E-ISSN: 2583-9667
Indexed Journal
Peer Reviewed Journal
https://multiresearchjournal.theviews.in

Received: 26-05-2025
Accepted: 25-06-2025

INTERNATIONAL JOURNAL OF ADVANCE RESEARCH IN MULTIDISCIPLINARY

Volume 3; Issue 2; 2025; Page No. 445-455

A comprehensive review of the therapeutic applications and bioactive profiles of three underutilized edible flowers: *Matricaria chamomilla*, *Clitoria ternatea*, and *Hibiscus sabdariffa*

[1]Nasalwai Spoorthi Kulakarni, [2]Dr. Lokesh AC and [3]Adrita Banerjee

[1-3]Department of Food Technology, M.S Ramaiah University of Applied Sciences, Bengaluru, Karnataka, India

DOI: https://doi.org/10.5281/zenodo.15746743

Corresponding Author: Nasalwai Spoorthi Kulakarni

Abstract

Medicinal plants have gained increasing attention for their rich sources of natural compounds with significant health benefits. This review highlights the phytochemical composition and therapeutic applications of three widely studied plants: *Matricaria chamomilla* (chamomile), *Clitoria ternatea* (butterfly pea), and *Hibiscus sabdariffa* (roselle). These plants are known for their abundance of flavonoids, anthocyanins, phenolic acids, and essential oils, which contribute to their strong antioxidant, anti-inflammatory, neuroprotective, and heart-protective effects.

Matricaria chamomilla is widely used for its calming, anti-inflammatory, and digestive properties, attributed to bioactive compounds such as apigenin and bisabolol. *Clitoria ternatea* contains blue pigments known as ternatins, which have demonstrated potential in enhancing brain function and reducing stress. *Hibiscus sabdariffa* is recognized for its capacity to lower blood pressure and cholesterol levels, primarily due to its anthocyanin and organic acid content.

By combining traditional knowledge with modern research, this review shows the strong potential of these herbs in natural therapies, functional foods, and dietary supplements. To fully benefit from their medicinal value, more clinical studies, standardization methods, and safety evaluations are needed. These plants may provide a natural option for supporting health and could help reduce reliance on synthetic drugs.

Keywords: *Matricaria chamomilla*, *Clitoria ternatea*, *Hibiscus sabdariffa*, Phytochemicals, Antioxidants, Anti-inflammatories, Functional foods, Herbal medicine

1. Introduction

Medicinal Plants have long served as a foundation for traditional medicine and modern pharmacology due to their rich content of bioactive compounds. Among the vast array of medicinal plants, *Matricaria chamomilla*, *Clitoria ternatea*, and *Hibiscus sabdariffa* have gained scientific attention for their nutritional, therapeutic, and pharmacological relevance. These botanicals are widely recognized for their antioxidant, anti-inflammatory, antihypertensive, and neuroprotective properties, making them valuable in functional foods, herbal supplements, and natural remedies (Montalvo-González *et al*., 2022) [1].

In India, the production statistics of German chamomile (*Matricaria chamomilla* Linn.) indicate promising potential for commercial cultivation, particularly in southern regions. Under experimental conditions in the northern dry zone of Karnataka, specifically in the Ghataprabha river command area, the crop recorded a fresh flower yield of 6.35 tonnes per hectare and a dry flower yield of 1.88 tonnes per hectare at a spacing of 30 × 20 cm. Similarly, under Bangalore conditions, the crop produced a fresh flower yield of 6.09 tonnes per hectare and a dry flower yield of 1.64 tonnes per hectare, along with an essential oil yield of 6.36 kg per hectare. The oil content in dry flowers varied between 0.3% and 1.3%, depending on genotype and environmental factors. Shade-dried flowers yielded the highest oil content of 0.44% and a farnesene content of 15.16%, while sun-dried flowers exhibited a higher chamazulene content of 22.77% but lower overall oil yield. These figures demonstrate the crop's adaptability to diverse climatic conditions and its potential as a high-value medicinal and aromatic crop in India (Nidagundi and Hegde, 2006) [2].

Clitoria ternatea (butterfly pea) demonstrates strong biomass production capabilities in Indian agro-climatic conditions. Under optimal agronomic practices-such as adequate moisture, soil fertility, and timely harvesting-the plant yields up to 30 tonnes per hectare of dry matter annually. Across broader tropical regions, dry matter yields generally vary from 1 to 29 tonnes per hectare, with typical well-managed systems achieving 2 to 6 tonnes per hectare. High-yielding cultivars like 'Milgarra' have shown the ability to produce 4.2 tonnes per hectare of dry matter within just four months of planting. These results highlight the species' fast growth rate and suitability as a multi-purpose plant for both forage and medicinal use (Dairy Knowledge Portal, 2025; Tropical Forages FAQ, 2025).

In India, Hibiscus sabdariffa (roselle) is widely cultivated for its edible calyces, seeds, and fiber, showcasing notable productivity under favorable agronomic conditions. From 1997 to 2001, dry fiber yields in various Indian regions averaged around 1.9 tonnes per hectare. Fresh calyx yields typically range from 4 to 6.5 tonnes per hectare, which equates to about 0.8 to 1.2 tonnes per hectare of dried calyces at 12% moisture content. In exceptionally conducive agro-climatic zones in Asia, including parts of India, fresh calyx yields may reach up to 15 tonnes per hectare. Furthermore, seed yield varies between 0.2 to 1.5 tonnes per hectare depending on cultivar selection, soil fertility, and crop management. These agronomic metrics emphasize roselle's versatility and its growing potential in the herbal tea and nutraceutical sectors (Plant Use PROTA, n.d.).

This review provides a comprehensive overview of the Bioactive profiles, and therapeutic applications of chamomile, butterfly pea, and roselle, emphasizing recent advances in clinical research and their potential for future health interventions.

2. Botanical Description and Distribution

2.1 *Matricaria chamomila*

Matricaria chamomilla is an annual herbaceous plant characterized by thin, spindle-shaped roots and erect, branched stems growing between 10 and 80 cm in height. Its leaves are long, narrow, and pinnately divided, while the flower heads measure 10–30 mm in diameter, featuring small white ray florets surrounding yellow tubular disc florets. The plant thrives in well-drained, light soils and tolerates alkaline conditions and temperatures ranging from 2 °C to 20 °C. Due to its shallow root system, frequent irrigation is necessary, and nitrogen fertilization along with organic matter application enhances flower and essential oil yields. Native to temperate regions of Asia and Europe, it is widely cultivated in countries including Germany, Hungary, France, Russia, Brazil, and parts of China (Singh *et al*., 2010; Dai *et al*., 2020; Sah *et al*., 2021) [3, 4, 6].

Fig 1: Chamomile Flowers (NCCIH, 2025)

Table 1: Scientific classification of *Matricaria chamomilla*

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperms
Clade	Eudicots
Clade	Asterids
Order	Asterales
Family	Asteraceae (Compositae)
Genus	*Matricaria*
Species	*Matricaria chamomilla Linn.*

2.2 *Clitoria ternatea*

Clitoria ternatea is a deep-rooted, perennial climbing legume with slender stems and compound leaves comprising three to five leaflets. It produces solitary, zygomorphic flowers with five petals arranged as two wings, two keels, and one banner-often featuring a yellow center. The flat pods measure 6-12 cm in length and contain 6-8 seeds, while the plant's fibrous root system develops large nodules that enable nitrogen fixation via symbiosis with Rhizobium species. Although its precise origin is unclear due to extensive cultivation, the species is considered native to tropical Asia and is now widely distributed across tropical and subtropical regions worldwide. It thrives in varied soil types (pH 5.5–8.9), including calcareous soils, and adapts well to both high rainfall and drought conditions (Oguis *et al*., 2019; Jeyaraj *et al*., 2021) [7, 8].

