Phytotherapy in Oncology: The Use of Herbal Medicine for Cancer Treatment

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Abstract

Herbal medicine, or phytotherapy, is gaining significant attention as a complementary strategy in oncology, primarily due to its ability to offer therapeutic benefits with fewer side effects than conventional treatments. Cancer, marked by uncontrolled and abnormal cell growth, continues to pose a major global health challenge. While chemotherapy and radiotherapy remain central to cancer care, their toxicity often damages healthy tissues and compromises patients' quality of life. In light of these limitations, there is growing interest in herbal medicines rooted in traditional systems such as Ayurveda and Traditional Chinese Medicine. This review explores the therapeutic potential of herbs like turmeric, green tea, garlic, ginger, ashwagandha, ginseng, and cannabis. These plants exert anti-cancer effects through various mechanisms, including immune modulation, induction of apoptosis, inhibition of angiogenesis, and reduction of inflammation. Bioactive compounds such as curcumin, EGCG, allicin, and withaferin A have shown promising results in preclinical studies. Additionally, AI-assisted methods are enhancing the understanding of these herbs, helping to identify active components, optimize dosing, and predict herb–drug interactions. However, challenges like poor bioavailability, lack of standardization, and safety concerns persist. Integrating phytotherapy into modern oncology requires rigorous clinical validation, regulatory oversight, and professional guidance. Ultimately, evidence-based phytotherapy may offer safer, more personalized cancer treatment options and improve overall patient outcomes.

Key point- Herbal medicine, Oncology, Phytotherapy, Mechanism of Action

Introduction

Cancer remains one of the leading causes of morbidity and mortality worldwide, placing a significant burden on healthcare systems, with cases steadily rising and projected to reach 21million by 2030.[1–3] It is marked by the abnormal and unregulated proliferation of cells, which can invade nearby tissues and spread throughout the body, ultimately disrupting normal cellular function and, if left untreated, leading to death.[4–6] Chemotherapy and chemoradiotherapy have proven to be highly beneficial for many patients; however, their cytotoxic impact on healthy tissues often results in a variety of distressing side effects, such as nausea, vomiting, loss of appetite, diarrhea, oral mucositis, and peripheral neuropathy. These adverse effects can severely compromise patients' quality of life (QOL) and may, at times, necessitate discontinuation of treatment.[7–10] While several supportive strategies have been introduced to address these toxicities, their effectiveness remains limited. This underscores the urgent need for novel or complementary approaches to minimize treatment-related complications. Despite advances in conventional cancer therapies, including surgery, chemotherapy, radiotherapy, and

targeted treatments, challenges such as drug resistance, persistent side effects, and reduced quality of life continue to affect patients. Consequently, there is growing interest in integrating complementary and alternative therapies to enhance conventional oncology care and improve overall patient outcomes. Among these, herbal drugs have gained considerable attention for their potential role in cancer therapy.[11,12] Derived from medicinal plants, herbal preparations are often used by patients either to enhance the effectiveness of conventional treatments, to reduce therapy-related side effects, or to improve overall well-being. Several herbs have demonstrated anti-cancer properties in preclinical studies, including antioxidant, anti-inflammatory, immunomodulatory, and direct anti-tumor effects. Moreover, certain herbal formulations are believed to help mitigate chemotherapy-induced toxicity and improve patients' tolerance to treatment.[13–16]

Given the widespread and often unsupervised use of herbal medicine in oncology, it is essential to understand both the potential benefits and associated risks of these therapies. This involves evaluating possible interactions between herbal remedies and conventional cancer treatments, which may either enhance therapeutic efficacy or interfere with treatment outcomes. The purpose of this review is to explore the role of herbal drugs as complementary or alternative therapies in cancer management, assess their therapeutic potential, and investigate the implications of herb– drug interactions. Through this comprehensive evaluation, the review aims to support the safe and effective integration of herbal medicine into mainstream cancer care.[17–20]

