

Phytochemical Profiling and Therapeutic Potential of Medicinal Plants for Cancer

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Abstract-

Medicinal plants have been used as medication for human diseases because they contain chemical components of curative value. Medicinal plants are good source to obtain a variety of therapeutic medicines. Dry powder of *O. sanctum*, stem of *Curcuma longa*, Stem of *Withania somnifera*, Stem of *Tinospora cordifolia* and leaves of *Andrographis peniculata* was prepared by grinding method. Plant extract prepared through Soxhlet distillation method in Methanol, distilled water and Ethanol organic solvents separately. The plant extract was prepared for phytochemical activity. Phytochemical analysis was done and it was found that extracted phytochemicals from the plants has a great remedy for the cure of cancer cells. It has been evident from the present review that phytochemicals serve as promising and effective research area with bright future.

Key word: *Soxhlet distillation, therapeutic medicines, Phytochemical*

Introduction

Plants are utilised for treating a variety of diseases from time im- memorial. The oldest ancient (4500 BCE) still living traditions are Traditional Chinese Medicine, Traditional Indian Medicine, Ayurveda, and. The information of selecting the proper plants, a precise collection time and the method of medication production with their detailed usage was passed down from one generation to the next verbally. In the later 18th to early 19th centuries, with advancement in organic chemistry and proper chemical investigation, a systematic investigation of mechanisms of bioactive principles of medicinal plants was done for purification and characterization after isolation of many herbal bioactive principles. Cancer is a leading cause of death globally. Chemotherapy has side effects; thus, plant-based therapies are gaining attention. Many medicinal plants have phytochemicals (alkaloids,

flavonoids, terpenoids, saponins, etc.) with anticancer properties. Example: *Taxol* from *Taxus brevifolia*, *Vincristine* from *Catharanthus roseus*. Cancer remains one of the leading causes of mortality worldwide, characterized by uncontrolled cell growth and the potential to invade or spread to other parts of the body. Despite advances in chemotherapy, radiation therapy, and surgical interventions, current treatment modalities often come with significant side effects and limitations, including drug resistance, toxicity to normal tissues, and high cost. Consequently, there is a growing interest in exploring natural and plant-based alternatives as complementary or potential primary anticancer therapies Balunas MJ, Kinghorn AD, (2005). Among these, medicinal plants have shown promising potential due to their rich reservoir of bioactive compounds with various therapeutic properties. These plants produce secondary metabolites like alkaloids, flavonoids, terpenoids, glycosides, and polyphenols, many of which exhibit cytotoxic, antiproliferative, pro-apoptotic, antiangiogenic, and antioxidant activities Bhat, R., & Karim, A.A. (2012). With increasing evidence from in vitro, in vivo, and clinical studies, researchers are now focusing on identifying, isolating, and characterizing these phytochemicals to develop safer and more effective anticancer agents.

Herbal medicine is the world's oldest system of traditional medicine. The World Health Organization (WHO) defines it as the practice involving herbs, herbal materials, preparations, and products containing bioactive compounds or other plant materials, either alone or in combination. Herbal medicine is widely used across all societies, with diverse preparation methods and treatment practices globally. Bioactive compounds derived from herbs can inhibit cancer growth by modulating hormone and enzyme activities. Herbal medicine is generally regarded as safe and is associated with fewer complications. Many cancer patients use herbal remedies alongside chemotherapy to enhance its effectiveness and reduce adverse reactions. Those who incorporate herbal remedies often report improvements in clinical symptoms, quality of life, reduced side effects, and extended survival. Many bioactive compounds extracted from herbs have been reported to support the immune system in fighting cancer more effectively. While traditional healers in Ethiopia use numerous medicinal plants, most of these species lack scientific evidence for their anticancer effects, Tafere Mulaw Belete and Alemante Tafese Beyna 2025. several new anticancer agents of natural origin have recently been approved for therapeutic use, with many others currently undergoing clinical trials. Thomford NE,*et.al.*, 2018 the plant-derived anticancer agents are available in medicinal plants.

Methods and Materials

1. Selection of Plant- Five plants are selected on the basis of Traditional use in ethnomedicine. Plants are *Curcuma longa* (turmeric), *Withania somnifera* (ashwagandha), *Tinospora cordifolia*, *Andrographis peniculata* and *Ocimum sanctum*.

2. Extraction of Plant Material

2.1. Collection & Sample Preparation of *O. sanctum*

The leaves of *O. sanctum*, stem of *Curcuma longa*, Stem of *Withania somnifera*, Stem of *Tinospora cordifolia* and leaves of *Andrographis peniculata* were collected from the market and were identified. Leaves harvesting, and sample extraction were performed on the same day. The *O. sanctum* leaves were separated from the stalks and the flowers. The leaves were washed thoroughly. Then, they were dried for 72 hours using a freeze dryer (ALPHA Freeze Dryer Model 1-2 LD plus Vacuubrand, Germany). The dried leaves were then ground into a powder using a blender (Model BL 335, Kenwood, stored in amber-colored glass bottles that were covered with aluminum foil, and kept airtight with Parafilm. The ground leaves were stored at -20°C until further use.