Fig 2: Butterfly Pea Flower

Table 2: Scientific classification of *Clitoria ternatea*

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperms
Clade	Eudicots
Clade	Rosids
Order	Fabales
Family	Fabaceae
Subfamily	Faboideae
Genus	*Clitoria*
Species	*C. ternatea*

2.3 *Hibiscus sabdariffa*
Hibiscus sabdariffa is an erect, annual shrub of the Malvaceae family, growing 1.5 to 2.4 meters tall with reddish, smooth, branched stems. Its alternate leaves are ovate to lanceolate, deeply 3–5-lobed, and serrated. The axillary, solitary flowers have large yellow petals with a red or maroon base, and the fleshy, enlarged red calyx develops after flowering, used widely for various applications (Mohammed *et al*., 2020) [9]. Originating in West and Central Africa and parts of Southeast Asia, it is now cultivated extensively across tropical and subtropical regions including Sudan, Egypt, Nigeria, India, Thailand, and Mexico, favoring warm climates with well-drained soils (Ali *et al*., 2018) [10].

Fig 3: Roselle Flowers

Table 3: Scientific classification of *Hibiscus sabdariffa*

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperms
Clade	Eudicots
Clade	Rosids
Order	Malvales
Family	Malvaceae
Subfamily	Malvoideae
Tribe	Hibisceae
Genus	Hibiscus
Species	H. sabdariffa

3. Bioactive Composition
3.1 *Matricaria chamomilla*
Matricaria chamomilla exhibits a complex bioactive profile responsible for its diverse therapeutic properties. Its chemical constituents have been extensively characterized using advanced techniques like GC-MS and HPLC, revealing a rich array of bioactive compounds including essential oils, flavonoids, phenolic acids, coumarins, terpenoids, organic acids, and other secondary metabolites (El Mihyaoui *et al*., 2022; Wang *et al*., 2023) [11, 12]. The main phytochemical constituents of chamomile flowers are summarized in Fig. 1, highlighting their roles in the plant's therapeutic efficacy. Chamomile essential oils contain over 100 volatile components with significant geographic and genetic variability. For instance, Moroccan chamomile oils are high in chamazulene and cis-β-farnesene, whereas Egyptian oils predominantly consist of α-bisabolol oxide A (El Mihyaoui *et al*., 2022) [11]. Turkish and Romanian variants show sesquiterpenes as major constituents, with bisabolol oxide A sometimes comprising over 70% of the oil content. These variations impact the pharmacological activities of the oils (El Mihyaoui *et al*., 2022) [11].

Flavonoids represent the major group of chamomile's bioactive compounds, with over 50 identified, including quercetin, apigenin, luteolin, and rutin, which exhibit potent antioxidant, anti-inflammatory, antibacterial, and anticancer activities (Wang *et al*., 2023) [12]. As depicted in Fig. 1, apigenin-7-O-β-D-glucoside and luteolin-7-O-β-D-glucoside are important glycosides found in alcoholic extracts, contributing to neuroprotective effects through pathways such as GSK-3β/Nrf2 and modulation of cytokines like interferon-γ and interleukin-10 (Dai *et al*., 2023) [12].

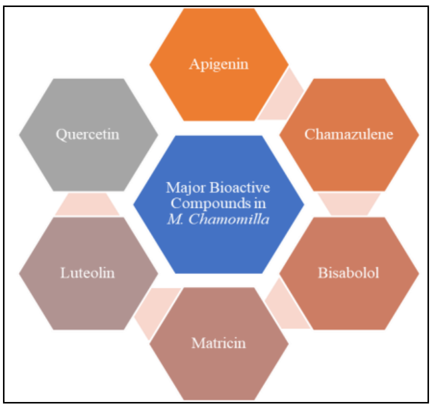

Fig 4: Major bioactive compounds present in *Matricaria chamomilla* flowers.

The phenolic acids-chlorogenic, caffeic, rosmarinic, ellagic, and benzoic acids-contribute to antioxidant and anti-inflammatory properties, while coumarins including daphnin and skimmin play roles in anti-inflammatory and anticoagulant effects (El Mihyaoui *et al*., 2022) [11]. Terpenoids are also prominent, encompassing 39 monoterpenes (e.g., ocimene, geraniol, citronellol), 27 sesquiterpenes with α-bisabolol as a key anti-inflammatory agent, and several diterpenes and triterpenes like phytanetriol and oleanolic acid, which support hepatoprotective and antioxidant functions (Dai *et al*., 2023) [12].

In addition, chamomile contains 26 organic acids, with 22 acting as biologically active secondary metabolites involved in cardiovascular and immune modulation and anticancer effects (Dai *et al*., 2023) [12]. Other constituents such as tannins, alkaloids, saponins, sterols, and amino acids including proline and asparagine further enhance its therapeutic profile (El Mihyaoui *et al*., 2022) [11].

Environmental influences notably affect chamomile's phytochemical composition. Abiotic stressors such as heavy metal exposure alter phenolic and mineral contents, and the application of growth regulators like ethephon can modify flavonoid and coumarin levels, demonstrating metabolic adaptability (El Mihyaoui *et al*., 2022) [11]. These factors underscore the importance of standardizing cultivation and extraction methods to ensure consistent quality and efficacy.

Overall, the phytochemical diversity of *Matricaria chamomilla* (Fig. 4), shaped by genetic and environmental factors, provides a robust basis for its pharmacological activities and traditional uses. Ongoing research into its bioactive compound interactions, bioavailability, and clinical applications will further harness its therapeutic potential (Dai, Li, Wang *et al*., 2023) [12].

Table 4: Key Bioactive Compounds from *Matricaria chamomilla* and their Biological Activities

Category	Compound Name	Biological Activity
Primary Metabolites	Palmitic acid	Anti-inflammatory, emollient
	Linoleic acid	Antioxidant, skin barrier repair
	Oleic acid	Anti-inflammatory, cardioprotective
Secondary Metabolites	Isobutyric acid	Flavor compound, mild antimicrobial
	Tiglic acid	Antimicrobial, insect deterrent
	Isovaleric acid	Sedative, calming effects
	DL-2-Methylbutyric acid	Flavoring, antimicrobial
	Cinnamic acid	Antioxidant, antimicrobial
Flavonoids	Apigenin	Anxiolytic, antioxidant, anti-inflammatory
	Galangin	Antimicrobial, anti-cancer
	Naringenin	Antioxidant, neuroprotective
	Luteolin	Anti-inflammatory, neuroprotective
	Kaempferol	Antioxidant, cardioprotective
Coumarins	Coumarin	Anticoagulant, vasodilator
	3,4-Dihydrocoumarin	Antioxidant, anti-aging
	Umbelliferone	Antioxidant, hepatoprotective
	7-Methoxycoumarin	Antibacterial, skin-soothing
	Esculetin	Antioxidant, anti-inflammatory, anti-proliferative

3.2. *Clitoria ternatea*

Clitoria ternatea flowers are a rich source of diverse bioactive phytochemicals, prominently anthocyanins that include a unique group of acylated delphinidin glycosides collectively known as ternatins fig 2 (e.g., ternatin A1, A2, B1, B2, D1, and D2), which are primarily responsible for the flower's vivid blue coloration (Shen *et al*., 2015; Kumar *et al*., 2019) [13, 14]. The anthocyanin content varies among flower color variants; the white-flowered type notably lacks anthocyanins, while the mauve variant accumulates specific delphinidin derivatives lacking 3′ and 5′ polyacylated glucosyl moieties, highlighting structural diversity within these pigments (Shen *et al*., 2015) [13]. Key anthocyanin derivatives such as cyanidin-3-sophoroside and multiple delphinidin glycosides have been identified as principal contributors to the intense blue hue in blue-flowered varieties (Shen *et al*., 2015) [13].