Herbal Medicine used in the treatment of Cancer Therapy

Herbal medicine involves using whole plants or their components to treat diseases, enhance health, and support overall well-being. Rooted in ancient traditions, it represents one of the earliest forms of medical practice, long preceding the development of modern pharmacology. Herbal medicines combat cancer through mechanisms fundamentally distinct from conventional chemotherapy drugs, notably without inducing DNA mutations in surviving cells. Instead, natural compounds bolster the body's immune defenses, inhibit angiogenesis—the formation of new blood vessels that nourish tumors—limit the spread of cancerous cells, support detoxification processes, and help prevent the accumulation of harmful toxins within the body.[21–24]

Since ancient times, plants have been used to treat a wide range of diseases, including cancer. Herbal medicine—utilizing plants and their extracts for therapeutic purposes—has long been a cornerstone of traditional healing systems such as Ayurveda, Traditional Chinese Medicine (TCM), Unani, Siddha, and various indigenous practices. Herbal medicine remains a fundamental part of traditional healthcare systems and continues to serve as a primary source of treatment for nearly 80% of the global population, especially in developing countries. In recent years, there has been a renewed interest in herbal remedies due to their natural origin, rich diversity of bioactive compounds, and comparatively lower toxicity than many synthetic drugs.[25–30] Some of the examples of herbal medicine have been given in Table 1.

Table 1. List of herbal medicines used for the treatment of cancer

Herbal Name	**Active Constituents**	**Type of Cancer**	**Mechanism of Action**
Turmeric (*Curcuma longa*)	Curcumin	Breast, Colon, Pancreatic, Prostate	Anti-inflammatory, induces apoptosis, inhibits angiogenesis
Green Tea (*Camellia sinensis*)	EGCG (Epigallocatechin gallate)	Prostate, Breast, Lung, Skin	Antioxidant, inhibits tumor growth, modulates signal transduction
Garlic (*Allium sativum*)	Allicin, S-allyl cysteine	Colon, Stomach, Prostate	Induces apoptosis, enhances immune function, and antioxidant
Ginger (*Zingiber officinale*)	Gingerol, Shogaol	Ovarian, Colon, Breast	Anti-inflammatory, induces apoptosis, suppresses metastasis

Ashwagandha (*Withania somnifera*)	Withaferin A	Breast, Lung, Prostate	Induces cell cycle arrest, apoptosis, and inhibits metastasis
Ginseng (*Panax ginseng*)	Ginsenosides	Lung, Liver, Colorectal	Modulates immune response, induces apoptosis
Milk Thistle (*Silybum marianum*)	Silymarin	Liver, Prostate, Breast	Antioxidant, detoxification, and cell regeneration
Neem (*Azadirachta indica*)	Nimbolide, Azadirachtin	Breast, Cervical, Prostate	Apoptosis induction, anti-proliferative, immunomodulatory
Holy Basil (*Ocimum sanctum*)	Eugenol, Ursolic acid	Oral, Lung, Skin	Antioxidant, anti-inflammatory, anti- metastatic
Cannabis (*Cannabis sativa*)	Cannabinoids (THC, CBD)	Brain (Glioma), Breast, Prostate	Anti-proliferative, apoptosis induction, and pain relief

