has warming qualities and increases the bioavailability of other herbs (4). Because of its antibacterial, analgesic, and anti-inflammatory qualities, clove (Syzygiumaromaticum) is

used extensively in traditional medicine in China, India, and Indonesia. It is used to treat infections, gastric issues, and tooth pain [29]. Black seed, or kalonji (Nigella sativa), has anti-inflammatory, immune-stimulating, and digestive properties that are well-known in Unani and Ayurvedic medicine. The oil and seeds are used in a number of treatments [30].

For ages, Chinese and Japanese medicine has utilised green tea (Camellia sinensis) due to its anti-inflammatory, antioxidant, and neuroprotective properties. Both an extract and a beverage are made from it [31]. Ayurveda places great importance on the Indian gooseberry, or Emblica officinalis, better known as Amla, due to its high vitamin C concentration, ability to boost immunity, and ability to reduce inflammation [32]. Traditional Indian medicine makes use of neem (Azadirachtaindica) because of its antibacterial, antifungal, and anti-inflammatory qualities [33]. Because of its adaptogenic and anti-inflammatory properties, tulsi (Ocimum sanctum), often known as holy basil, is highly valued in Ayurvedic medicine and is frequently used in teas, tinctures, and topical applications [34].

A common ingredient in Ayurvedic medicine, ashwagandha (Withaniasomnifera) is well-known for its adaptogenic qualities, which include reducing inflammation, stress, and enhancing general vitality [35]. India has long utilised sarpagandha (Rauvolfiaserpentina) to treat a variety of neurological illnesses, including hypertension [36]. Because of its calming and anti-inflammatory properties, aloe vera (Aloe barbadensis) is frequently utilised, especially for skin diseases and digestive health [37]. In traditional Mediterranean medicine, rosemary (Rosmarinus officinalis) is prized for its anti-inflammatory and cognitive properties [38].

Because bamboo (Bambusoideae spp.) has anti-inflammatory and antioxidant qualities, it is employed in many traditional medical systems [39]. Traditional Indian medicine makes considerable use of isabgol (Plantagoerosa) due to its laxative and anti-inflammatory qualities [40]. Because of its digestive and stimulating qualities, paan (Piper betle) is commonly used in South and Southeast Asia [41]. In traditional Asian medicine, gingkhali (Paederiafoetida) is used to treat inflammation and gastrointestinal problems [42]. Ayurvedic medicine uses niggundi (Vitex negundo) for its analgesic and anti-inflammatory properties [43]. Finally, because of its anti-inflammatory qualities, Boswellia serrata, also known as Indian Frankincense, is utilised in traditional Indian medicine to treat inflammatory diseases including arthritis [44].

4. The study of phytochemistry:

Table 1: lists of the compounds with anti-inflammatory properties.

Plant	Phytoconstituents	Phytochemical category	Parts	Reference
Ginger (*Zingiber officinale*)	Gingerols (6-gingerol, 8-gingerol 10-gingerol 12-gingerol)	Phenolics	Rhizome	[45],[46],[47]
	paradols(6-paradol 8-paradol 10-paradol)	Phenolics		
	shogaol(6- shogaol, 8-shogaol, 10- shogaol)	Phenolics		
	β-bisabolene, α-curcumene, zingiberene, α-farnesene, βsesquiphellandrene, Zingerone,	Terpenes		
	Quercetin, Gingerenone-A, 6-dehydrogingerdione	Flavonoids		
Turmeric (*Curcuma longa*)	Curcuminoids: curcumin, Curcumenol, dimethoxycurcumin, bisdemethoxycurcumin	Phenolics	Rhizome	[48],[49]
	Turmerone, germacrone, zingiberene, and atlantone	Essential oil		
	Turmerone,Atlantone	Essential oil		
Garlic (*Allium sativum*)	Alliin, allicin, ajoenes	Sulphur containing compounds	Bulb	[50],[51]
	Quercetin, Kaempferol, Myricetin	Flavonoids		
	Gallic acid, p- coumaric acid	Phenolics		
Long pepper (*Piper longum*)	Piperine, Piperlongumine	Alkaloids	Seed	[52],[53],[54]
Clove	quercetin , kaempferol , phenolic acids like ferulic, caffeic, ellagic,	Flavonoids	Flower bud	[55]