In addition to anthocyanins, the flowers contain a complex profile of flavonoid glycosides, including kaempferol 3-neohesperidoside, quercetin 3-(2G-rhamnosylrutinoside), and rutin, all known for their potent antioxidant and anti-inflammatory activities (Kumar *et al*., 2019) [14]. The phytochemical spectrum further includes phenolic acids such as ellagic acid and chlorogenic acid, which add to the overall antioxidant capacity and health-promoting potential of the flower extracts. Besides phenolics, C. *ternatea* flowers also harbor triterpenoids, alkaloids, and tannins, which collectively contribute to their neuroprotective, anti-inflammatory, antimicrobial, and antidiabetic properties, substantiating their traditional medicinal use.

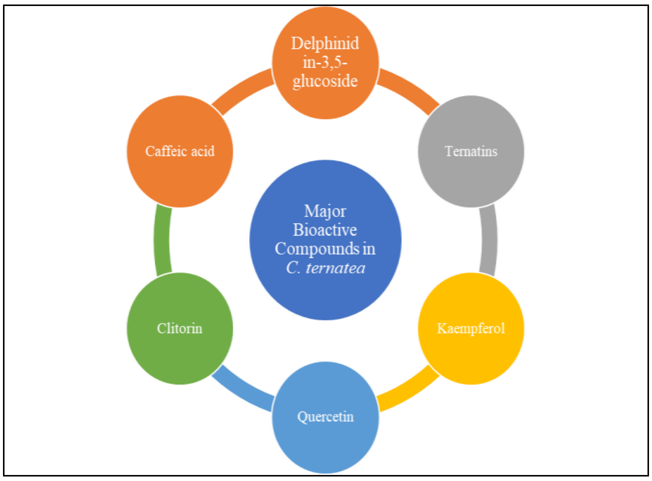

Fig 5: Major Bioactive Compounds in *C. ternatea*

Extraction techniques play a crucial role in maximizing the yield and bioactivity of these phytochemicals. Recent studies have investigated various extraction methods, including ultrasonic-assisted extraction, solvent extraction, and microwave-assisted extraction, to enhance the recovery of anthocyanins and flavonoids while preserving their stability and bioactivity (Shirodkar *et al*., 2022; Jeyaraj *et al*., 2021) [15, 8]. Optimization of parameters such as solvent type, temperature, time, and ultrasonic frequency has demonstrated improved extraction efficiency, making *C. ternatea* flower extracts promising candidates for functional food ingredients and natural therapeutic agents.

The growing scientific interest in *Clitoria ternatea* is driven not only by its vivid pigmentation but also by its broad spectrum of bioactivities attributed to its phytochemical composition. These include antioxidant, anti-inflammatory, anxiolytic, cognitive-enhancing, and antimicrobial effects, which are being increasingly validated through *in vitro* and *in vivo* studies, indicating a strong potential for application in nutraceuticals, cosmetics, and pharmaceutical formulations.

Table 5: Key Bioactive Compounds from *Clitoria ternatea* and their Biological Activities

Category	Compound Name	Biological Activity
Flavonoids	Kaempferol	Antioxidant, anti-inflammatory, anti-cancer
	Quercetin	Antioxidant, neuroprotective, anti-inflammatory
	Myricetin	Antioxidant, antimicrobial, anti-diabetic
Flavonoid Glycoside	Delphinidin-3,5-glucoside	Antioxidant, anti-obesity, neuroprotective
Anthocyanin	Ternatins (A1–A5, B1–B4, C1)	Antioxidant, Memory enhancer, hepatoprotective
Phenolic Acids	Caffeic acid	Antioxidant, anti-inflammatory, enzyme inhibition
	Ferulic acid	UV-protective, anti-aging, anti-inflammatory
Triterpenoid	Taraxerol	Anti-inflammatory, anti-diabetic, anticancer
Alkaloid	Aparajitin	Antimicrobial, cytotoxic, antitumor (potential)
Cyclotides	Clitorin	Antimicrobial, insecticidal, cytoprotective
Saponin	Clitoria saponin	Antioxidant, immunomodulatory, anti-inflammatory

3.3 *Hibiscus sabdariffa*

Hibiscus sabdariffa renowned for its rich phytochemical composition, which contributes to its diverse nutritional and medicinal properties. The content of bioactive compounds varies significantly depending on cultivar, growing conditions, and harvest time. On average, 100 g of fresh calyces contains approximately 1.9 g protein, 0.1 g fat, 12.3 g carbohydrates, 2.3 g dietary fiber, and 14 mg vitamin C, along with minerals such as 57 mg iron and 1.72 mg calcium. Leaves of the plant show higher protein (3.3 g/100 g), phosphorus (214 mg/100 g), and beta-carotene (4135 µg/100 g) levels, and provide essential vitamins including thiamine and riboflavin. Seeds are especially rich in crude fat (21.85%) and crude protein (27.78%), with considerable carbohydrate, fiber, ash, and potassium content (Da-Costa-Rocha *et al*., 2014) [17].

The seed oil predominantly contains saturated fatty acids like palmitic acid (20.84%) and stearic acid (5.88%), along with significant amounts of unsaturated fatty acids, including linoleic acid (39.31%) and oleic acid (32.06%) (Nzikou *et al*., 2011) [18]. In Malaysia, this oil finds practical use in cosmetic formulations such as scrubs and soaps (Ismail, Ikram, & Nazri, 2008) [19].