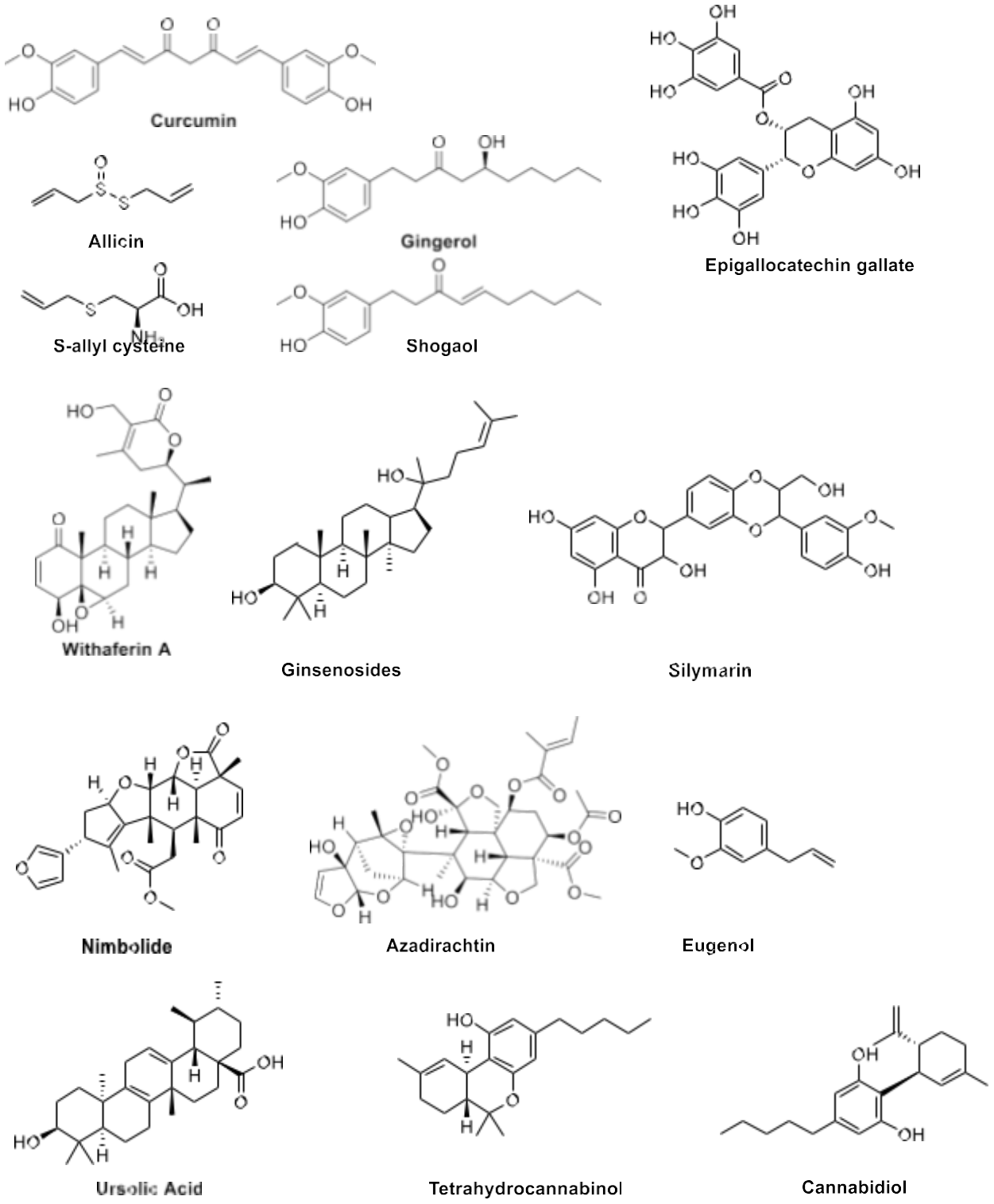

Figure 1. Active compounds from different herbal medicines are used for the prevention of cancer

Turmeric (*Curcuma longa*)

Turmeric, a widely used spice and traditional medicinal herb, has garnered significant attention for its potential role in the prevention and treatment of cancer. The primary bioactive compound in turmeric, curcumin, exhibits potent anti-inflammatory, antioxidant, and anticancer properties.