	and salicylic acids			
	eugenol, eugenol acetate and β-cariofileno cinnamaldehyde, eugenol, carvacrol, and thymol α humelene, α Copaene	essential oil		
	hydroxycinnamic acids, hydroxyphenyl propens flavonoids, and hydroxybenzoic acids	Phenolic compounds		[56]
Kalonji (*Nigella sativa*)	Nigellicimine, Nigellidine, nigellicine	Alkaloids	Seed	[57],[58]
	Kaempferol 3-glucosyl galactosyl glucoside, quercetin 3-galactosyl glucoside, trigillin, vanillic acid	Flavonoids		
	p-cymene, α-pinene, dithymoquinone, thymohydroquinone, Carvacrol, carvone, limonene, 4-terpineol, citronellol, anethol	Terpenes		
	Oleic acid, Linoleic acid, dihomolinoleic acid, eicodadienoic acid, Palmitic acid, stearic acid	Essential oils		
Green tea (*Camellia sinensis*)	Epigallocatechin-3-gallate (EGCG), epicatechin-3-gallate (ECG), epigallocatechin (EGC), epicatechin, Gallocatechin	Polyphenolics	Leaves	[59][60]
	Carotenoids, quinic acid, chlorogenic acids and trigalloylglucose.	Flavonoids		
	Caffeine , gallic acid	Phenolics		

Indian Gooseberry (*Emblica officinalis*)	Gallic Acid, Ellagic Acid, Chebulinic Acid	polyphenol	Fruit	[61],[62]
	Emblicanin A and B	Tannins		
	Phyllantine and Phyllantidine	Alkaloids		
Neem (*Azadirachtain dica*)	Azadirachtin, Nimbin, Nimbidin	Limonoids	Leaves	[63],[64]
	Quercetin, Kaempferol	Flavonoids		
	Nimbolide, Nimocinol	Terpenoids		
	Gallic acid, catachin	Polyphenolics		
Tulsi (*Ocimum sanctum*)	Caffeic acid, menthylsalicylic glucoside, chlorogenic acid, vanillic acid, ocimumnaphthanoic acid	Phenolics	Leaves	[65],[66]
	luteolin, isothymusin, cirsimartin	Flavonoids		
	ocimarin, aeculetin and aesculin	Coumarins		
	β-caryophyllene, 4,5-epoxy-caryophyllene, carnosic acid, oleanolic acid, β-Amyrin-glucopyranoside	Terpenoids		
	Eugenol	Essential oils		
Ashwagandha (*Withniasomnifera*)	withamine, withanmine, Somniferine, ,somniferinine, withanaminine, mesoanaferine, withasomnine, withanine, ashwagandhine	Alkaloids	Root	[67],[68]
	withanolides (withanolideA,D,E,G), Withaferin A	Steroidal lactones		

Sarpagandha (*Rauvolfia serpentine*)	ajmaline, ajmalimine, ajmalicine, deserpidine, indobine, indobinine, reserpine, reserpiline, rescinnamine, rescinnamidine, serpentine, serpentinine	Alkaloid	Root, stem, leaves	[69]
Aloe vera (*Aloe barbadensis* Miller)	Aloin, Emodin, aloetic acid, anthranol,	Anthraquinones	Leaves	[70],[71],[72]
	campesterol, and β-sitosterol	Polyphenolics		
	quercetin and kaempferol	Flavonoids		
	aloin A and B (barbaloin), isobarbaloin	Saponins		
Rosemary (*Rosemarinusofiicinalis*. L)	rosmarinic acid	polyphenol	Leaves	[73],[74],[75]
	carnosic acid and carnosol	Phenolic diterpenes		
	rosmanol, epirosmanol, isorosmanol, rosmadial, rosmaridiphenol, and rosmariquinone	phenolics		
	betulin, amyrin, betulinic acid, oleanic acid, and ursolic acid	Triterpenes		
	apigenin, genkwanin, luteolin, hispidulin, rutin, kaempferol, naringin, hesperetin, apigenin-7-O-glucoside, and quercetin.	Flavonoids		
	Orientin, homoorientin, vitexin and isovitexin	Flavonoids		
Bamboo (Bambusoiseae spp.)	p-coumaric acid, ferulic acid, caffeic acid	Phenolic compounds	Leaves, stem	[76],[77]
	Pinoresinol,Syringaresinol	Lignans		
	Beta-sitosterol	Sterols		
Isabgol (*Plantagoeros*	Luteolin, Apigenin	Flavonoids		[78]