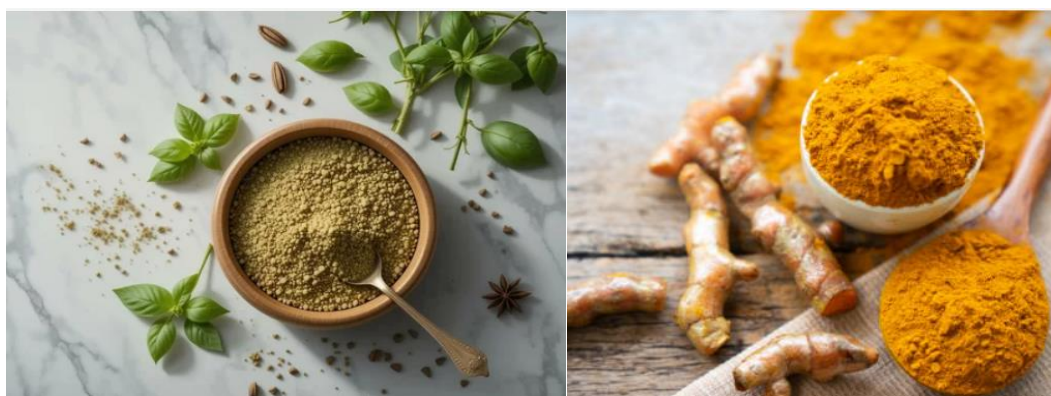


Figure-1: Ground powder of (a) *O. sanctum* (b) *Curcuma longa* (c) *Withania somnifera* (d) *Tinospora cordifolia* (e) *Andrographis peniculata*

Extraction Methods:

1. Soxhlet extraction in water, Methano and Ethanol-

Approximately 50 g of ground leaves were extracted for 4 hours in a bath of hot distilled water. Whatman No. 1 filter paper was used to filter the resulting crude extract. The same volume of hot (85°C) distilled water was added to repeat the extraction. The crude extract was filtered using Whatman No. 1 filter paper. The filtrate was dried into a powder using a freeze dryer (ALPHA Freeze Dryer model 1-2 LD plus, Vacuubrand, Germany). The powdered extract was stored at –20°C until further use. Same process done for all five plant samples.



Figure-14: Soxhlet Extraction Unit

4. Phytochemical Screening of Plant Extract

The phytochemical investigations for different biochemical compound like glycosides, alkaloids, flavonoids, glycosides, phenols, steroids, resins, saponins, tannins, terpenoids, triterpenoids and ascorbic acid were made by following standard procedures.

I. Qualitative: Tests for alkaloids, flavonoids, tannins, saponins, etc.

1) Alkaloids: Principle: Alkaloids (basic N compounds) form insoluble complexes/precipitates with heavy-metal iodides or picrate. Mayer's test, Dragendorff's test, Wagner's test, Hager's test are used to find out the composition of alkaloids.

2) Flavonoids: Principle: Flavonoids undergo reduction (Shinoda) or form-colored complexes with bases/metal salts. Shinoda (Mg–HCl) test, Alkaline reagent test, Lead acetate test and AlCl_3 complexation are used to find out the composition of Flavonoids.

3) Tannins (phenolic tannins): Principle: Tannins chelate Fe^{3+} and precipitate proteins/gelatin. Ferric chloride test, Gelatin test, Lead acetate test and Vanillin–HCl test (for condensed tannins) are used to find out the composition of Tannins.

4) Saponins: Principle: Surface-active glycosides that foam and can lyse RBCs. Foam test (froth test) and Hemolysis test are used to find out the composition of Saponins.

5) Terpenoids & Steroids- Salkowski (terpenoids/steroids) and Liebermann–Burchard (sterols/triterpenes) are used to find out the composition of Terpenoids and Steroids.

6) Glycosides- Keller–Killiani (cardiac glycosides: deoxy-sugars) and Bornträger (anthraquinone glycosides) are used to find out the composition of Glycosides.

7) Phenolics (general)- Ferric chloride (phenols) test is used to find out the composition of Phenolics.

8) Reducing sugars (quick screen)- Benedict's test is used to find out the composition of reducing sugars.

II. Quantitative test:

a. Total phenolic content (TPC)- Phenolics reduce the Folin–Ciocalteu (F–C) reagent (phosphomolybdotungstate) under alkaline conditions to a blue complex measured at $\lambda = 760\text{--}765$ nm (often read at 750 or 765 nm).

b. Total flavonoid content (TFC)- Al^{3+} forms stable acid-labile complexes with the keto and hydroxyl groups of flavonols/flavones (and, via diazotization, also detects flavan-3-ols in Method A), giving a yellow/orange chromophore. Measure absorbance and express as mg CE or QE per g sample (dry weight).