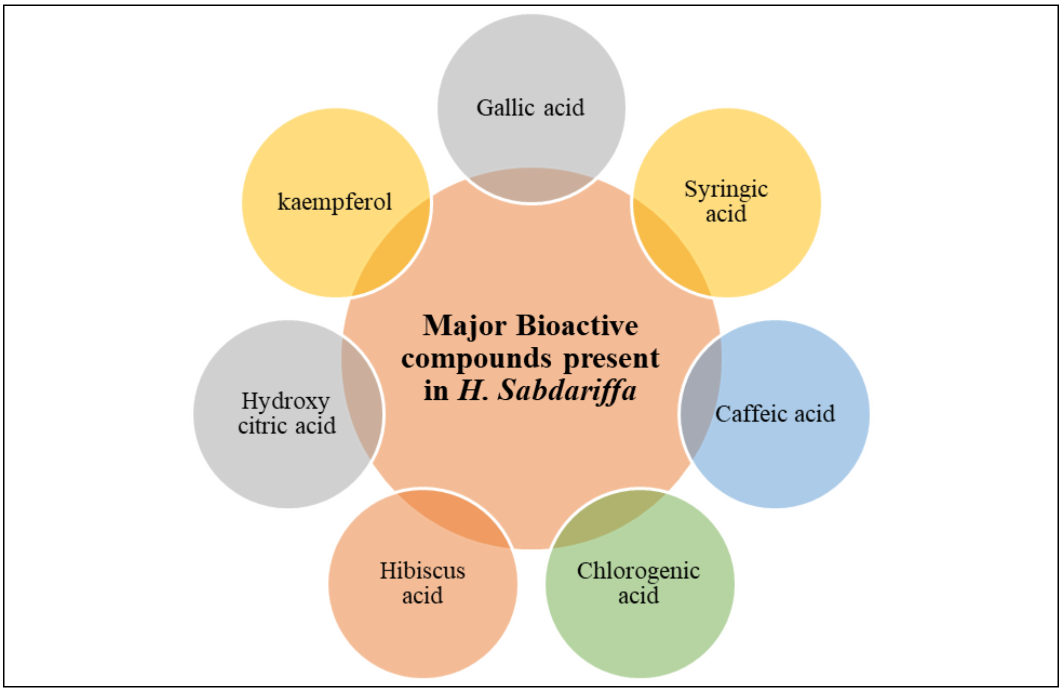

Fig 6: Major Bioactive compounds present in *Hibiscus Sabdariffa*

Organic acids are central to *H. sabdariffa's* distinctive sour taste and contribute to its pharmacological effects. The principal organic acid is fig 3 hibiscus acid, a lactone derivative of (+)-allo-hydroxycitric acid, which features a citric acid backbone with an additional hydroxyl group and two chiral centers. Hydroxycitric acid and related compounds are present in both leaf and calyx extracts (Da-Costa-Rocha *et al*., 2014) [17]. Other organic acids found in hibiscus extracts include citric, malic, tartaric, oxalic, and ascorbic acids. The concentration of these acids varies by plant part and processing method, with hibiscus acid comprising roughly 13–24% and citric acid about 12–20% of the organic acid fraction (Eggensperger & Wilker, 1996; Schilcher, 1976) [20, 21].

Historical studies from the early 20th century confirmed citric and malic acids in aqueous calyx extracts (Buogo & Picchinenna, 1937; Indovina & Capotummino, 1938; Reaubourg & Monceaux, 1940) [22, 23, 24], and diverse H. sabdariffa strains from regions such as Egypt, Senegal, India, Thailand, and Central America exhibit similar organic acid profiles. Notably, ascorbic acid content varies markedly, with fresh calyces containing 6.7–14 mg/100 g, while dried calyces may reach 260–280 mg/100 g (Ismail, Ikram, & Nazri, 2008; Morton, 1987) [19, 25]. Variations in ascorbic acid levels are influenced by plant genetics, cultivation environment, and post-harvest handling.

The vivid red color of roselle calyces is primarily due to anthocyanins, a class of flavonoids sensitive to pH changes. The main anthocyanins identified are delphinidin-3-sambubioside (hibiscin), cyanidin-3-sambubioside (gossypicyanin), cyanidin-3,5-diglucoside, delphinidin, and cyanidin-3-glucoside (chrysanthenin). The levels of these pigments fluctuate across cultivars, typically ranging between 1.7% and 2.5% of dry weight, with some strains lacking delphinidin glycosides altogether (Da-Costa-Rocha *et al*., 2014) [17]. These compounds contribute not only to the aesthetic appeal but also exhibit potent antioxidant activities.

Hibiscus sabdariffa contains various flavonoids such as hibiscitrin (hibiscetin-3-glucoside), sabdaritrin, gossypitrin, gossytrin, quercetin, and luteolin. The leaves also contain catechin and ellagic acid. Water extracts reveal the presence of phenolic acids including protocatechuic acid (PCA)-the most abundant-caffeic acid, gallocatechin, and gallocatechin gallate. Additionally, chlorogenic acid, an ester of cinnamic acids and quinic acid, is present in both leaves and calyces and contributes to the antioxidant potential (Da-Costa-Rocha *et al*., 2014) [17].

The aroma and flavor profile of H. sabdariffa is shaped by volatile compounds such as fatty acid derivatives (e.g., 2-ethylfuran, hexanal), sugar degradation products like furfural and 5-methyl-2-furaldehyde, phenolics including eugenol, and terpenes such as 1,4-cineole and limonene (Da-Costa-Rocha *et al*., 2014) [17]. These volatiles influence sensory qualities that are important for consumer acceptance.

Ethanol precipitation of aqueous extracts yields about 10% reddish polysaccharides composed mainly of mucilage and pectin. These polysaccharides play a crucial role in determining the texture and potential bioactivity of herbal formulations and have applications in food and pharmaceutical products (Da-Costa-Rocha *et al*., 2014) [17].

Table 6: Key Bioactive Compounds from *Hibiscus sabdariffa* and their Biological Activities

Category	Compound Name	Biological Activity
Anthocyanin	Cyanidin-3,5-diglucoside	Anti-inflammatory
	Cyanidine-3-sambubioside	Anti-inflammatory Hepatoprotective Antihypertensive
	Delphinidin-3-sambubioside	Hepatoprotective
	Delphinidin-3-glucoside	Hepatoprotective
Phenolic Acid	5-O-Caffeoyl-shikimic acid	Antimicrobial
	3-Caffeoylquinic acid	Antioxidant
	5-Caffeoylquinic acid	Anti-inflammatory
	4-Caffeoylquinic acid	Antimicrobial
	4-0-methylgallic acid	Antihypertensive Antioxidant
	3-0-methylgallic acid	Antihypertensive Antioxidant
	Caffeic acid	Anti-inflammatory
	Chlorogenic acid	Immune booster
	Chlorogenic acid isomer I	Immune booster

4. Therapeutic Applications

4.1 *Matricaria chamomila*

4.1.1 Anti-Inflammatory Properties

Chamomile's anti-inflammatory efficacy is attributed to its ability to suppress multiple pro-inflammatory signaling pathways. Key flavonoids such as apigenin and luteolin inhibit NF-κB activation, a central transcription factor that governs the expression of numerous inflammatory genes. These compounds significantly downregulate pro-inflammatory cytokines including tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), interleukin-8 (IL-8), and monocyte chemoattractant protein-1 (MCP-1), thereby curbing inflammatory cascades (Sah *et al*., 2019; Dai *et al*., 2018) [26, 27].

Studies in models of atopic dermatitis and irritable bowel syndrome (IBS) have shown that chamomile reduces serum immunoglobulin levels (IgE and IgG1) and inhibits macrophage activation, which plays a key role in chronic inflammatory conditions (Naseef *et al*., 2020) [28]. Additionally, chamomile decreases nitric oxide (NO) levels by suppressing inducible nitric oxide synthase (iNOS), further mitigating oxidative and nitrosative stress-induced inflammation (Kuruniyan *et al*. 2022; Gao *et al*. 2019) [29, 30].

4.1.2 Antioxidant Activity

Chamomile possesses strong antioxidant potential, a property intricately linked to its anti-inflammatory and chemo preventive effects. The flavonoids and terpenoids in chamomile actively scavenge reactive oxygen species (ROS) and protect cellular biomolecules from oxidative damage. Chamomile has been shown to reduce oxidative stress markers such as 8-iso-prostaglandin F2α, contributing to the preservation of cellular integrity and function (Jain *et al*., 2018; Dai *et al*., 2018) [31, 27].

In vitro studies have also demonstrated chamomile's capacity to inhibit cyclooxygenase (COX) and lipoxygenase (LOX) enzymes, both of which are critical in the biosynthesis of inflammatory eicosanoids like prostaglandin E2 (PGE2) (Zakir *et al*., 2021; Sah *et al*., 2019) [32, 26]. This dual inhibition positions chamomile as a candidate for anti-inflammatory therapy in oxidative stress-related diseases such as colorectal cancer (Gao *et al*., 2019) [30].