Curcumin targets multiple molecular pathways involved in cancer progression, including growth factors (such as VEGF), inflammatory cytokines (like IL-6 and TNF-α), transcription factors (such as NF-κB), and enzymes (including COX-2 and iNOS). Studies have demonstrated its ability to induce apoptosis, inhibit angiogenesis, and arrest the cell cycle across various cancer cell types, including those found in breast, colon, lung, prostate, and pancreatic cancers. [26,30,31]

Green Tea (*Camellia sinensis*)

Green tea, derived from *Camellia sinensis*, is rich in polyphenols, particularly catechins, with epigallocatechin gallate (EGCG) being the most prominent. These compounds possess potent antioxidant, anti-inflammatory, and anticancer properties. Green tea has been shown to neutralize free radicals, reduce oxidative stress, and inhibit the growth of cancer cells by blocking key processes such as angiogenesis and metastasis. Additionally, it supports cardiovascular health by improving blood lipid profiles and enhancing endothelial function. Green tea may also aid in weight management by boosting metabolism and fat oxidation. However, its catechins have low bioavailability, limiting their effectiveness. To address this, various formulations, like encapsulation, are being developed to improve absorption. Despite its benefits, excessive green tea consumption may cause gastrointestinal discomfort or interfere with iron absorption, so it is recommended to consume it in moderation.[30,32,33]

Garlic (*Allium sativum*)

Garlic (*Allium sativum*) is a medicinal herb known for its antioxidant, anti-inflammatory, and anticancer properties. Its therapeutic effects are largely due to organosulfur compounds like allicin, diallyl sulfide, and S-allyl cysteine. These bioactive molecules have been shown to inhibit cancer cell proliferation, induce apoptosis, and suppress angiogenesis, particularly in cancers of the stomach, colon, breast, and prostate. Garlic also supports heart health by lowering blood pressure, reducing cholesterol, and preventing blood clot formation. Additionally, it boosts immune function and has antimicrobial properties. However, the bioavailability of its active compounds can be influenced by preparation methods such as cooking or aging. To enhance effectiveness, standardized garlic extracts and supplements are used. While garlic is generally safe, excessive intake may cause gastrointestinal discomfort or interact with medications like blood thinners. Therefore, it is best consumed in moderation as part of a balanced diet.[30,31,33]

Ginger *(Zingiber officinale)*

Ginger (*Zingiber officinale*), a widely used spice and medicinal root, possesses potent anti- inflammatory, antioxidant, and anticancer properties. Its primary bioactive compounds— gingerols, shogaols, and paradols—are responsible for its therapeutic effects. Studies have shown that ginger can inhibit cancer cell growth, induce apoptosis, and suppress angiogenesis in various cancers, including colorectal, ovarian, and pancreatic malignancies.

Beyond its anticancer potential, ginger is commonly used to relieve nausea, improve digestion, reduce pain and inflammation, and manage conditions like arthritis. It also supports cardiovascular health by enhancing blood circulation and helping to lower blood pressure.[30,30,34–36]

Ashwagandha (*Withania somnifera*)

Ashwagandha (*Withania somnifera*), renowned for its adaptogenic, anti-inflammatory, and antioxidant properties, is a cornerstone of traditional Ayurvedic medicine. Its primary bioactive compounds—including withanolides, alkaloids, and sitoindosides—are responsible for its wide- ranging therapeutic effects. Ashwagandha has shown potential in various cancers, including lung, breast, and colon, by inhibiting cancer cell growth, promoting apoptosis, and preventing metastasis.

Beyond its anticancer benefits, ashwagandha is widely used to enhance energy levels, improve cognitive function, and alleviate stress, anxiety, and fatigue. It also supports immune health and may help regulate cortisol levels and blood sugar.[30,30]

However, its effects can vary depending on dosage and individual health conditions. High doses may cause gastrointestinal discomfort or interact with certain medications. For optimal safety and efficacy, it is recommended to use ashwagandha under the guidance of a healthcare professional.

Ginseng (*Panax ginseng*)

Ginseng (*Panax ginseng*) is a widely recognized medicinal herb known for its adaptogenic, antioxidant, and anticancer properties. Its key bioactive compounds, ginsenosides, are primarily responsible for its therapeutic effects. Ginseng has shown promise in various cancers, including breast, lung, and liver, by inhibiting cancer cell growth, inducing apoptosis, and reducing angiogenesis and metastasis.