a)				
	Arabinoxylans, Rhamnogalacturonans	Polysaccharides		
	Aucubin	Glycosides		
Paan (*Piper betle*)	Hydroxychavicol, Chavibetol	Phenols		[79],[80]
	Vitexin, Orientin	Flavonoids		
	Piperine	Alkaloids		
	Eugenol	Essential oils		
Gandhali (Paederiafoetida)	Paederoside, Asperuloside	Iridoid		[81],[82]
	Oleanolic acid, Ursolic acid	Triterpenoids		
	Quercetin	Flavonoids		
Nirgundi (*vitex negundo*)	Casticin, Luteolin	Flavonoids	Whole plant	[83],[84]
	Negundoside, Agnuside	Terpenoids		
	Sabinene, Limonene	Essential oils		
Indian Frankincense *(Boswellia serrata*)	AKBA (Acetyl-11-keto-beta-boswellic acid), KBA (11- keto-beta-boswellic acid)	Boswellic Acids	Resin	[85],[86]
	Incensole, Incensole acetate	Essential oils		

5. Anti-inflammatory activity of Selected Plants:

1. Ginger

Ginger's anti-inflammatory qualities have long been recognised and appreciated. The early 1970s finding of ginger's inhibitory effects on prostaglandin production has been validated

time and time again. This finding revealed ginger to be a natural remedy with pharmacological characteristics similar to nonsteroidal anti-inflammatory medication. By inhibiting cyclooxygenase-1 and cyclooxygenase-2, ginger reduces the generation of prostaglandins. The discovery that ginger also inhibits 5-lipoxygenase, which decreases leukotriene production, was a significant expansion of this early work. Ginger's pharmacological characteristic sets it apart from nonsteroidal anti-inflammatory medications. It has been demonstrated that ginger chemicals, such as 6-gingerol, prevent the generation of pro-inflammatory cytokines such TNF-α, IL-1β, and IL-6. These cytokines are essential for the inflammatory response, and inhibiting them contributes to the reduction of inflammation [88].

Nearly forty antioxidant chemicals found in ginger can be used to treat a variety of inflammatory diseases. Therefore, some symptoms associated with an inflammatory process may be relieved by the gingerols, shogaols, and diarylheptanoids found in ginger. Ginger has the potential to treat some disorders, including obesity, which is marked by elevated levels of pro-inflammatory markers. This is because ginger acts through the paraoxonase-1 mechanism, which prevents the buildup of lipidic substances in vessel walls.

Moreover, ginger chemicals including 6-gingerol and 6-shogaol reduce inflammation by preventing the synthesis of pro-inflammatory transcription factor (NF-κB), prostaglandin E2, NO, inflammatory cytokines (TNF-α), and interleukin-1β (IL-1β). Moreover, they suppress COX-1 and COX-2. According to several publications, 6-shogaol limits the release of arachidonic acid more than 6-gingerol and reduces the synthesis of nitric oxide (NO) more than the latter [89].

2. Ginger

In India, turmeric has long been used topically to treat skin conditions, insect stings, and chickenpox. It is considered an alternative medicine that promotes wound healing. In mouse-wound models with diabetes and hydrocortisone, curcumin therapy promotes granulation tissue development and neovascularization, speeds up wound contraction, and increases fibronectin and collagen production in myofibroblasts. Curcumin dramatically shortens the time it takes for wounds to heal by reducing hydrogen peroxide-induced damage in yellow keratinocytes and fibroblasts. Curcumin has antiulcer properties in mice models by decreasing oxidation of proteins and lipids and encouraging re-epithelialization to repair damage to gastric epithelial cells.