Result and Discussion-

1. Phytochemical screening of Medicinal Plant

Phytochemical screening of medicinal plants is a preliminary process carried out to identify the presence of various bioactive compounds that are responsible for their therapeutic properties. The procedure generally begins with the collection of fresh plant materials such as leaves, stems, roots, bark, or seeds, which are then cleaned, shade-dried, and powdered to preserve the active constituents. The powdered material is subjected to extraction using different solvents such as ethanol, methanol, chloroform, petroleum ether, or water, depending on the polarity of the phytochemicals to be extracted. The concentrated extracts are then tested for the presence of different classes of secondary

metabolites through a series of qualitative chemical tests. Alkaloids are usually detected using Mayer's, Wagner's, or Dragendorff's reagents, while flavonoids are confirmed by the Shinoda or alkaline reagent test. Tannins are identified through ferric chloride reaction, and saponins by their ability to produce stable froth in the foam test. Similarly, phenols, glycosides, terpenoids, steroids, carbohydrates, proteins, and amino acids are identified using specific reagents and characteristic color changes or precipitate formation. The results are recorded as the presence or absence of particular phytochemicals, which provide valuable insights into the medicinal potential of the plant. This initial screening not only helps in validating traditional medicinal claims but also serves as a foundation for further quantitative estimation, advanced chromatographic analysis, and structural elucidation of the bioactive compounds for pharmaceutical applications.

1.1 *Curcuma longa* (Turmeric) phytochemical availability

Curcuma longa (turmeric) is one of the most widely studied medicinal plants, valued for its rich phytochemical profile and extensive therapeutic applications. The rhizome of turmeric contains a diverse range of bioactive compounds, mainly curcuminoids (curcumin, demethoxycurcumin, and bisdemethoxycurcumin), essential oils (turmerone, atlantone, zingiberene), and other constituents such as flavonoids, tannins, saponins, steroids, alkaloids, and carbohydrates. Among these, curcumin is the principal polyphenolic compound responsible for the characteristic yellow color of turmeric and its potent pharmacological effects. The essential oils, especially ar-turmerone, are known for their antioxidant, antimicrobial, and anti-inflammatory properties, while the combination of phenolic and flavonoid compounds enhances its free radical scavenging ability.

The phytochemicals present in turmeric contribute to a wide spectrum of applications in medicine and health care. Turmeric exhibits strong anti-inflammatory and antioxidant properties, making it beneficial in the management of chronic inflammatory conditions such as arthritis and cardiovascular diseases. Its antimicrobial and antiseptic activities have led to its traditional use in treating wounds, skin infections, and digestive ailments. Curcumin has been extensively researched for its anticancer potential, as it can inhibit tumor initiation, progression, and metastasis through the modulation of various molecular pathways. Turmeric also shows hepatoprotective, neuroprotective, and immunomodulatory effects, supporting its use in liver disorders, neurodegenerative diseases like Alzheimer's, and in boosting overall immunity. Beyond medicinal uses, turmeric is applied in the food industry as a natural coloring agent, preservative, and flavour enhancer, and in the cosmetic industry for its skin-lightening and anti-aging properties.

Thus, the phytochemical richness of *Curcuma longa* not only validates its role in traditional Ayurvedic and Chinese medicine but also establishes it as a modern therapeutic agent with applications spanning pharmaceuticals, nutraceuticals, food technology, and dermatology.

Table-Phytochemical screening of *Curcuma longa* (Stem)

S.N.	Phytochemical compound	Plant part	Methanol	Ethanol
1	Alkaloids	Stem	+	-
2	Carbohydrates	Stem	+	-
3	Cardiac Glycosides	Stem	+	+
4	Proteins	Stem	+	+
5	Phytosterols	Stem	+	+
6	Flavonoids	Stem	+	+
7	Tannins	Stem	+	-
8	Terpenoids	Stem	+	-
9	Saponins	Stem	+	-
10	Phenols/ Polyphenols	Stem	+	+

1.2 *Withania somnifera* (Ashwagandha) phytochemical availability

Withania somnifera (commonly known as Ashwagandha or Indian ginseng) is a highly valued medicinal plant in Ayurveda, widely recognized for its adaptogenic, rejuvenating, and therapeutic properties. Its pharmacological potential is attributed to a broad spectrum of phytochemicals present in its roots, leaves, and berries. The most important bioactive compounds are withanolides (steroidal lactones), including withaferin A, withanolide D, withanone, and withanosides, which are considered the primary markers for its medicinal activity. Along with withanolides, the plant also contains alkaloids (somniferine, anaferine, tropine, cuscohygrine, anahygrine), saponins, steroids, flavonoids, tannins, and trace amounts of essential oils and amino acids. The availability of these phytochemicals varies depending on the part of the plant. The roots are particularly rich in withanolides, alkaloids, and sitoindosides, making them the main source of therapeutic preparations. The leaves contain withaferin A and other withanolides with strong anticancer and antimicrobial activities, while the berries are rich in alkaloids and certain flavonoids that contribute to their medicinal and nutraceutical applications. The diverse phytochemical profile of *Withania somnifera* underlies its multiple health applications. Withanolides and alkaloids act as powerful adaptogens and anti-stress agents, enhancing

