Review

Beyond Curcumin: Highlighting the Potential of Ayurvedic Medicinal Flora in Cancer Research

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Beyond Curcumin: Highlighting the Potential of Ayurvedic Medicinal Flora in Cancer Research

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Abstract: Conventional cancer therapies pose a toxicity risk to healthy cells, which leads to severe physical and physiological changes in both cancer patients and survivors. These treatments, in combination with phytochemicals, have been found to exhibit minimal side effects and additional anti-oxidant effects. The Indian state of Kerala is well known for its Ayurvedic history and harbors medicinal flora whose phytochemicals have been broadly studied for their anticancer properties. Prompt advancements in preclinical and clinical studies surrounding the bioavailability and stability of bioactive compounds are essential to incorporating phytotherapy into cancer treatment. This review delves into a few rarely discussed yet promising medicinal plants found in Kerala, presenting existing evidence of their anticancer properties, mainly focusing on their phytoconstituents.

Keywords: Anticancer; Phytochemicals; Ayurveda; Medicinal flora; Kerala; Traditional medicine

1. Introduction

Curcumin, the phytochemical in turmeric (*Curcuma longa*), has garnered widespread attention as a "magical compound" in cancer research. Initially studied and documented by Vogel and Pelletier in 1815 (1), turmeric was already an essential part of South Asian kitchens and medical systems like Ayurveda. To date, India continues to be the largest global producer, accounting for over 60% of the turmeric exports in the global market (2). Notably, curcumin is only one of many phytochemicals that hold therapeutic significance in Indian traditions.

Ayurveda, one of the ancient healing systems in the world, is deeply rooted in historical scriptures and integrative approaches. Despite its natural and holistic perspectives gaining global recognition, the lack of scientific validation and clinical trials limits the broader acceptance of the system. This is considerably evident in the treatment of complicated diseases such as cancer, where contemporary scientific research remains insufficient (3).

Cancer persists as a condition with no guaranteed cure, and several factors such as nutrition, contribute significantly to pre- and post-onset cancer management (4). Most of the medicinal plants, which are native species from India, and utilized in Ayurveda, serve as an essential part of the traditional diet. In cancer patients, their antioxidant properties add to the anti-cancer effects by ameliorating oxidative stress in cancer cells. The key components promoting these qualities are primarily the phytochemicals present in the medicinal flora, including polyphenols, alkaloids, flavonoids, tannins, and saponins. The rising interest in Ayurvedic ingredients such as turmeric (curcumin), periwinkle (vincristine and vinblastine), and black pepper (piperine) in cancer research emphasizes their potential to reduce the toxicity of mainstream cancer treatments.

The South Indian state of Kerala is well known for its abundant flora and rich Ayurvedic legacy. The state is home to the cultural tradition of conserving ten ayurvedic plants known as 'Dashapushpam' (ten flowers) in Malayalam (the official language of Kerala). This includes *Aerva lanata*, *Biophytum sensitivum*, *Cardiospermum halicacabum*, *Curculigo orchioides*, *Cynodon dactylon*, *Eclipta prostrata*, *Emilia sonchifolia*, *Evolvulus alsinoides*, *Ipomoea obscura*, and *Cyanthillium cinereum*. Another example of how traditional medicine is upheld in Kerala is the 'Oushadhakanji' (medicinal porridge), generally consumed during the monsoon and packed with Ayurvedic ingredients, believed to boost

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immunity and help tackle seasonal illnesses. With its Ayurvedic wisdom and optimal climatic conditions for nurturing medicinal vegetation, Kerala continues to be the epicenter of Ayurveda (5).

This review is based on the Ayurvedic medicinal species that are frequently found and used as home remedies in Keralite households. The existing scientific evidence regarding the effects of each species on different cancers is briefly discussed, although extensive research and comprehensive biochemical analyses are still largely lacking for most species. While this is not an exhaustive list, it sheds light on a few traditionally esteemed yet rarely discussed therapeutic plants with immense potential to become the next "golden compound" in cancer research. However, It must be noted that this paper does not offer guidance on these species' formulation, or administration.

2. Review Method

The plants included in this review were primarily chosen based on my familiarity with them, owing to their frequent use in Keralite households, a knowledge rooted in my upbringing in Kerala. This information was then cross-referenced with the help of sources such as the Indian Systems of Medicine website (Kerala government) (6), and the State Medicinal Plants Board Kerala database (7). Subsequently, I conducted an extensive literature search with keywords related to the plant names and their anticancer properties, thoroughly reviewing contextually important studies. All images included in this review were photographed in Kerala to provide an authentic representation of their appearance in their native environment.