4.1.3 Anti-Allergic Activity

Chamomile exhibits anti-allergic effects through the inhibition of mast cell degranulation, thus preventing the release of histamine and other mediators that cause allergic symptoms (Naseef *et al*., 2020; Dai *et al*., 2018) [28, 27]. Animal studies have shown that chamomile extract significantly lowers levels of histamine, nitric oxide, and other allergic response markers, often outperforming conventional anti-allergic drugs (Kuruniyan *et al*., 2022; Sah *et al*., 2019) [29, 26]. These effects support its use in conditions like allergic dermatitis, allergic rhinitis, and seasonal allergies (Jain *et al*., 2018) [31].

4.1.4 Antimicrobial Properties

Chamomile essential oil contains potent antimicrobial agents such as α-bisabolol and bisabolol oxide A, which exhibit broad-spectrum activity against both Gram-positive and Gram-negative bacteria, including methicillin-resistant Staphylococcus aureus (MRSA) and Pseudomonas aeruginosa (Zakir *et al*., 2021; Dai *et al*., 2018) [32, 27]. It is effective in disrupting biofilm formation, a major barrier to successful treatment of persistent bacterial infections (Sah *et al*., 2019) [26].

When used in conjunction with antibiotics, chamomile extracts demonstrate synergistic antimicrobial effects, potentially enhancing treatment efficacy and reducing required antibiotic doses (Kuruniyan *et al*., 2022) [29]. Moreover, antiviral assays indicate that chamomile essential oil inhibits herpes simplex virus (HSV) replication and may have future potential in the management of respiratory viruses, including SARS-CoV-2 (Gao *et al*., 2019) [30].

4.1.5 Analgesic Effects

Chamomile also shows promising analgesic (pain-relieving) properties. In experimental models, such as the formalin-induced paw licking test in rodents, chamomile extracts significantly reduced both early and late phases of nociceptive response, indicating both central and peripheral analgesic mechanisms (Sah *et al*., 2019; Naseef *et al*., 2020) [26, 28]. This supports chamomile's role in managing pain associated with inflammation, menstrual cramps, and gastrointestinal discomfort (Jain *et al*., 2018) [31].

4.1.6 Anti-Cancer Activity

Chamomile exhibits multifaceted anticancer effects, primarily through apigenin, which has been shown to induce cell cycle arrest, apoptosis, and inhibition of angiogenesis in a range of human cancer cell lines, including prostate, skin, and liver cancers (Dai *et al*., 2018; Sah *et al*., 2019) [27, 26]. Chamomile extracts suppress cell proliferation and stimulate caspase-dependent apoptosis, highlighting their role as natural chemopreventive agents (Kuruniyan *et al*., 2022; Gao *et al*., 2019) [29, 30]. Chamomile has demonstrated selective cytotoxicity-inducing apoptosis in cancerous cells without affecting normal cells-making it a promising candidate for adjuvant cancer therapies (Zakir *et al*., 2021) [32]. Nevertheless, further mechanistic and clinical studies are warranted to confirm its therapeutic efficacy and safety in cancer patients.

4.2 *Clitoria ternatea*

4.2.1 Anti-Inflammatory and Anti-Arthritic Effects

Clitoria ternatea exhibits potent anti-inflammatory and anti-arthritic properties through multiple mechanisms. *In vitro* studies demonstrate that its methanolic and aqueous extracts inhibit protein denaturation, a key process in inflammatory conditions like arthritis. *In vivo* models, such as carrageenan-induced paw edema and collagen-induced arthritis in rodents, show significant reductions in edema, joint swelling, and cartilage degradation. The flavonoids, particularly quercetin and kaempferol, suppress pro-inflammatory cytokines (e.g., TNF-α, IL-1β, IL-6) by downregulating NF-κB signaling pathways. Additionally, these compounds inhibit cyclooxygenase (COX) and lipoxygenase (LOX) enzymes, reducing prostaglandin and leukotriene synthesis.

The plant's antihistaminic effects further alleviate inflammation by blocking histamine-mediated pathways, which are critical in allergic and arthritic responses. In rheumatoid arthritis models, C. *ternatea* extracts reduced synovial hyperplasia and pannus formation, suggesting potential as an adjunct therapy for autoimmune arthritis. Traditional uses of the plant for joint pain and swelling in Ayurveda are thus supported by these findings. The synergistic action of flavonoids and saponins may offer a safer alternative to non-steroidal anti-inflammatory drugs (NSAIDs), with fewer gastrointestinal side effects (Shirodkar *et al*., 2023) [16].

4.2.2 Respiratory and Anti-Asthmatic Effects

The respiratory benefits of *C. ternatea* are well-documented in traditional medicine, particularly for asthma, bronchitis, and allergic rhinitis. Its flavonoids and saponins act as natural H1 receptor antagonists, reducing histamine-induced bronchoconstriction and airway inflammation. In animal models of asthma (e.g., ovalbumin-sensitized guinea pigs), pretreatment with *C. ternatea* extracts significantly attenuated bronchospasm, decreased eosinophil infiltration, and lowered mucus hypersecretion in the airways. These effects are mediated by the inhibition of mast cell degranulation and the suppression of Th2 cytokines (e.g., IL-4, IL-5), which drive allergic responses.

Moreover, the plant's antioxidant properties protect airway epithelial cells from oxidative damage caused by reactive oxygen species (ROS) during allergic inflammation. The bronchodilatory effects are comparable to standard drugs like salbutamol in some experimental settings, highlighting its therapeutic potential. Traditional preparations, such as decoctions of leaves or flowers, have been used to relieve cough and dyspnea, and these are now validated by pharmacological studies (Shirodkar *et al*., 2023) [16].

4.2.3 Analgesic and Antipyretic Activity

Clitoria ternatea demonstrates significant analgesic and antipyretic effects, supporting its traditional use for pain relief and fever management. Leaf and root extracts exhibit dose-dependent analgesia in models like acetic acid-induced writhing and hot plate tests in mice. The analgesic effects are mediated by both peripheral and central mechanisms: peripherally, flavonoids inhibit prostaglandin synthesis by blocking COX enzymes; centrally, the extracts modulate opioid receptors and pain perception pathways in the brain.

The antipyretic activity is attributed to the suppression of pyrogenic cytokines (e.g., IL-1β, TNF-α) and the modulation of hypothalamic thermoregulatory centers. In yeast-induced pyrexia models, *C. ternatea* extracts reduced body temperature with efficacy comparable to paracetamol, without the hepatotoxicity associated with prolonged NSAID use. The presence of phenolic compounds and anthocyanins enhances these effects by reducing oxidative stress, which exacerbates fever and pain (Shirodkar *et al*., 2023) [16].

4.2.4 Antidiabetic Effects and Metabolic Regulation

Clitoria ternatea shows promising antidiabetic effects through multiple pathways. Its extracts inhibit carbohydrate-hydrolyzing enzymes (α-amylase and α-glucosidase), delaying glucose absorption in the gut and reducing postprandial hyperglycemia. In streptozotocin-induced diabetic rats, the plant improved insulin secretion from pancreatic β-cells and enhanced insulin sensitivity in peripheral tissues, likely via activation of PPAR-γ (peroxisome proliferator-activated receptor gamma) pathways.