the body's resilience against physiological and psychological stress. The plant demonstrates significant anti-inflammatory, antioxidant, anticancer, neuroprotective, and immunomodulatory activities. It is traditionally used to improve vitality, memory, and reproductive health, and modern studies support its role in managing neurodegenerative disorders like Alzheimer's and Parkinson's disease. Ashwagandha is also beneficial in conditions such as arthritis, diabetes, cardiovascular diseases, and certain microbial infections.

Thus, the phytochemical richness of Ashwagandha provides a scientific basis for its extensive use in traditional medicine and validates its growing importance in modern pharmacology, nutraceuticals, and functional foods.

Phytochemical Groups in *Withania somnifera*

1. **Withanolides (Steroidal Lactones) Examples:** Withaferin A, Withanolide D, Withanone, Withanosides IV & VI. Found mainly in roots and leaves. Withaferin A shows potent anticancer properties, inducing apoptosis and inhibiting angiogenesis in tumor cells. Withanolides act as adaptogens, reducing stress and improving mental and physical stamina. Some withanolides have anti-inflammatory and immunomodulatory activities, helpful in arthritis and autoimmune conditions.
2. **Alkaloids-Examples:** Somniferine, Anaferine, Tropine, Cuscohygrine, Anahygrine. Found in roots and berries. Show analgesic and sedative effects, contributing to Ashwagandha's traditional use as a sleep-inducing agent. Help in neuroprotection, improving memory and reducing anxiety. Some alkaloids exhibit antimicrobial properties against bacteria and fungi.
3. **Saponins-Examples:** Sitoindosides VII and VIII. Found in roots. Exhibit antioxidant and anti-stress activity, helping the body adapt to oxidative stress. Enhance immune function and may improve resistance to infections.
4. **Sterols-Examples:** β -Sitosterol. Available in Roots and aerial parts. It Show anti-inflammatory and cholesterol-lowering effects. It Support cardiovascular health by reducing LDL levels.
5. **Flavonoids and Phenolic Compounds-Examples:** Quercetin, Kaempferol (in small amounts). Present in leaves and berries. It Provide antioxidant protection, neutralizing free radicals. It Help in neuroprotection and anti-aging effects.

6. Other Compounds like Tannins – contribute to antimicrobial and antioxidant activity. Amino acids – support nutritional and metabolic functions. Iron and trace elements – contribute to Ashwagandha's role in treating anemia.

Table-Phytochemical screening of *Withania somnifera* (Stem)

S.N.	Phytochemical compound	Plant part	Methanol	Ethanol
1	Alkaloids	Stem	+	-
2	Carbohydrates	Stem	+	-
3	Cardiac Glycosides	Stem	+	+
4	Proteins	Stem	+	+
5	Phytosterols	Stem	+	+
6	Flavonoids	Stem	+	+
7	Tannins	Stem	+	-
8	Terpenoids	Stem	+	-
9	Saponins	Stem	+	-
10	Phenols/ Polyphenols	Stem	+	+

Applications of Ashwagandha Based on Phytochemicals

Adaptogenic & Anti-stress-Withanolides, saponins (reduce cortisol, improve stress tolerance). Ashwagandha (*Withania somnifera*), also known as Indian ginseng or winter cherry, is a well-known medicinal plant in Ayurveda, valued for its adaptogenic and anti-stress properties. Adaptogens are natural substances that help the body adapt to physical, emotional, and environmental stressors while restoring balance and homeostasis. The bioactive constituents of Ashwagandha, primarily withanolides, alkaloids, and sitoindosides, play a crucial role in modulating stress response pathways. They act by regulating the hypothalamic–pituitary–adrenal (HPA) axis and cortisol secretion, thereby reducing excessive stress hormone levels. This helps in alleviating anxiety, improving mood, and enhancing resilience against chronic stress.

Clinical studies suggest that Ashwagandha supplementation can reduce cortisol levels, perceived stress, and anxiety scores while improving energy, concentration, and sleep quality. Its adaptogenic effect not only protects the nervous system from stress-induced damage but also boosts immune

function, supports cognitive health, and improves overall well-being. Thus, Ashwagandha serves as a natural anti-stress remedy that enhances both physical and mental performance, making it a valuable herb for managing modern lifestyle-related stress disorders.