Curcumin has exhibited the capacity to inhibit multiple inflammatory targets, such as inducible nitric oxide synthase, cyclooxygenase-2, and lipoxygenase. In addition, it inhibits a number of inflammatory cytokines, including TNF-α, interleukin-1, -6, -8, and -12 (45). It is suggested that curcumin inhibits the transcription factor nuclear factor kappa B (NF-κB), which controls cyclooxygenase-2 and inducible nitric oxide synthase and controls cellular proliferation. Psoriasis and atopic dermatitis are linked to TNF-α, which also promotes NF-κB and pro-inflammatory cytokines. Therefore, curcumin's possible inhibition of NF-κB may enhance its therapeutic effectiveness in treating inflammatory skin conditions.

Curcumin also has an impact on the creation of platelets, the elimination of mitogens that promote the quick development of mononuclear blood cells, and a partial inhibition of the protein kinase enzyme. Curcumin's anti-inflammatory and antioxidant qualities are supported by the well-established role that oxidative stress plays in the pathophysiology of numerous diseases (such as cancer, cardiac ischemia, ischemia–reperfusion, haemorrhage, shock, and damage to nerve cells). It gets rid of all kinds of reactive oxygen species (ROS), such as nitrogen dioxide and hydroxyl radicals. It has been observed that curcuminoids have antioxidant potential comparable to ascorbic acid [90].

3. Garlic

An extensively researched spice with numerous alleged health benefits is allium sativum. Studies have demonstrated the anti-inflammatory properties of garlic extracts. In one trial, treating with garlic dramatically reduced liver damage and inflammation brought on by Eimeria papillata infections. Garlic oil primarily exhibits its anti-inflammatory properties by impeding the cytoskeleton's construction and disassembly processes. It has been demonstrated that an allicin-derived lead molecule is a suitable place to start when creating anti-inflammatory medications with fewer adverse effects.

According to one study, thiacremonone, a sulphur molecule derived from garlic, suppresses NF-κB activity, which in turn decreases neuroinflammation and amyloidogenesis. As a result, it may be used as an intervention for inflammation-related neurodegenerative illnesses, such as Alzheimer's disease. Among A's many biological actions is immunomodulation. Sativum. It has been demonstrated that aged garlic extract has better immunomodulatory qualities than raw garlic extract. The altered organosulfur compounds are thought to be responsible for this impact of garlic. It has recently been demonstrated that aged garlic fructans exhibit immunomodulatory properties in vitro. The effect of garlic extract on stimulated lymphocytes' interleukin (IL)-2 and interferon (INF)-γ gene expression proliferates in a

concentration-dependent manner. Nitric oxide (NO) generation was induced in vitro by garlic extracts, which decreased macrophage infection. [91]

In lipopolysaccharide-treated J774A.1 macrophages, the anti-inflammatory effects of Allium 14-kDa protein were examined through blocking the nuclear factor-kappa B (NFkB) communication route. This protein suppressed inflammatory agents. AG extract has been shown to have a potent anti-inflammatory impact that helps to avoid inflammatory reaction in animal models with apolipoprotein E deletion (ApoE-KO) [92]. It has been demonstrated that the essential fatty acid ethyl linoleate (ELA), which is derived from garlic cloves, suppresses the synthesis of pro-inflammatory cytokines, the transcription of cyclooxygenase-2 (COX-2), and the iNOS that is created in response to exposure to lipopolysaccharides (LPS). This study's findings showed that ELA has anti-inflammatory qualities, indicating that it could be used as a medicine to treat inflammation-related illnesses [93]. Garlic may have played a role in the altered Th1/Th2 cytokine balance that resulted in the blood levels of pro-inflammatory cytokines and markers of liver fibrosis by significantly inhibiting the expression of inflammatory cytokines. Minimising the size, quantity, and composition of inflammatory cells, collagen fibres, and eggs within the granuloma, along with lowering serum ALT and AST levels, all contributed to the preservation of these signals [94].