3. Ayurvedic Medicinal Plants: Promising Candidates in Cancer Research

With the widespread interest in phytochemicals in neoplastic research, the exploration of traditional medicinal plants has gained global popularity. The list below consists of traditionally acknowledged medicinal plants that are potential candidates for natural anticancer sources and require further scientific investigation.

3.1. STONEBREAKER (Phyllanthus amarus):

An important medicinal plant in Ayurveda, *Phyllanthus amarus* (Figure 1) (*P. amarus*, commonly known as Keezharnelli in Malayalam), is categorized as a weed found across Kerala. Traditionally, the entire plant is believed to have detoxifying properties and is used to treat jaundice with reported benefits for liver health, treating ulcers, and healing wounds.

Figure 1. *Phyllanthus amarus* (Stone Breaker) photographed in Kerala, India (Photo taken by the author).

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Spectrophotometric studies have identified several bioactive phytochemicals in *P. amarus*, with lignans (phyllanthin and hypophyllanthin) playing a key role in its cytotoxicity against cancer cells. Other constituents, flavonoids, and phenolic compounds such as ellagic acid and gallic acid, along with vitamin C, contribute significantly to its antioxidant effects (8). In another study, Lignans in the plant in combination with polyphenols, have also shown apoptotic effects in HCT116 human colorectal cancer cells by regulating a caspase-dependent pathway (9).

As additional evidence supporting its anticancer potential, the *P. amarus* aqueous extract has exhibited anticarcinogenic effects in vivo, inhibiting tumor growth and boosting survival rates in mice with Dalton's Lymphoma Ascites (DLA) and Ehrlich Ascites Carcinoma (EAC). The mechanism involves the inhibition of the P-450 enzyme, aniline hydroxylase associated with oxidative activation of carcinogens. In mutant yeast cells, the extract interferes with DNA repair and additionally disrupts cell cycle progression by targeting Cdc25 tyrosine phosphatase (10). As a validation of its established role in Ayurveda, scientific research has explored its potential in liver-related cancers. Interestingly, studies have demonstrated increased survival in hepatocellular carcinoma-induced Wistar rats upon *P. amarus* extract administration (11). Existing studies suggest that the plant's anticarcinogenic actions which involve suppressing metabolic activation and cell cycle regulation in the cells highlight its potential to become a valuable ingredient in cancer phytotherapy.

3.2. CREEPING WOODSORREL (Oxalis corniculata):

This Ayurvedic plant, known as Puliyaral (Figure 2) in Malayalam, is a widely grown medicinal herb often found as a weed in Kerala, particularly around gardens. Traditionally, the entire plant is considered medicinal and has been used to treat gastrointestinal (GI) ailments such as diarrhea and various skin conditions, particularly warts.

Oxalis corniculate (*O.corniculata)* contains abundant phytochemicals, including flavonoids, alkaloids, tannins, saponins, glycosides, polyphenols, and phytosterols. The plant's ethanolic extract has induced apoptotic effects on the human MCF-7 breast cancer cell line, reportedly due to its flavonoid and polyphenolic content. The extract was found to modulate the expression of pro-apoptotic genes (*p53, bax,* and *CD95*) while downregulating the anti-apoptotic gene *bcl-2*, thereby inducing apoptosis in breast cancer cells (12).

Figure 2. *Oxalis corniculata* (Creeping Woodsorrel) photographed in Kerala, India (Photo taken by the author).

Recent research has further identified acacetin and luteolin—flavonoids present in *O. corniculata*—as promising anticancer compounds. These bioactive compounds interact with cancer-

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related targets, such as PD-L1 and BRAF with their receptors showing high affinity interactions with acacetin and luteolin (13). Additionally, an in vitro study revealed that the plant exhibited selective cytotoxicity against the Hep-G2 human hepatocarcinoma cell line (14). Despite the limited prior investigations on *O.corniculata* 's anticancer properties, a growing interest in its therapeutic potential is evident from the rise in recent studies. The plant's ayurvedic use in improving GI and skin health, along with its established cancer-inhibitory effects demands further analyses into its impact on gastrointestinal and skin cancers.

3.3. LITTLE TREE PLANT (Biophytum sensitivum):

Widely known as Mukkutti (Figure 3) in Kerala, *Biophytum sensitivum* is considered one of ten sacred plants conserved during the monsoon season in Kerala and is commonly identified as a weed across the state. In traditional usage, the entire plant is believed to have medicinal value and is used to treat diarrhea, heal wounds, and relieve coughs and colds.