Neuroprotective-Alkaloids and flavonoids (used in Alzheimer's, Parkinson's, and anxiety disorders). Ashwagandha (*Withania somnifera*) exhibits strong neuroprotective effects, mainly due to its bioactive compounds such as withanolides, sitoindosides, and alkaloids. These compounds help protect nerve cells from oxidative stress, inflammation, and toxic insults. Ashwagandha enhances antioxidant enzyme activity (superoxide dismutase, catalase, glutathione peroxidase), thereby reducing free radical damage in the brain. It also promotes neuronal regeneration and synaptic plasticity, supporting memory, learning, and cognitive functions. Research shows that Ashwagandha can reduce neurodegeneration, making it beneficial in conditions like Alzheimer's, Parkinson's, and Huntington's disease, where neuronal loss is a major concern. Additionally, it lowers beta-amyloid plaque accumulation and inhibits acetylcholinesterase activity, thereby improving cholinergic transmission. Overall, Ashwagandha acts as a natural neuroprotective agent, improving cognition, memory, mood stability, and resilience against neurodegenerative disorders.

Anti-inflammatory & Analgesic-Withaferin A, β -sitosterol (helpful in arthritis and pain relief). Ashwagandha (*Withania somnifera*) is well recognized for its anti-inflammatory and analgesic effects, which contribute to its wide therapeutic applications in traditional and modern medicine. The active constituents, particularly withanolides, sitoindosides, and alkaloids, act by modulating inflammatory pathways. They inhibit the release of pro-inflammatory cytokines (TNF- α , IL-1 β , IL-6) and suppress the activity of nuclear factor-kappa B (NF- κ B) and cyclooxygenase (COX) enzymes, thereby reducing inflammation at both acute and chronic levels. In addition, Ashwagandha reduces oxidative stress in inflamed tissues, prevents cartilage degradation, and helps in conditions like arthritis, asthma, and inflammatory bowel disease. Its analgesic (pain-relieving) activity is attributed to its action on the central nervous system and modulation of pain receptors, which alleviates both nociceptive and neuropathic pain. Thus, Ashwagandha acts as a natural anti-inflammatory and analgesic agent, providing relief in chronic inflammatory diseases, joint disorders, and stress-related pain without the side effects commonly associated with synthetic drugs.

Anticancer-Withaferin A, withanolides (inhibit tumor growth and metastasis). Ashwagandha (*Withania somnifera*) demonstrates significant **anticancer potential** due to its rich phytoconstituents, especially withanolides (withaferin A, withanolide D), alkaloids, and sitoindosides. These bioactive

compounds exhibit cytotoxic, anti-proliferative, and pro-apoptotic effects against various cancer cell lines. Mechanistically, Ashwagandha works by Inducing apoptosis (programmed cell death) and Activates caspase pathways and increases pro-apoptotic proteins (Bax) while suppressing anti-apoptotic proteins (Bcl-2). It Inhibiting cell proliferation by Downregulates signaling pathways like PI3K/Akt, MAPK, and NF- κ B, which are crucial for tumor growth. It shows Anti-angiogenic effect and prevents the formation of new blood vessels that supply nutrients to tumors. It Reducing metastasis Inhibits cancer cell migration and invasion by modulating matrix metalloproteinases (MMPs). Enhancing immune surveillance and boosts the activity of natural killer (NK) cells and macrophages, improving the body's defense against tumor cells. Research indicates promising effects of Ashwagandha against breast, colon, prostate, lung, and cervical cancers, both as a standalone therapy and as an adjuvant to chemotherapy/radiotherapy, where it reduces side effects and improves tolerance. Thus, Ashwagandha acts as a natural anticancer agent with multi-targeted action, combining tumor-suppressing, immune-boosting, and protective effects.

Immunomodulatory-Sitoindosides, withanolides (boost immunity, fight infections). Ashwagandha (*Withania somnifera*) possesses strong immunomodulatory properties, helping to balance and regulate the body's immune responses. Its active compounds, mainly withanolides, sitoindosides, and alkaloids, enhance both innate and adaptive immunity. Ashwagandha stimulates the activity of immune cells such as macrophages, natural killer (NK) cells, and lymphocytes, thereby strengthening the body's defense against infections. It also promotes antibody production and supports T-helper cell activity, which improves cellular immunity. At the same time, Ashwagandha helps control excessive immune responses by downregulating pro-inflammatory cytokines, thus preventing autoimmune reactions and chronic inflammation. Through its adaptogenic and antioxidant actions, it not only boosts immunity during conditions of weakness or stress but also protects immune cells from oxidative damage, ensuring long-term immune balance. Therefore, Ashwagandha acts as a natural immunomodulator, enhancing resistance to diseases while maintaining overall immune homeostasis.