4. Long Pepper

Numerous bioactive substances found in long pepper, such as piperine, have been shown to have strong anti-inflammatory properties. The main alkaloid in long pepper, piperine, is what gives it its medicinal properties. The protein complex known as nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB), which is essential for controlling the immune system's reaction to infection, is inhibited by piperine. Piperine's anti-inflammatory actions are achieved by reducing the generation of pro-inflammatory cytokines and mediators by inhibiting NF-κB activation [95]. The signalling system known as mitogen-activated protein kinases (MAPKs), which is involved in cell proliferation, differentiation, and inflammatory responses, is modulated by piperine. Inflammatory cytokines are downregulated as a result of this modulation, which lowers oxidative stress and inflammation [96]. The cyclooxygenase (COX) and lipoxygenase (LOX) pathways, which are involved in the production of pro-inflammatory mediators such prostaglandins and leukotrienes, are suppressed by long pepper extracts. This inhibition aids in the reduction of pain and inflammation [97]. Long pepper's other constituents, including piperine, have antioxidant qualities that aid in lowering

oxidative stress, which is intimately related to inflammatory processes. These substances stop inflammatory reactions from starting and spreading by scavenging free radicals [98].

5.Clove

Clove oil's main anti-inflammatory ingredient is eugenol, a phenolic molecule that is present in large quantities. Eugenol reduces inflammation by preventing prostaglandins and other inflammatory mediators from being synthesised. Research has demonstrated that eugenol is capable of efficiently suppressing the synthesis of pro-inflammatory cytokines, including TNF-α, IL-1β, and IL-6 [99]. The inflammatory pathway's key enzymes, lipoxygenase (LOX) and cyclooxygenase (COX), have been shown to be inhibited by clove oil and its constituents. Clove lowers the synthesis of pro-inflammatory eicosanoids by blocking these enzymes [100]. Clove extracts influence a number of inflammatory cellular signalling pathways. As an example, they suppress the nuclear factor-kappa B (NF-κB) pathway, which is important for controlling the immune system's reaction to an infection. Genes associated with inflammation are expressed less when NF-κB is inhibited [101]. Research has indicated that clove oil has the ability to reduce macrophage inflammatory responses. It has the ability to modify the immune response because it prevents the release of prostaglandin E2 (PGE2) and nitric oxide (NO) in macrophages activated with lipopolysaccharide (LPS) [102].

6. Kalonji

The main bioactive ingredient in Nigella sativa, thymoquinone, has strong anti-inflammatory qualities. Research shows that TQ can prevent the production of eicosanoid, which is essential for inflammatory reactions. The process is based on the time- and dose-dependent suppression of pro-inflammatory mediator biosynthesis-related enzymes such as cyclooxygenase and 5-lipoxygenase [103]. It has been demonstrated that TQ inhibits the synthesis of pro-inflammatory cytokines, including TNF-α, interleukin-1 (IL-1), and interleukin-6 (IL-6). When it comes to ailments like asthma and arthritis, this modulation aids in reducing the inflammatory response [104]. One important regulator of inflammatory reactions, the nuclear factor kappa B (NF-κB) pathway, can be inhibited by TQ. Many inflammatory genes are expressed under the direction of NF-κB, and suppression of this protein reduces inflammation [105].

7. Green Tea

Green tea's main anti-inflammatory properties come from its catechins, among which epigallocatechin-3-gallate (EGCG) is the most powerful and well-researched. Because EGCG

prevents NF-κB from being activated, pro-inflammatory cytokines including TNF-α, IL-6, and IL-1β are produced at a lower rate.

It has been demonstrated that green tea polyphenols, especially EGCG, inhibit mitogen-activated protein kinases (MAPKs), which include p38, JNK, and ERK1/2. These pathways have a role in the way cells react to inflammation and stress. The expression of inflammatory mediators is reduced when MAPKs are inhibited [106]. The pro-inflammatory eicosanoids' manufacturing is aided by the enzymes lipoxygenase (LOX) and cyclooxygenase (COX), which are inhibited by EGCG and other catechins. As a result of this inhibition, prostaglandin and leukotriene synthesis is reduced, which lowers inflammation [107]. T cells, neutrophils, and macrophages are just a few of the immune cells whose functions are impacted by green tea catechins. EGCG prevents these cells from producing pro-inflammatory cytokines and chemokines and lessens their penetration into inflammatory areas [108].