Beyond its anticancer activity, ginseng is commonly used to manage stress, boost physical and mental performance, reduce fatigue, and strengthen the immune system. It may also support cardiovascular health and help regulate blood sugar levels.[26,33]

Although generally considered safe, ginseng's effects can vary depending on the dosage and individual health status. Overuse may lead to side effects such as headaches, gastrointestinal discomfort, or insomnia, and it may interact with certain medications. For safe and effective use, consultation with a healthcare professional is recommended.

Milk thistle (*Silybum marianum*)

Milk thistle (*Silybum marianum*) is a well-known medicinal herb celebrated for its anticancer, antioxidant, and liver-protective properties. The active compound, silymarin, is a blend of flavonolignans with powerful anti-inflammatory and free radical-scavenging effects. Milk thistle has shown promise in inhibiting cancer cell growth, inducing apoptosis, and preventing metastasis, particularly in liver, breast, and prostate cancers.

Beyond its anticancer benefits, milk thistle is commonly used to support liver health, particularly in conditions like cirrhosis and hepatitis. It may also help regulate blood sugar and cholesterol levels and protect the liver from toxins.[30,30,31,37,38]

While generally safe, milk thistle may cause mild side effects, such as allergic reactions or gastrointestinal discomfort. For optimal use, especially in individuals with pre-existing health conditions, it is advisable to seek professional guidance.

Neem (*Azadirachta indica*)

Neem (*Azadirachta indica*) is a well-known medicinal plant recognized for its antibacterial, anti- inflammatory, and antioxidant properties. Its primary bioactive compound, azadirachtin, offers

numerous health benefits. Neem has shown potential in inhibiting the growth of cancer cells, inducing apoptosis, and preventing metastasis, particularly in skin, breast, and colon cancers.

Beyond its anticancer effects, neem is widely used to treat infections, reduce inflammation, and promote skin health, helping manage conditions such as psoriasis, eczema, and acne. It also supports liver function, regulates blood sugar levels, and strengthens the immune system.[39]

Holy basil (*Ocimum sanctum*)

Holy basil (*Ocimum sanctum*), commonly known as tulsi, is a sacred herb in traditional Ayurvedic medicine, valued for its adaptogenic, antioxidant, and anti-inflammatory properties. It contains a rich array of bioactive compounds, including eugenol, ursolic acid, and rosmarinic acid, which contribute to its wide-ranging therapeutic effects. Holy basil has demonstrated potential in inhibiting the growth of cancer cells, inducing apoptosis, and reducing angiogenesis and metastasis, particularly in lung, breast, and oral cancers.

Beyond its anticancer potential, holy basil is widely used to alleviate stress and anxiety, strengthen the immune system, and support respiratory and cardiovascular health. Additionally, it helps regulate blood sugar levels and exhibits natural antimicrobial activity, making it beneficial for overall wellness and disease prevention.[30,30]

Cannabis (*Cannabis sativa*)

Cannabis (*Cannabis sativa*) is a well-known medicinal herb recognized for its anti-inflammatory, analgesic, and anticancer properties. Its primary active compounds, tetrahydrocannabinol (THC) and cannabidiol (CBD), interact with the endocannabinoid system to regulate various physiological processes. Studies suggest that cannabis may inhibit the proliferation of cancer cells, induce apoptosis, and reduce tumor angiogenesis in cancers such as glioma, breast, and prostate.