Figure 3. *Biophytum sensitivum* (Little Tree Plant) photographed in Kerala, India (Photo taken by the author).

B. sensitivum contains key phytochemicals such as isoorientin (a flavonoid), amentoflavone (a biflavone), tannins, and phenolic compounds (15). Among these bioactive compounds, amentoflavone extracted from the plant has been shown to induce apoptosis in B16F-10 melanoma cells while also suppressing nitric oxide and pro-inflammatory cytokine production in both cancer cells and associated macrophages. Moreover, *B. sensitivum* inhibits lung metastasis hijacking extracellular matrix-modulating enzymes such as MMPs and lysyl oxidase, while also regulating signaling pathways like VEGF and STAT, as well as pro-inflammatory cytokines (16,17). A major study reported cytotoxic effects of the methanolic extract of *B. sensitivum* on DLA and EAC cells, showing a reduction in solid tumor volume with a 93.3% increase in lifespan in tumor-induced mice (18). The aqueous extract of *B. sensitivum* also demonstrated significant cytotoxicity against HepG2 liver cancer cells, further reinforcing its broad-spectrum effects across multiple cancer types (19).

3.4. MALABAR NUT (Justicia adhatoda):

Justicia adhatoda (*J. adhatoda*) (Figure 4) is a shrub known for its extreme bitterness and is locally referred to as Aadalodakam in Kerala. The leaves are the most commonly used part of the plant, typically consumed to treat respiratory tract infections such as whooping cough and asthma.

J. adhatoda contains alkaloids such as vasicine and vasicinone, along with flavonoids, saponins, and phenolics, which are especially abundant in the roots and leaves of the plant (20,21). The

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alkaloids present in the methanolic extract of *J. adhatoda* display significant NF-κB inhibitory activity. Additionally, it has been shown to induce apoptosis in MCF-7 breast cancer cells, activating proteins such as caspase-3, Bax, and cleaved-PARP, while also disrupting mitochondrial membrane potential, inhibiting cell migration, and altering NO, ROS, and antioxidant enzyme levels (21).

Figure 4. *Justicia adhatoda* (Malabar Nut) photographed in Kerala, India (Photo taken by the author).

Furthermore, the ethanolic extract of the plant has been found to regulate anemia and prolong the lifespan of DLA-induced mice (22). Although *J. adhatoda* is broadly recognized for its therapeutic potential in cancer studies, its well-established traditional use in respiratory tract ailments has not been directly examined in detail.

3.5. ASTHMA- PLANT (Euphorbia hirta):

Euphorbia hirta (*E. hirta*) (Figure 5), known as Nilappaala in Kerala, is an annual weed with a hairy appearance. As implied by its name, the whole plant extract has been used in Ayurveda to treat respiratory conditions like asthma and to help regulate hormonal imbalances in women. This plant, along with its closely related species, *Euphorbia thymifolia*, has been scientifically explored for its anticancer activity at Kottakkal Arya Vaidya Sala, one of the highly acclaimed Ayurvedic centers in Kerala (24).

The major phytochemicals found in *E. hirta* include phenolic compounds (gallic acid and caffeic acid), flavonoids (quercetin and kaempferol), phytosterols, tannins, saponins, and alkaloids (25,26). Another study reported the presence of 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one (DDMP), an important phenolic compound believed to be responsible for the plant's anticancer properties. For instance, in human colon cancer cells, DDMP exhibited apoptotic effects by regulating nuclear factor (NF)-κB activity. Additionally, the ethanolic extract of *E. hirta* has demonstrated significant cytotoxicity against the HL-60 leukemia cell line in vitro (27,28). Similarly, the methanolic extract of *E. hirta* exerted apoptotic effects on MCF-7 breast cancer cells via caspase activation, DNA fragmentation, and cell cycle arrest at the S and G2/M phases(29).

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Figure 5. *Euphorbia hirta* (Asthma Plant) photographed in Kerala, India (Photo taken by the author).

Furthermore, in EL4 T-lymphoma cell line, the plant's chloroform and ethanolic extracts have shown substantial antitumor activity, reportedly due to the presence of flavonoids in the species (30). Meanwhile, in a similar study, the ethanolic leaf extract of *E. hirta* exhibited potent cytotoxic activity against DLA and EAC cell lines, further supporting its potential as a wide-ranging anticancer agent (31).