8. Indian Gooseberry

An important enzyme in the inflammatory process, COX-2, is inhibited in a way that is demonstrated by Indian gooseberry. Inhibiting COX-2 has the anti-inflammatory effect by lowering the production of prostaglandins that promote inflammation. Research conducted in vitro has demonstrated that extracts from Amla can impede the growth of several types of inflammatory cells and lower the amount of inflammatory mediators produced in cell cultures. Its promise as a therapeutic agent for inflammatory disorders is supported by these findings [109]. Research has indicated that Amla possesses the ability to regulate the synthesis of inflammatory cytokines. For example, it has been demonstrated to suppress the release of interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF-α), two important inflammatory mediators [110].

9. Neem

Important proinflammatory enzymes including lipoxygenase (LOX) and cyclooxygenase (COX) are regulated by neem. Because they aid in the synthesis of proinflammatory mediators including prostaglandins and leukotrienes, these enzymes play a crucial role in the inflammatory process. Neem effectively lowers inflammation by blocking these enzymes [111]. Research has indicated that neem has the ability to regulate the generation of many inflammatory cytokines, such as interleukins and tumour necrosis factor-alpha (TNF-α). This modulation aids in tissue damage reduction and inflammatory response management [112]. It has been noted that neem affects the immune system, namely by changing the way

macrophages and other immune cells function. Through regulation of the magnitude and direction of the immune response, this immunomodulatory action aids in the management of inflammation [113].

10. Tulsi

The main mechanism by which tulsi reduces inflammation is through blocking the cyclooxygenase (COX) and lipoxygenase (LOX) pathways. The production of pro-inflammatory mediators such prostaglandins and leukotrienes depends on these enzymes. Tulsi lessens inflammation and its related symptoms by obstructing these pathways [114]. Tulsi's anti-inflammatory qualities are partly attributed to its enhancement of humoral and cellular immunity. It modulates the immune response to reduce inflammation by inducing the production of pro-inflammatory cytokines while decreasing the production of anti-inflammatory cytokines [115]. Eugenol, ursolic acid, and rosmarinic acid are just a few of the many bioactive substances that Tulsi's high quantity of is connected to its anti-inflammatory properties. Through their interference with several inflammatory pathways and mediators, these substances demonstrate notable anti-inflammatory activities. For example, rosmarinic acid has a strong reputation for inhibiting inflammation [116]. Research has demonstrated that the pro-inflammatory enzymes COX-2 and 5-LOX, which are involved in the inflammatory process, are inhibited by tulsi. Inflammation is decreased as a result of this inhibition because fewer inflammatory mediators are produced [117].

11. Ashwagandha:

It has been demonstrated that ashwagandha inhibits pro-inflammatory cytokines such interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF-α), and interleukin-1 beta (IL-1β). Reducing inflammation and averting chronic inflammatory disorders depend heavily on this modulation [118]. The root extract of ashwagandha has the ability to block two key pathways that are involved in controlling inflammatory responses: mitogen-activated protein kinase (MAPK) and nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB). Inhibiting these pathways lessens the generation of mediators that cause inflammation [119]. Ashwagandha stimulates macrophage and natural killer (NK) cell activity, which in turn modifies the immune system. In order to preserve immunological homeostasis and lower the prevalence of inflammation, this immunomodulatory impact is essential [120].

12. Sarpagandha:

One of the primary methods by which sarpagandha reduces inflammation is by blocking the NF-κB pathway. One transcription factor that is essential for controlling the immune system's reaction to infection is NF-κB. Pro-inflammatory cytokine production is decreased when this pathway is inhibited [121]. The action of cyclooxygenase-2 (COX-2), an enzyme essential to the production of prostaglandins, which act as mediators of inflammation, has been observed to be inhibited by sarpagandha. Sarpagandha lowers the synthesis of prostaglandins that promote inflammation by blocking COX-2 [122]. According to research, sarpagandha can reduce the levels of inflammatory markers such TNF-α, IL-1β, and IL-6 by modulating the expression of genes involved in the inflammatory response[123].