Cardioprotective- β -sitosterol, flavonoids (lower cholesterol, protect heart function). Ashwagandha (*Withania somnifera*) exhibits significant cardioprotective effects, making it beneficial for maintaining heart health and preventing cardiovascular disorders. Its active constituents, mainly withanolides and sitoindosides, contribute to reducing oxidative stress and inflammation, both of which play major roles in heart disease progression. Ashwagandha lowers serum cholesterol, triglycerides, and low-density lipoprotein (LDL) while increasing high-density lipoprotein (HDL), thereby improving lipid profile and reducing the risk of atherosclerosis. It also supports blood

pressure regulation by promoting vasodilation and reducing stress-induced hypertension through modulation of the hypothalamic–pituitary–adrenal (HPA) axis and cortisol levels. Additionally, Ashwagandha enhances cardiac muscle strength, improves circulation, and protects myocardial tissue against ischemic injury by reducing free radical damage. Its adaptogenic effect further helps in reducing stress-related cardiac strain. Overall, Ashwagandha acts as a natural cardioprotective agent, supporting heart function, preventing oxidative damage, and lowering the risk of cardiovascular diseases.

Reproductive Health -Alkaloids and withanolides (enhance fertility, testosterone levels, and vitality). Ashwagandha (*Withania somnifera*) plays an important role in promoting reproductive health in both men and women, owing to its adaptogenic, antioxidant, and hormone-regulating properties. In men, Ashwagandha enhances spermatogenesis, semen quality, sperm motility, and testosterone levels, thereby improving fertility and managing conditions like oligospermia and erectile dysfunction. Its ability to reduce oxidative stress and improve mitochondrial function protects sperm from DNA damage, enhancing reproductive potential. In women, Ashwagandha helps regulate the menstrual cycle, supports ovarian function, and balances reproductive hormones, which is beneficial in conditions such as polycystic ovary syndrome (PCOS) and infertility. It also reduces stress-related reproductive issues by lowering cortisol levels and improving overall hormonal balance. Additionally, Ashwagandha enhances libido, vitality, and sexual wellness due to its rejuvenating effects on the endocrine and nervous systems. Thus, it acts as a natural fertility booster and reproductive tonic, supporting overall sexual and reproductive health.

Withania somnifera contains a cocktail of phytochemicals where withanolides are the signature compounds giving it anticancer, adaptogenic, and anti-inflammatory potential; alkaloids support nervous system health; and flavonoids, saponins, and sterols add antioxidant, immunomodulatory, and cardioprotective effects.

Withania somnifera (Ashwagandha) possesses a wide variety of phytochemicals that are responsible for its diverse therapeutic effects. The most important compounds are withanolides, which are steroidal lactones including withaferin A, withanolide D, and withanone. These are mainly concentrated in the roots and leaves and are known for their strong anticancer, anti-inflammatory, and adaptogenic properties. Ashwagandha also contains several alkaloids such as somniferine, anaferine, tropine, cuscohygrine, and anahygrine, which contribute to its sedative, analgesic, neuroprotective, and antimicrobial effects. In addition, saponins like sitoindosides enhance its antioxidant, anti-stress,

and immune-boosting properties, while sterols such as β -sitosterol are associated with cholesterol-lowering and cardioprotective activities. The plant also contains flavonoids and phenolic compounds that provide antioxidant and neuroprotective benefits, along with tannins, amino acids, and trace elements that support antimicrobial action, metabolic health, and nutritional value. Owing to this rich phytochemical composition, Ashwagandha is recognized as a powerful adaptogen that reduces stress and anxiety, protects the nervous system, strengthens immunity, improves memory, and supports reproductive health. It has also been studied for its anticancer potential, cardiovascular benefits, and role in managing neurodegenerative and inflammatory disorders. Thus, the diverse phytochemicals present in *Withania somnifera* make it one of the most important medicinal plants in Ayurveda, with applications extending into modern pharmacology, nutraceuticals, and functional foods.

1.3 Phytochemical Groups in *Tinospora cordifolia* (Giloy)

Tinospora cordifolia, commonly known as Giloy, contains a wide range of phytochemicals that contribute to its medicinal properties. The major phytochemical groups present in Giloy include alkaloids, glycosides, steroids, diterpenoid lactones, aliphatics, and polysaccharides. Important alkaloids such as berberine, palmatine, and magnoflorine are responsible for its antimicrobial and immunomodulatory activities. The plant is also rich in glycosides and diterpenoid lactones (tinosporin, cordifolide, and cordifol) which show strong antioxidant, hepatoprotective, and anti-inflammatory effects. Steroids and phenolic compounds provide anti-diabetic, cardioprotective, and adaptogenic benefits. Additionally, the polysaccharides, particularly arabinogalactan polysaccharide, play a key role in immunostimulation and enhancing the body's defense mechanisms. The combined action of these phytochemical groups makes Giloy a potent medicinal plant with diverse therapeutic applications, including antipyretic, anti-inflammatory, antioxidant, hepatoprotective, and immunomodulatory effects. *Tinospora cordifolia* is a highly valued medicinal plant in Ayurveda, widely used for its rejuvenating, immunomodulatory, and therapeutic properties.