The polyphenols and anthocyanins in *C. ternatea* bolster antioxidant defenses, mitigating oxidative stress that contributes to diabetic complications like neuropathy, nephropathy, and retinopathy. The plant also reduces serum lipid levels (e.g., triglycerides, LDL cholesterol) and increases HDL cholesterol, suggesting cardioprotective benefits. These effects were observed in both type 1 and type 2 diabetes models, indicating broad applicability. Traditional uses of the plant in managing "madhumeha" (diabetes in Ayurveda) align with these findings (Shirodkar *et al*., 2023) [16].

4.2.5 Wound Healing and Hemostasis

Clitoria ternatea accelerates wound healing through its anti-inflammatory, antioxidant, and tissue-regenerative properties. Extracts promote fibroblast proliferation, collagen deposition, and angiogenesis, essential for tissue repair. In excision and incision wound models in rats, topical application of *C. ternatea* extracts significantly reduced wound closure time and increased tensile strength of healed tissue. The anti-inflammatory effects minimize excessive inflammation at the wound site, preventing chronic wounds.

A key compound, ternatin D1, inhibits platelet aggregation by modulating thrombin and ADP pathways, suggesting antithrombotic potential. This dual role in wound healing and hemostasis makes *C. ternatea* a unique candidate for cardiovascular health, as it may prevent thrombus formation while aiding tissue repair. Traditional poultices made from leaves or flowers for cuts and bruises are supported by these mechanisms (Shirodkar *et al*., 2023) [16].

4.2.6 Anticancer Properties

Polyphenol-rich extracts of *C. ternatea* exhibit anticancer effects across various cell lines, including breast, lung, and colon cancers. The extracts induce apoptosis via the intrinsic mitochondrial pathway, characterized by increased Bax/Bcl-2 ratios, cytochrome c release, and caspase-3/7 activation. They also inhibit cell proliferation by downregulating cyclin-dependent kinases (CDKs) and upregulating p53 expression.

The antioxidant capacity of anthocyanins and flavonoids protects against DNA damage caused by ROS, a key factor in carcinogenesis. *In vivo* studies using tumor xenograft models showed reduced tumor volume and metastasis with *C. ternatea* treatment. These chemopreventive and therapeutic effects align with its traditional use in managing abnormal growths (Shirodkar *et al*., 2023) [16].

4.2.7 Neuroprotective and Cognitive Enhancement

Clitoria ternatea has significant neuroprotective and nootropic effects, supporting its traditional use as a "medhya rasayana" (cognitive enhancer) in Ayurveda. Extracts improve memory and spatial learning in animal models (e.g., Morris water maze) by upregulating brain-derived neurotrophic factor (BDNF) and enhancing synaptic plasticity. The plant increases acetylcholine levels by inhibiting acetylcholinesterase, benefiting conditions like Alzheimer's disease.

Additionally, *C. ternatea* modulates autophagy pathways, clearing misfolded proteins implicated in neurodegeneration. Its anxiolytic and antidepressant effects are mediated by GABAergic and serotonergic systems, reducing stress-induced cognitive deficits. These effects were observed in models of chronic stress and scopolamine-induced amnesia (Shirodkar *et al*., 2023) [16].

4.2.8 Antioxidant Defense

The antioxidant properties of *C. ternatea* are primarily driven by anthocyanins (e.g., delphinidin, malvidin) in its petals, which scavenge ROS and reactive nitrogen species (RNS). These compounds chelate metal ions, preventing Fenton reactions that generate hydroxyl radicals. The extracts also upregulate endogenous antioxidants like glutathione, superoxide dismutase (SOD), and catalase, protecting cellular macromolecules (DNA, proteins, lipids) from oxidative damage.

This antioxidant capacity underpins the plant's protective effects against chronic diseases, including neurodegeneration, diabetes, cardiovascular diseases, and cancer. *In vitro* assays (e.g., DPPH, ABTS) confirm the high radical-scavenging activity of *C. ternatea* extracts, comparable to synthetic antioxidants like ascorbic acid (Shirodkar *et al*., 2023) [16].

4.3 *Hibiscus sabdariffa*

4.3.1 Cardiovascular Health and Antihypertensive Effects: Pharmacologically, *Hibiscus sabdariffa* has been shown to exert multifaceted cardiovascular benefits, primarily due to its rich content of anthocyanins, flavonoids, and organic acids such as hibiscus acid. These bioactives possess antioxidant, anti-inflammatory, and vasodilatory properties that contribute to both atheroprotection and blood pressure regulation. Experimental studies on hyperlipidemic animal models have demonstrated a significant reduction in plasma triglycerides, low-density lipoprotein (LDL), and total cholesterol, with a concurrent decrease in atherosclerotic plaque development, thus indicating potential for the prevention of coronary artery disease (El-Saadany *et al*., 1991; Chen *et al*., 2003) [33, 34].

Mechanistically, these lipid-lowering effects may be mediated by the inhibition of HMG-CoA reductase, enhancement of bile acid excretion, and upregulation of LDL receptors, thereby facilitating improved lipid clearance. The antioxidant capacity of hibiscus polyphenols further inhibits oxidized LDL formation, a key factor in endothelial dysfunction and atherogenesis.

Clinical trials involving regular consumption of roselle calyx infusions have shown marked decreases in systolic and diastolic blood pressure, attributed to endothelial nitric oxide synthase (eNOS) activation, angiotensin-converting enzyme (ACE) inhibition, and increased renal sodium excretion via its mild diuretic effect (Ali *et al*., 2015; Huang *et al*., 2019; Wang *et al*., 2023) [35, 36, 12]. These findings collectively establish H. sabdariffa as a potential adjuvant in the dietary management of hypertension and cardiovascular risk.

4.3.2 Metabolic Regulation and Antidiabetic Potential

H. sabdariffa plays a critical role in regulating carbohydrate metabolism and mitigating insulin resistance, which are central to managing type 2 diabetes mellitus and metabolic syndrome. Its anthocyanins and phenolic compounds have been shown to enhance glucose uptake in adipose and muscle tissues by activating AMP-activated protein kinase (AMPK) and upregulating GLUT4 translocation.

In vitro and *in vivo* studies demonstrate its ability to inhibit key digestive enzymes, including α-glucosidase and α-amylase, which slows postprandial carbohydrate digestion and glucose absorption, thereby minimizing blood glucose spikes (Ali *et al*., 2015; Kim *et al*., 2018) [35, 37]. Furthermore, its antioxidant effects help reduce reactive oxygen species (ROS) in pancreatic β-cells, preserving their insulin-secreting capacity.

Anti-inflammatory activity via suppression of TNF-α, IL-1β, and IL-6 also improves systemic insulin sensitivity and reduces metabolic inflammation. Clinically, regular consumption of roselle extracts has been correlated with improved glycemic control, lipid profiles, and insulin sensitivity, supporting its therapeutic utility in metabolic disorders (Ali *et al*., 2015; Kim *et al*., 2018) [35, 37].

4.3.3 Antimicrobial and Anti-inflammatory Activity

H. sabdariffa exhibits potent antimicrobial activity due to the presence of hibiscus acid, astragalin, protocatechuic acid, and organic acids, which collectively disrupt microbial cell wall integrity, enzyme function, and nucleic acid synthesis. Its extracts have shown effectiveness against Gram-positive bacteria such as Staphylococcus albus and Bacillus anthracis, as well as fungi like Aspergillus fumigatus, confirming its broad-spectrum antimicrobial potential (Ali *et al*., 2015; Johnson *et al*., 2019) [35, 38].