13. Aloe Vera

The cyclooxygenase (COX) pathway, which is essential for the production of prostaglandins—molecules implicated in the inflammatory process—is inhibited by aloe vera. Aloe vera lowers the synthesis of prostaglandins that promote inflammation by blocking COX [124]. Research has demonstrated that aloe vera has the ability to suppress the production of pro-inflammatory cytokines such IL-1β and TNF-α. This downregulation contributes to the reduction of inflammatory reactions [125]. Because aloe vera stabilises lysosomal membranes, it stops lysosomal enzymes that cause inflammation from leaking out [126]. One important regulator of the inflammatory response is the NF-κB pathway. Aloe vera reduces inflammation by preventing NF-κB from being activated [127].

14. Rosemary

Two of the main diterpenes in rosemary, carnosic acid (CA) and carnosol, are highly crucial in the plant's anti-inflammatory properties. It has been demonstrated that these substances prevent the synthesis of pro-inflammatory cytokines and enzymes including COX-2 and iNOS, which lowers inflammation [128]. Another important component of rosemary with strong anti-inflammatory properties is rosmarinic acid. It works by blocking the NF-κB pathway, an essential component of the inflammatory response. Pro-inflammatory genes express themselves less as a result of this suppression [129]. The pro-inflammatory prostaglandin and leukotriene production enzymes, cyclooxygenase (COX) and lipoxygenase (LOX), have been demonstrated to be inhibited by rosemary extracts. This inhibition aids in the reduction of pain and inflammation [130].

15. Bamboo

Bamboo's anti-inflammatory qualities are attributed to a variety of bioactive substances, including alkaloids, phenolic acids, and flavonoids. Bamboo leaves contain flavonoids called orientin and homoorientin, which are known to suppress the synthesis of pro-inflammatory cytokines including TNF-α and IL-6, therefore lowering inflammation [131]. It has been demonstrated that bamboo extracts block the NF-κB signalling pathway, which is essential for the inflammatory response. A transcription factor called NF-κB controls the expression of several genes that promote inflammation. Reduced synthesis of inflammatory mediators such as COX-2 and iNOS occurs when this pathway is inhibited [132]. Research on bamboo ethanol extracts has shown that they have strong anti-inflammatory properties by blocking pro-inflammatory cytokines. For instance, the ethanol extract of bamboo tali leaves shown a decrease in TNF-α and IL-1β levels, suggesting that it may have anti-inflammatory properties [133].

16. Isabgol

Because it inhibits prostaglandin synthesis and suppresses the release of pro-inflammatory cytokines such as IL-1β, TNF-α, and IL-6, isabgol's anti-inflammatory qualities play a critical role in the fight against periodontal disease. Moreover, the fermentation of isabgol in the stomach generates SCFAs, which have anti-inflammatory properties throughout the body. Overall, Isabgol promotes tissue healing and lessens gum inflammation linked to periodontal disease by regulating the inflammatory response in the oral cavity. [134]

17. Paan

Extractions from the leaves of the Piper betle have been shown to suppress the synthesis of pro-inflammatory cytokines such TNF-α, IL-6, and IL-1β. Piper betle's anti-inflammatory actions may be mediated through the reduction of these cytokines, which are important mediators in the inflammatory response [135]. One essential regulatory system in inflammation is the NF-κB signalling pathway. It has been discovered that piper betle extracts block NF-κB activation, which lowers the expression of genes linked to inflammation. The main cause of this suppression is the downregulation of IκB kinase (IKK), which stops NF-κB from translocating to the nucleus when IκB is broken down [136]. Enzymatic processes called cyclooxygenase (COX) and lipoxygenase (LOX) lead to the synthesis of pro-inflammatory eicosanoids. Extracts from piper betles inhibit the LOX and COX enzymes, which reduces the production of leukotrienes and prostaglandins, two powerful inflammatory mediators [137].