Beyond its anticancer potential, cannabis is widely used to manage chronic pain, chemotherapy- induced nausea, muscle spasms, anxiety, and sleep disorders. CBD, in particular, is favored for its therapeutic benefits without the psychoactive effects associated with THC, making it a preferred option for medical use.[40–45]Mechanism of Action

Herbal remedies act through multiple pathways to target various stages of cancer development, including initiation, progression, and metastasis. Herbal substances generally exhibit multi- targeted actions, potentially offering greater efficacy and fewer side effects compared to conventional chemotherapeutic agents, which often focus on a single molecular pathway. The primary mechanisms through which herbal remedies exert their anticancer effects include:

1. **Induction of Apoptosis (Programmed Cell Death)**

Apoptosis is a natural cellular mechanism that eliminates damaged or unwanted cells. However, many cancer cells evade apoptosis, leading to uncontrolled growth and proliferation. Herbal compounds can help reactivate this process through several mechanisms:

i. Activation of pro-apoptotic proteins such as p53 and Bax
ii. Initiation of the mitochondrial (intrinsic) pathway, leading to cytochrome c release
iii. Inhibition of anti-apoptotic proteins like Bcl-2 and Bcl-xL

Activation of caspase enzymes, particularly caspase-3 and caspase-9, which mediate cellular breakdown. For example, berberine promotes mitochondrial-mediated apoptosis, while curcumin (*Curcuma longa*) suppresses Bcl-2 expression and activates caspases.[46–49]

2. Cell Cycle Arrest

Uncontrolled cell cycle progression is a hallmark of cancer, leading to excessive cell proliferation. Herbal compounds can inhibit cancer cell growth by arresting the cell cycle at specific checkpoints, such as G0/G1, S, or G2/M phases thereby halting further division.

Key mechanisms include:

i. Modulation of cyclins and cyclin-dependent kinases (CDKs)
ii. Upregulation of cell cycle inhibitors such as p21 and p27

Examples: Genistein, a compound found in soy, induces G2/M phase arrest in various cancer cell lines. Resveratrol, derived from grapes, suppresses CDK activity, contributing to cell cycle inhibition.[50–55]

Inhibition of AngiogenesisAngiogenesis formation of new blood vessels-is a critical process that supports tumor growth and metastasis by supplying oxygen and nutrients. Certain herbal compounds can inhibit this process by downregulating key angiogenic factors, particularly vascular endothelial growth factor (VEGF). They may also interfere with angiogenesis-related signaling pathways, such as the PI3K/Akt/mTOR pathway. [21,56–58] Examples: Epigallocatechin gallate (EGCG) from green tea suppresses VEGF expression, thereby inhibiting angiogenesis.

3. Antioxidant and Anti-Inflammatory Effects

Oxidative stress and chronic inflammation play key roles in the initiation and progression of cancer. Many herbal compounds possess strong antioxidant and anti-inflammatory properties that contribute to their anticancer effects. These actions include:

i. Neutralizing free radicals to reduce oxidative damage
ii. Inhibiting inflammatory enzymes such as iNOS and COX-2
iii. Suppressing pro-inflammatory cytokines like IL-6 and TNF-α

Examples: Gingerol (from ginger) and curcumin (from *Curcuma longa*) are known to downregulate inflammatory mediators. Quercetin scavenges reactive oxygen species (ROS) and modulates redox-sensitive transcription factors involved in inflammation and cell survival.[4,59–63]

Conclusion

Herbal medicine presents a promising complementary and alternative approach to cancer treatment, owing to its multi-targeted mechanisms, lower toxicity, and potential to enhance the effectiveness of conventional therapies. Numerous medicinal plants and their active constituents have shown notable anticancer activities, including the induction of apoptosis, inhibition of angiogenesis, suppression of inflammation, and arrest of the cell cycle. Herbs such as turmeric, green tea, garlic, ginger, ashwagandha, and cannabis have demonstrated significant potential against various types of cancer. Despite encouraging preclinical and some clinical evidence, the use of herbal treatments in oncology requires careful consideration.

Challenges such as standardization, appropriate dosing, bioavailability, and potential interactions with conventional cancer therapies remain significant concerns. Therefore, well-designed clinical trials and robust regulatory oversight are essential to establish the safety, efficacy, and proper integration of phytotherapy into mainstream oncology care.

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