S.N.	Phytochemical compound	Plant part	Methanol	Ethanol
1	Alkaloids	Stem	+	-
2	Carbohydrates	Stem	+	-
3	Cardiac Glycosides	Stem	+	+
4	Proteins	Stem	+	+
5	Phytosterols	Stem	+	+
6	Flavonoids	Stem	+	+

7	Tannins	Stem	+	-
8	Terpenoids	Stem	+	-
9	Saponins	Stem	+	-
10	Phenols/ Polyphenols	Stem	+	+

These health benefits are mainly attributed to its diverse range of phytochemicals. The plant contains a rich composition of alkaloids, diterpenoid lactones, glycosides, steroids, flavonoids, phenolics, lignans, tannins, and polysaccharides. Alkaloids such as berberine, palmatine, magnoflorine, and tembetarine contribute to antimicrobial, anti-inflammatory, and hepatoprotective effects. Diterpenoid lactones like tinosporide, tinosporon, cordifolide, and cordifol are responsible for antioxidant, antidiabetic, and anticancer properties. Steroids (e.g., β -sitosterol, ecdysterone, giloinsterol) help in cardioprotection, cholesterol regulation, and anti-inflammatory activities. Glycosides and flavonoids play a role in antipyretic, anti-stress, and free radical scavenging actions, supporting immunity and metabolic health. Phenolic compounds and tannins provide strong antioxidant and antimicrobial effects, protecting tissues from oxidative damage. Polysaccharides, particularly arabinogalactan polysaccharides, have potent immunomodulatory and anti-stress activities, enhancing host defense mechanisms. The synergistic action of these phytochemicals makes Giloy a multi-targeted medicinal herb, useful in managing fever, diabetes, liver disorders, infections, inflammatory conditions, and immune-related diseases.

1.4 Phytochemicals of *Andrographis paniculata* (Kalmegh)

Andrographis paniculata, commonly known as Kalmegh or “King of Bitters,” is a medicinal plant widely used in Ayurveda, Unani, and traditional Chinese medicine. Its therapeutic importance lies in its diverse range of phytochemicals, especially diterpenoid lactones, flavonoids, xanthones, and other secondary metabolites. Diterpenoid lactones are the principal bioactive constituents, with andrographolide being the most abundant and pharmacologically active. Others include neoandrographolide, deoxyandrographolide, and andrograpanin, which exhibit strong anti-inflammatory, anticancer, hepatoprotective, and antimalarial properties. Flavonoids such as andrographidine, apigenin, luteolin, and quercetin provide antioxidant, anti-inflammatory, and cardioprotective effects.

S.N.	Phytochemical compound	Plant part	Methanol	Ethanol
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1	Alkaloids	Stem	+	-
2	Carbohydrates	Stem	+	-
3	Cardiac Glycosides	Stem	+	+
4	Proteins	Stem	+	+
5	Phytosterols	Stem	+	+
6	Flavonoids	Stem	+	+
7	Tannins	Stem	+	-
8	Terpenoids	Stem	+	-
9	Saponins	Stem	+	-
10	Phenols/ Polyphenols	Stem	+	+

Xanthones and polyphenolic compounds contribute to antimicrobial, antioxidant, and neuroprotective activities. Sterols (β -sitosterol, stigmasterol) and terpenoids support immunomodulatory, hepatoprotective, and anti-stress functions. Alkaloids (though present in small amounts) add to the plant's antimicrobial and analgesic potential. The combined action of these phytochemicals makes *Andrographis paniculata* a powerful medicinal herb with broad therapeutic applications, including liver protection, fever reduction, immune enhancement, anti-inflammatory action, anticancer activity, and infection control.

Andrographis paniculata, popularly known as Kalmegh or the “King of Bitters,” is a well-known medicinal herb recognized for its broad therapeutic potential, which is attributed to its rich phytochemical composition. The plant is especially abundant in diterpenoid lactones, of which andrographolide is the major bioactive compound responsible for its bitter taste and pharmacological actions. Along with andrographolide, other diterpenoids such as neoandrographolide, deoxyandrographolide, and andrograpanin exhibit significant anti-inflammatory, antimalarial, anticancer, hepatoprotective, and immunomodulatory activities. In addition to diterpenoids, Kalmegh also contains a variety of flavonoids like andrographidine, apigenin, luteolin, and quercetin, which act as powerful antioxidants, protecting cells from oxidative stress and contributing to its cardioprotective, neuroprotective, and anti-aging effects.

The plant also contains xanthones, polyphenols, tannins, and saponins, which enhance its antimicrobial, antiviral, and antioxidant properties, making it useful in infections and immune-related

disorders. Furthermore, the presence of plant sterols such as β -sitosterol and stigmasterol supports cholesterol regulation, liver protection, and anti-inflammatory actions. Small amounts of alkaloids and terpenoids further contribute to its analgesic, antimicrobial, and adaptogenic potential. Together, these phytochemicals act synergistically to make *Andrographis paniculata* a potent herbal remedy, traditionally and scientifically valued for managing conditions such as fever, respiratory infections, liver disorders, inflammation, diabetes, cancer, and immune dysfunctions.