3.6. INDIAN GOOSEBERRY (Phyllanthus emblica):

Known as Nellikka (Figure 6) in Kerala, the Indian gooseberry (*Phyllanthus emblica (P. emblica)*, formerly *Emblica officinalis*), is a widely recognized Ayurvedic ingredient in Keralite households, renowned for its rejuvenating and gut-cleansing properties. In Ayurveda, this anti-diabetic fruit is also considered highly beneficial for urinary tract and eye health. Its fruit, which is a staple in Indian kitchens, is often consumed as a pickle or as chyavanaprasham, a herbal formulation where gooseberry serves as the primary ingredient.

Figure 6. *Phyllanthus emblica* (Indian Gooseberry) photographed in Kerala, India (Photo taken by the author).

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In addition to its rich vitamin C content, *P. emblica* encompasses several phytochemicals, including tannins (emblicanin A, emblicanin B, and punigluconin), phenolic acids (gallic acid and ellagic acid), flavonoids (quercetin and kaempferol), alkaloids (phyllantidine and phyllantine), and polyphenols such as resveratrol (32–34). Phenolic compounds, geraniin, and iso-corilagin are considered significant contributors to its anticancer activity, as they stimulate immune cell proliferation and exhibit strong cytotoxicity against MCF-7 breast cancer cells (35). Further evidence has revealed the strong antiproliferative effects of *P. emblica's* phenolic compounds, in combination with proanthocyanidin polymers, on the B16F10 melanoma cell line(36). One of the pioneering studies on the anticancer properties of *P. emblica* demonstrated its potential to reduce both ascitic and solid tumors in DLA mouse models. The aqueous extract significantly prolonged the lifespan of tumor-bearing animals. It inhibited key cell cycle-regulating enzymes, such as cell division cycle 25 (CDC25) phosphatase, suggesting its ability to modulate cell cycle progression (37).

Additionally, research has shown that *P. emblica* fruit extract suppresses activator protein-1 (AP-1) activity and HPV oncogene transcription, resulting in growth inhibition of cervical cancer cells (SiHa and HeLa) and induction of apoptotic cell death, highlighting its potential as a therapeutic agent for HPV-induced cervical cancer (38). *P. emblica's* traditional usage as a detoxifying agent has not been much explored scientifically except for one study that showed its cell growth inhibition in HepG2 (liver) and SW620 (colorectal) cell line along with its cytotoxicity on Cholangiocarcinoma (CCA) cells employing mitochondrial apoptotic pathway(39,40).

3.7. NEEM (Azadirachta indica):

Azadirachta indica (*A. indica*) (Figure 7), locally known as Aryaveppu in Kerala, has been traditionally used to treat chickenpox blisters. Even more bitter than *J. adhatoda*, *A. indica* leaves serve multiple purposes in Kerala households, ranging from mosquito repellent to wound healing. The plant is still widely used for treating fungal infections, diarrhea, gum disease, and mouth ulcers. Although various parts of the plant are believed to have medicinal value, the leaves are the most commonly used in home remedies.

Figure 7. *Azadirachta indica* (Neem) photographed in Kerala, India (Photo taken by the author).

A.indica comprises several bioactive compounds such as terpenoids (azadirachtin, nimbin, nimbidin, and gedunin,), flavonoids (quercetin), sterols (β-sitosterol), alkaloids, saponins, and tannins (41,42). This plant has been recognized for its anticancer potential for a long time, primarily due to its terpenoids and steroids. Owing to its ability in immunomodulation, apoptosis induction, and cancer prevention mechanisms, scientists have discovered its potential as a cost-effective cancer

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therapy. Neem extract modulates molecular pathways including tumor suppressor p53 upregulation and apoptosis induction via caspase activation and Bcl-2 family protein regulation. Additionally, it hampers angiogenesis by downregulating VEGF, thereby preventing tumor growth and metastasis (43).

An earlier study investigating the protective effects of methanolic neem leaf extract (MNLE) on cisplatin-induced hepatotoxicity revealed that MNLE alleviated oxidative stress and improved liver histology, while controlling apoptosis markers in rats(44). Neem has also demonstrated tumor-inhibitory properties in gynecological, breast, and oral cancers by promoting apoptosis and modulating key molecular pathways, including p53, NF-κB, Bcl-2, MAPK, and PI3K/Akt (45–47). In MDA-MB-231 breast cancer cells, ripe neem seed extract reduced cell viability by decreasing CD44 and CD326 marker expression, inhibiting cell proliferation, and inducing apoptosis (48). Several studies highlight neem's phytochemical-rich extract as playing a crucial role in silver nanoparticle bio-fabrication, both independently and in combination with chemotherapy drugs, offering an eco-friendly approach that enhances tumor inhibition and reduces side effects (49,50). Neem limonoids have become the focus of recent research, emphasizing their diverse anticancer mechanisms, including hindering cell proliferation, evading apoptosis, and targeting key oncogenic signaling pathways (51).