18.Gandhali

According to studies, Paederiafoetida works as an anti-inflammatory agent by blocking important mediators and enzymes that are involved in the inflammatory process. For example, it has been discovered that the plant's extracts inhibit the cyclooxygenase (COX) enzymes, which are essential for the manufacture of prostaglandins that promote inflammation. Furthermore, Paederiafoetida suppresses the synthesis of pro-inflammatory cytokines such interleukins (IL-6 and IL-1β) and tumour necrosis factor-alpha (TNF-α) in addition to nitric oxide (NO) [138]. Several cellular signalling pathways are modulated by Paederiafoetida in order to exert its anti-inflammatory effects. For instance, it has an impact on the NF-κB pathway, which is essential for controlling the expression of genes related to immunological response and inflammation. Gandhali lowers the transcription of pro-inflammatory genes by preventing NF-κB from being activated [139].

19. Nirgundi

It has been proven that niggundi suppresses the synthesis of pro-inflammatory cytokines, and that niggundi's aqueous extract inhibits the COX-2 enzyme, a crucial mediator of inflammation, and prevents cytokine-induced cell damage [140]. It has been demonstrated that nirgundi enhances the benefits of traditional anti-inflammatory medications. Nirgundi has a synergistic impact by increasing the effectiveness of conventional anti-inflammatory drugs [141]. A key route in the inflammatory response, prostaglandin production, is suppressed by niggundi [142].

20. Indian Frankincense

The manufacture of leukotrienes from arachidonic acid depends on the enzyme 5-lipoxygenase, which is inhibited by boswellic acids, especially acetyl-11-keto-β-boswellic acid (AKBA) and 11-keto-β-boswellic acid (KBA). Inflammatory mediators called leukotrienes are important in diseases including arthritis and asthma. Boswellic acids have an anti-inflammatory impact via reducing the generation of leukotrienes through the inhibition of 5-lipoxygenase [143]. Studies reveal that the generation of pro-inflammatory cytokines including tumour necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6) is inhibited by extracts from Boswellia serrata. These cytokines have a crucial role in the spread of autoimmune reactions and inflammation [144]. The nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) pathway, which is essential for controlling the immune system's reaction to infection, is likewise inhibited by boswellic acids. Numerous

pro-inflammatory genes are transcriptionally regulated by NF-κB. Reduced production of cytokines, chemokines, and adhesion molecules—all crucial to the inflammatory process—occurs when this pathway is inhibited [145].

6. Conclusion:

This analysis highlights the great therapeutic potential of twenty medicinal plants by thoroughly examining their ethnopharmacology, phytochemistry, and anti-inflammatory activities. Many of the traditional applications of the plants under examination, including garlic, ginger, and turmeric, have been supported by contemporary scientific research after decades of use in traditional medical systems. Every plant exhibits a distinct range of bioactive chemicals that support their anti-inflammatory properties via different methods, such as immune response modulation, oxidative stress suppression, and inhibition of pro-inflammatory cytokines.

Our research highlights the usefulness of these medicinal plants in treating inflammatory diseases and points to possible applications for them in contemporary medicine. The discovery of phytoconstituents, such as epigallocatechin gallate (EGCG) in green tea, allicin in garlic, and curcumin in turmeric, gives these substances a scientific foundation for their effectiveness and opens the door to the creation of new anti-inflammatory medications. Additionally, the traditional knowledge contained in ethnopharmacology is a useful manual for pharmacological research and medication development in the future.

More thorough clinical trials are still required to determine the standardised doses, safety profiles, and therapeutic efficacy of these botanicals in modern medicine, even in light of the encouraging results. Furthermore, in order to prevent overexploitation of these priceless plant resources and guarantee their continued availability for future generations, conservation activities must be given top priority.

The advancement of healthcare can be greatly anticipated through the synergy of traditional wisdom and contemporary scientific research. With their strong anti-inflammatory qualities, the medicinal plants examined in this paper offer a wealth of natural therapies that can be used in conjunction with conventional medical care to promote holistic health and well-being.

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