1.5. Phytochemicals of *Ocimum sanctum* (Holy Basil / Tulsi)

Ocimum sanctum, commonly known as Tulsi or Holy Basil, is a sacred medicinal plant in Ayurveda, revered for its wide spectrum of therapeutic effects. Its medicinal value comes from a rich profile of phytochemicals including alkaloids, glycosides, flavonoids, tannins, saponins, terpenoids, phenolic compounds, and essential oils.

The essential oils of Tulsi are particularly significant, containing compounds such as eugenol, methyl eugenol, caryophyllene, linalool, and 1,8-cineole, which contribute to its antimicrobial, antioxidant, anti-inflammatory, and analgesic properties. Flavonoids like orientin and vicenin act as strong free radical scavengers, protecting against oxidative stress and providing cardioprotective and neuroprotective benefits. Phenolic compounds further enhance antioxidant activity, while tannins and saponins add antimicrobial and adaptogenic effects.

Tulsi also contains alkaloids and glycosides that support its antidiabetic, anticancer, and immunomodulatory actions. The synergistic effect of these phytochemicals makes Tulsi highly effective in promoting immunity, reducing stress, protecting against infections, and supporting metabolic as well as cardiovascular health.

Overall, the diverse phytochemicals of *Ocimum sanctum* make it a powerful herbal remedy with applications in managing respiratory disorders, diabetes, cardiovascular diseases, stress-related conditions, and infections.

S.N.	Phytochemical compound	Plant part	Methanol	Ethanol
1	Alkaloids	Stem	+	-
2	Carbohydrates	Stem	+	-
3	Cardiac Glycosides	Stem	+	+
4	Proteins	Stem	+	+
5	Phytosterols	Stem	+	+

6	Flavonoids	Stem	+	+
7	Tannins	Stem	+	-
8	Terpenoids	Stem	+	-
9	Saponins	Stem	+	-
10	Phenols/ Polyphenols	Stem	+	+

Ocimum sanctum (Tulsi) is one of the most important medicinal plants in Ayurveda, valued for its preventive and therapeutic properties, which are attributed to its diverse and biologically active phytochemicals. Tulsi contains a variety of alkaloids, flavonoids, glycosides, saponins, tannins, phenolic compounds, terpenoids, and essential oils. Among these, the essential oil fraction is highly significant and is composed of bioactive compounds such as eugenol, methyl eugenol, linalool, ursolic acid, caryophyllene, and 1,8-cineole, which are responsible for its antimicrobial, analgesic, anti-inflammatory, and antioxidant actions. Tulsi is also rich in flavonoids such as orientin, vicenin, luteolin, and apigenin, which act as strong antioxidants, helping to neutralize free radicals and reduce oxidative stress, thereby offering cardioprotective, hepatoprotective, and neuroprotective benefits. Phenolic compounds and tannins enhance its antimicrobial and antioxidant potential, while saponins contribute to adaptogenic, anti-stress, and immunomodulatory effects. In addition, the plant contains triterpenoids like ursolic acid and oleanolic acid, which have been reported to possess anticancer, anti-inflammatory, and antidiabetic activities. Alkaloids and glycosides present in Tulsi further support its role in maintaining metabolic balance and improving overall vitality.

The synergistic action of these phytochemicals makes Tulsi a unique medicinal herb with multiple pharmacological applications. It has been traditionally used to manage respiratory ailments (cough, cold, asthma, bronchitis), fever, infections, stress disorders, diabetes, cardiovascular problems, liver diseases, and even as an adjunct in cancer therapy. By combining its adaptogenic, antioxidant, antimicrobial, and immunomodulatory effects, Tulsi stands as a holistic plant-based remedy that supports both preventive healthcare and therapeutic management.

Conclusion

It has been evident from the present review that phytochemicals serve as promising and effective research area with bright future. The growing incidence of cancer and high cost, various limitations in the conventional therapy including high cost, and high toxicity of present anticancer drugs has faced a severe challenge to all the researchers to design and develop an alternative, eco-friendly,

biocompatible and cost-effective strategy in a greener way. Under this scenario, phytomolecules are expected to revolutionize cancer treatment in the next decade. High biodegradability and biocompatibility have increased the efficacy of these phytomolecules in cancer therapy. This comprehensive review paper provides information on medicinal plants and their bioactive compounds with potential to cure different types of cancer. Potential anticancer phytochemicals described in this comprehensive review article should be further researched in clinical trials on different models for their effectiveness and toxicological documentation. Furthermore, extensive research work should be carried out on these phytochemicals to evaluate their possible applications, toxicological and particular genotoxic profile against a wide range of cancer in both either in-vitro or in-vivo.

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