The antimicrobial effect is further supported by acidification of the local environment, enhancing host defense mechanisms. These findings justify its ethnopharmacological use in treating skin infections, respiratory illnesses, and digestive tract disturbances.

Additionally, its anti-inflammatory effects are mediated through inhibition of COX-2, iNOS, and NF-κB, pathways commonly implicated in acute and chronic inflammatory diseases. The suppression of pro-inflammatory cytokine production supports its use in conditions such as arthritis, colitis, and systemic inflammation (Ali *et al*., 2015) [35]. However, more mechanistic studies are needed to fully understand the signaling pathways involved.

4.3.4 Analgesic and Antipyretic Effects

Pharmacological studies indicate that *H. sabdariffa* possesses significant analgesic and antipyretic activity, aligning with traditional uses in pain and fever relief. These effects are believed to result from the central inhibition of prostaglandin synthesis via COX pathway suppression, particularly COX-2, similar to non-steroidal anti-inflammatory drugs (NSAIDs) but with potentially fewer gastrointestinal side effects (Dafallah & Al-Mustafa, 1996; Ali *et al*., 2015) [35, 39].

Animal models demonstrated that roselle extracts significantly reduced acetic acid-induced writhing and formalin-induced nociception, suggesting both peripheral and central analgesic mechanisms. In febrile models, the extract normalized elevated body temperature by acting on the hypothalamic thermoregulatory center, likely through inhibition of PGE2 synthesis, thus validating its antipyretic efficacy (Ali *et al*., 2015) [35].

4.3.5 Renal and Uricosuric Effects

H. sabdariffa has demonstrated nephroprotective, diuretic, and uricosuric activities that support kidney function and aid in the management of gout and hyperuricemia. The aqueous extract promotes renal clearance of uric acid, sodium, potassium, and calcium, thereby improving electrolyte balance and decreasing the risk of stone formation (Kirdpon *et al*., 1994; Caceres *et al*., 1987; Ali *et al*., 2015) [40, 41, 35].

The diuretic activity is attributed to its organic acid content and flavonoids, which may act via renal tubular inhibition of Na^+/K^+-ATPase and interference with aldosterone-mediated sodium retention. These actions not only assist in managing fluid overload but also contribute to blood pressure reduction.

Additionally, its antioxidant profile protects renal tissues from oxidative nephrotoxicity, especially in the context of drug-induced renal damage or diabetes-related nephropathy, highlighting its role as a natural renal protectant (Ali *et al*., 2015) [35].

5. Conclusion

This review presents a comprehensive and integrative evaluation of the phytochemical profiles and therapeutic applications of *Matricaria chamomilla*, *Clitoria ternatea*, and *Hibiscus sabdariffa*, underscoring their enduring significance as medicinal plants with deep roots in traditional systems and growing prominence in evidence-based modern healthcare. These botanicals are exceptionally rich in diverse classes of bioactive constituents-including flavonoids, phenolic acids, terpenoids, anthocyanins, and essential oils-that contribute to their broad spectrum of pharmacological properties. Collectively, these phytochemicals mediate potent antioxidant, anti-inflammatory, hepatoprotective, neuroprotective, cardioprotective, anxiolytic, and antimicrobial effects, making these plants valuable candidates in the prevention and management of multiple chronic diseases.

Matricaria chamomilla is particularly distinguished for its calming, anti-inflammatory, and spasmolytic effects. Traditionally employed in the treatment of anxiety, insomnia, and gastrointestinal disturbances, its efficacy is attributed to sesquiterpenes like α-bisabolol and chamazulene, along with apigenin-a flavonoid with well-documented anxiolytic properties.

Clitoria ternatea is notable for its neuroprotective, nootropic, and antioxidant potential, primarily due to its rich content of anthocyanins, flavonol glycosides, and triterpenoids. These compounds have demonstrated efficacy in enhancing cognitive function, improving memory, and reducing oxidative stress in neuronal tissues, thus positioning the plant as a promising agent in the support of brain health and stress modulation.

Hibiscus sabdariffa is extensively recognized for its cardiometabolic benefits, including antihypertensive, diuretic, and lipid-lowering effects. These actions are largely mediated by anthocyanins such as delphinidin and cyanidin derivatives, as well as organic acids and polyphenols that help regulate blood pressure, lipid metabolism, and oxidative balance. Given these effects, H. sabdariffa offers considerable therapeutic promise in addressing the growing global burden of cardiovascular and metabolic disorders.

The intersection of traditional medicinal knowledge with contemporary pharmacological research provides compelling justification for continued exploration and integration of these botanicals into mainstream health systems. Their inclusion in dietary supplements, functional foods, and herbal formulations reflects a broader shift toward holistic, natural, and preventive health paradigms. However, realizing their full therapeutic potential necessitates the development and implementation of standardized extraction and processing methods, alongside in-depth mechanistic studies and clinical trials to validate efficacy and safety across diverse populations and disease conditions.

As consumer demand for natural health solutions continues to accelerate, these herbs are poised to contribute meaningfully to the development of evidence-based, plant-derived therapeutics. Their relatively low toxicity, cost-effectiveness, and multifaceted pharmacological profiles position them as promising alternatives or complements to conventional pharmaceuticals. Furthermore, innovations in formulation science, bioavailability enhancement, and personalized nutrition could enable more effective delivery and targeted health benefits.

In conclusion, *M. chamomilla*, *C. ternatea*, and *H. sabdariffa* exemplify the therapeutic richness of medicinal plants and their potential to shape the future of preventive and integrative medicine. With continued interdisciplinary research, investment in sustainable cultivation, and commitment to clinical validation, these botanicals may offer safe, effective, and accessible interventions for a wide array of health challenges-bridging the gap between ancient traditions and modern medical science.

6. References

1. Montalvo-González E, Villagrán Z, González-Torres S, Iñiguez-Muñoz LE, Isiordia-Espinoza MA, Ruvalcaba-Gómez JM, *et al*. Physiological effects and human health benefits of Hibiscus sabdariffa: a review of clinical trials. Pharmaceuticals. 2022;15(4):464.
2. Hegde M, Nidagundi J. Effect of newer chemicals on planthoppers and their mirid predator in rice. Karnataka Journal of Agricultural Sciences. 2010;22(3).
3. Singh A, Agrawal M, Marshall FM. The role of organic vs. inorganic fertilizers in reducing phytoavailability of heavy metals in a wastewater-irrigated area. Ecological Engineering. 2010;36(12):1733-1740.
4. Dai M, Liu D, Liu M, Zhou F, Li G, Chen Z, *et al*. Patients with cancer appear more vulnerable to SARS-CoV-2: a multicenter study during the COVID-19 outbreak. Cancer discovery. 2020;10(6):783-791.
5. Ali GH. Nutrient composition and biological evaluation of Hibiscus sabdariffa seeds. Plant Foods Hum Nutr. 1999;49:27–34.
6. Sah P, Fitzpatrick MC, Zimmer CF, Abdollahi E, Juden-Kelly L, Moghadas SM, *et al*. Asymptomatic SARS-CoV-2 infection: A systematic review and meta-analysis. Proceedings of the National Academy of Sciences. 2021;118(34):e2109229118.
7. Oguis GK, Gilding EK, Jackson MA, Craik DJ. Butterfly pea (*Clitoria ternatea*), a cyclotide-bearing plant with applications in agriculture and medicine. Front Plant Sci. 2019;10:645.
8. Jeyaraj EJ, Lim YY, Choo WS. Extraction methods of butterfly pea (*Clitoria ternatea*) flower and biological activities of its phytochemicals. J Food Sci Technol. 2021;58(6):2054–2067.
9. Mohammed H, Oljira L, Roba KT, Yimer G, Fekadu A, Manyazewal T. Containment of COVID-19 in Ethiopia and implications for tuberculosis care and research. Infectious diseases of poverty. 2020;9:1-8.
10. Rasoolimanesh SM, Ali F. Partial least squares-structural equation modeling in hospitality and tourism. Journal of Hospitality and Tourism Technology. 2018;9(3):238-248.
11. El Mihyaoui A, Esteves da Silva JC, Charfi S, Candela Castillo ME, Lamarti A, Arnao MB. Chamomile (*Matricaria chamomilla* L.): a review of ethnomedicinal use, phytochemistry and pharmacological uses. Life. 2022;12(4):479.
12. Dai YL, Li Y, Wang Q, Niu FJ, Li KW, Wang YY, *et al*. Chamomile: a review of its traditional uses, chemical constituents, pharmacological activities and quality control studies. Molecules. 2023;28(1):133.
13. Shen Z, Jin F, Wang F, McMillan O, Al-Tabbaa A. Sorption of lead by Salisbury biochar produced from British broadleaf hardwood. Bioresource technology. 2015;193:553-556.
14. Kumar M, More D. Phytochemical analysis and bioactivity of selected medicinal plant of butterfly-pea (*Clitoria ternatea* L.) used by Kolam tribe adjoining