3.8. INDIAN BORAGE (Plectranthus amboinicus):

Plectranthus amboinicus (*P. amboinicus*) (Figure 8), also known as *Coleus amboinicus* or Mexican mint, is a widely recognized succulent herb cultivated in Kerala, where it is referred to as panikkoorkka or kanjikkoorkka in Malayalam. This leaf extract, known for its distinct tingling spiciness, is commonly used as a remedy for colds and intestinal infections, particularly in children.

Figure 8. *Plectranthus amboinicus* (Indian Borage) photographed in Kerala, India (Photo taken by the author).

P. amboinicus, a storehouse of essential oils such as thymol, carvacrol, and β-Caryophyllene, also contains phenolic compounds (caffeic acid, rosemarinic acid, and gallic acid), flavonoids (crisimaritin, salvigenin, luteolin, and quercetin), saponins, tannins, terpenoids, and alkaloids (52,53). In alignment with its traditional usage, the leaf extract of this plant is considered particularly therapeutic, demonstrating significant cancer-inhibiting properties in EAC mice by regulating immune responses and hindering cancer cell growth (52).

Earlier studies primarily focused on the flavonoids to explain the plant's anticancer potential. However, an important investigation also highlighted the role of the sterol compound, β-sitosterol,

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present in the plant which has demonstrated anticancer activity against T47D, MCF-7, HeLa, and WiDr cell lines. While flavonoids have been shown to interact with cancer-associated receptors such as phosphatidylinositol-3-kinase (PI3K), P-Glycoprotein-1 (P-gp), Cyclin-Dependent Kinase-2 (CDK2), Cyclooxygenase-2 (COX-2), and Phosphoenolpyruvate Carboxykinase (PEPCK), β-sitosterol exhibits affinity towards epidermal growth factor receptor (EGFR), Human Epidermal Growth Factor Receptor 2 (HER-2), and Estrogen Receptor Alpha and beta (ER-α, β) suggesting its potential to modulate these cancer-related pathways (54,55). Additionally, the methanolic extract has been shown to impart cancer inhibitory effects against WiDr colon cancer cells, reportedly due to an upregulation of pro-apoptotic genes (BAX, P53, Caspase 9) and downregulation of anti-apoptotic genes (BCL2, Caspase 8) (56). According to a recent study on nanoparticles, the leaf extract of *P. amboinicus* enhances the anticancer activity of copper oxide nanoparticles against HCT 116 colon cancer cells, interfering with cancer-related targets and increasing cytotoxicity (57).

3.9. CURRY LEAF (Murraya koenigii):

A staple in Kerala's kitchens, *Murraya koenigii* (*M. koenigii*) (Figure 9) is cultivated for various purposes, ranging from its role as an essential culinary herb in Kerala cuisine to its use in hair oils. The leaves, in particular, are frequently utilized to promote digestive health, especially in cleansing the gut and improving bowel movements.

Figure 9. *Murraya koenigii* (Curry Leaf) photographed in Kerala, India (Photo taken by the author).

M. koenigii contains several important alkaloids, such as mahanine, mahanimbine, koenimbine, murrayanol, murrayone, murrayanine, and girinimbine, which exhibit cytotoxic and anticancer activities. Additionally, it is rich in flavonoids (quercetin, kaempferol, and apigenin), terpenoids such as blumenol A, along with polyphenols, saponins, tannins, and glycosides (58,59). Its alkaloids have been the primary focus of most investigations regarding the plant's anticancer properties. For instance, mahanimbine demonstrates significant cytotoxicity against MCF-7, P388, and HeLa cell lines, while murrayazoline, O-methylmurrayamine A, and mahanimbine are toxic against DLD-1 cells (60,61). Furthermore, girinimbine, a carbazole alkaloid found in the plant, exhibits cancer-inhibitory effects against HT-29 colon cancer cells, with dose-dependent inhibition of cell proliferation (62).