region of Telangana and Maharashtra states. Pharma Innov J. 2019;8(1):417–421.
15. Sharma G, Garg N, Hasan S, Shirodkar S. Prevotella: An insight into its characteristics and associated virulence factors. Microbial Pathogenesis. 2022;169:105673.
16. Shirodkar SM, Multisona RR, Gramza-Michalowska A. The potential for the implementation of pea flower (*Clitoria ternatea*) health properties in food matrix. Appl Sci. 2023;13(12):7141.
17. Da-Costa-Rocha I, Bonnlaender B, Sievers H, Pischel I, Heinrich M. *Hibiscus sabdariffa* L.–A phytochemical and pharmacological review. Food Chem. 2014;165:424–443.
18. Nzikou JM, Bouanga-Kalou G, Matos L, Ganongo-Po FB, Mboungou-Mboussi PS, Moutoula FE, *et al*. Characteristics and nutritional evaluation of seed oil from Roselle (*Hibiscus sabdariffa* L.) in Congo-Brazzaville. Current Research Journal of Biological Sciences. 2011;3(2):141-146.
19. Ismail A, Ikram EHK, Nazri HSM. Roselle (*Hibiscus sabdariffa* L.) seeds nutritional composition protein quality and health benefits. Food. 2008;2(1):1–16.
20. Wilker C, Johnson L, Safe S. Effects of developmental exposure to indole-3-carbinol or2, 3, 7, 8-tetrachlorodibenzo-p-dioxin on reproductive potential of male rat offspring. Toxicology and applied pharmacology. 1996;141(1):68-75.
21. von Schilcher F. The function of pulse song and sine song in the courtship of Drosophila melanogaster. Animal Behaviour. 1976;24(3):622-625.
22. Buogo G, Picchinenna D. Chemical characteristics of Roselle hemp. Annali Di Chimica Applicata. 1937;27:577-582.
23. Indovina R, Capotummino G. Chemical analysis of karkade, the extract derived from *Hibiscus sabdariffa* L. cultivated in Sicily (Palermo). Ann Chim Applicata. 1938;28:413-418.
24. Reaubourg G, Monceaux RH. The chemical, botanical and pharmacological characteristics of the karkade (rosella) *Hibiscus sabdariffa* (gossypifolius). J Pharm Chim. 1940;1(9):292.
25. Morton RB. A group majority voting model of public good provision. Social Choice and Welfare. 1987;4(2):117-131.
26. Sah S. Understanding the (perverse) effects of disclosing conflicts of interest: A direct replication study. Journal of Economic Psychology. 2019;75:102118.
27. Dai X, Zhuang Z, Zhao PX. psRNATarget: a plant small RNA target analysis server (2017 release). Nucleic acids research. 2018;46(W1):W49-54.
28. Naseef H, Amria A, Al-Shami NM, Dreidi M. The acceptance and awareness of healthcare providers towards doctor of pharmacy (Phram D) in the Palestinian health care system. Saudi Pharmaceutical Journal. 2020;28(9):1068-1074.
29. Sah A, Naseef PP, Kuruniyan MS, Jain GK, Zakir F, Aggarwal G. A comprehensive study of therapeutic applications of chamomile. Pharmaceuticals. 2022;15(10):1284.
30. Gao S, Tang G, Hua D, Xiong R, Han J, Jiang S, *et al*. Stimuli-responsive bio-based polymeric systems and their applications. Journal of Materials Chemistry B. 2019;7(5):709-729.
31. Jain C, Rodriguez-R LM, Phillippy AM, Konstantinidis KT, Aluru S. High throughput ANI analysis of 90K prokaryotic genomes reveals clear species boundaries. Nature communications. 2018;9(1):5114.
32. Zakir R, Iqbal SS, Rehman AU, Nosheen S, Ahmad TS, Ehsan N, *et al*. Spectral, electrical, and dielectric characterization of Ce-doped Co-Mg-Cd spinel nano-ferrites synthesized by the sol-gel auto combustion method. Ceramics International. 2021;47(20):28575-28583.
33. El-Saadany SS, El-Massry RA, Labib SM, Sitohy MZ. The biochemical role and hypocholesterolaemic potential of the legume Cassia fistula in hypercholesterolaemic rats. Food/Nahrung. 1991;35(8):807-815.
34. Chen F, D'Auria JC, Tholl D, Ross JR, Gershenzon J, Noel JP, *et al*. An Arabidopsis thaliana gene for methylsalicylate biosynthesis, identified by a biochemical genomics approach, has a role in defense. The Plant Journal. 2003;36(5):577-588.
35. Ali S, Li D, Congbin F, Khan F. Twenty first century climatic and hydrological changes over Upper Indus Basin of Himalayan region of Pakistan. Environmental Research Letters. 2015;10(1):014007.
36. Huang KY, Lee TY, Kao HJ, Ma CT, Lee CC, Lin TH, *et al*. dbPTM in 2019: exploring disease association and cross-talk of post-translational modifications. Nucleic acids research. 2019;47(D1):D298-308.
37. Joung B, Lee JM, Lee KH, Kim TH, Choi EK, Lim WH, *et al*. Korean guideline of atrial fibrillation management. Korean circulation journal. 2018;48(12):1033.
38. Johnson M. Archaeological theory: an introduction. John Wiley & Sons; c2019.
39. Dafallah AA, Al-Mustafa Z. Investigation of the anti-inflammatory activity of Acacia nilotica and Hibiscus sabdariffa. The American journal of Chinese medicine. 1996;24(03n04):263-269.
40. Kirdpon S, Nakorn SN, Kirdpon W. Changes in urinary chemical composition in healthy volunteers after consuming roselle (*Hibiscus sabdariffa* Linn.) juice. Journal of the Medical Association of Thailand= *Chotmaihet thangphaet*. 1994;77(6):314-321.
41. Cáceres A, Girón LM, Alvarado SR, Torres MF. Screening of antimicrobial activity of plants popularly used in Guatemala for the treatment of dermatomucosal diseases. Journal of ethnopharmacology. 1987;20(3):223-237.