The plant's methanolic extract has shown strong cytotoxicity against U373MG glioblastoma cells, effectively inducing cell death and displaying antioxidant activity (63). Supporting its traditional use, scientific evidence suggests its potential as a healthy fermented beverage. This study reported an increase in antioxidant properties and bioactive content, thereby enhancing its anticancer activity against A549 and CHOK1 cell lines (64).

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3.10. BLACK MUSLI (Curculigo orchioides):

Curculigo orchioides (*C. orchioides*) (Figure 10), one of the ten culturally significant plants in Kerala, is called nilappana in Malayalam. Traditionally valued for improving immunity and curing skin infections, it's also an ingredient in the medicinal monsoon porridge consumed by locals in Kerala, and its rhizome is considered exceptionally beneficial. It has been classified as an endangered herb with notable anticancer properties, as highlighted in earlier studies where in vitro experiments were conducted to cultivate the plant, emphasizing its high medicinal value (65).

Figure 10. *Curculigo orchioides* (Black Musli) photographed in Kerala, India. It has been categorized as an endangered herb by The International Union for Conservation of Nature (IUCN) (Photo taken by the author).

The plant's bioactive constituents include phenolic compounds such as curculigosides and curculigines, which are the major active components, along with polysaccharides, flavonoids, tannins, alkaloids, and others (65–67). Polysaccharides extracted from the whole herb of *C. orchioides* have been shown to upregulate caspase-3, caspase-9, and p53 expression, leading to reduced tumor growth in mice bearing HeLa cells (68). Furthermore, leaf-rhizome extracts have been utilized to create silver nanoparticles which enhanced cytotoxicity in cancer cells (69,70). The cancer inhibitory effects of *C. orchioides* ethyl acetate and aqueous ethyl acetate fractions in HepG2, HeLa, and MCF-7 cell lines are regulated through apoptosis via upregulation of caspase-3 and caspase-8 and downregulation of Bcl-2 expression(71). Although there is evidence to demonstrate its major role in improving liver health, limited studies have been done on hepatic and related cancers to validate its traditional usage.

4. Conclusion

Phytochemicals derived from Ayurvedic medicinal flora are gaining attention as potential anticancer agents in global research. However, their rapid digestion and metabolism, leading to poor bioavailability and stability within the body, continue to hinder the inhibitory effects demonstrated invitro in cancer therapies. As discussed above, the state of Kerala possesses geographical conditions favorable for the growth of numerous medicinal plants, including the above-mentioned, while also harboring endangered species such as *Curculigo orchioides*. Ayurveda is deeply ingrained in the daily lives of Keralites, preserving indigenous knowledge about Ayurvedic flora, many of which have been grown in households for generations. Kerala and its traditional diet serve as evidence that Ayurveda is more than just a medical system; it follows a holistic approach that emphasizes dietary regulations and lifestyle modifications alongside medicinal consumption.

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One of the major advantages of Ayurvedic medicine is its minimal cytotoxicity to normal cells, making it a safer alternative to conventional chemotherapy drugs. The anticancer potential of Ayurvedic medicinal plants is largely attributed to their phytochemicals. Among these, polyphenols and flavonoids are frequently associated with anticancer mechanisms at the molecular level. Nevertheless, since traditional Ayurvedic formulations utilize whole plant material, the beneficial bioactive compounds might not be present in desirable quantities, potentially reducing their therapeutic efficiency. Therefore, the characterization, isolation, and validation of phytochemicals are essential to establish standardized doses and the optimal formulations to enhance their therapeutic effectiveness. Treating cells with a combination of phytochemicals or conventional therapies may further improve their efficacy, while considerably lowering toxicity. Another approach is to incorporate nanotechnology into cancer treatments, which facilitates better delivery of phytochemicals. With an optimal size to hold phytochemicals and penetrate tumor sites, nanoparticles that target cancer cells have become a significant area of interest in cancer biology(72). The findings from this review suggest that recent advancements in anticancer plant research are increasingly centered around nanoparticle-based drug delivery systems.

Overall, with the growing recognition of phytochemicals in both scientific research and commercial markets—such as the widespread availability of functional beverages like curcumin-piperine shots—many more plant-derived compounds are under investigation for their anticancer properties. The medicinal flora discussed in this review represents only a fraction of Kerala's vast repository of bioactive plants, many of which remain underexplored despite their long-standing traditional use. Further scientific exploration and refinement of traditional medical systems worldwide could pave the way for integrating these therapies into modern oncology, ultimately offering more effective and less toxic treatment options for cancer patients, including survivors who continue to experience long-term side effects from conventional therapies.

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