

A comprehensive review of the anti-cancer properties of alkaloids, polysaccharides, and organosulfur compounds: A Scientific Approach

Dass K ^{1*}, Suresh Sekar², Prakash N³, Prabhu S⁴, Murugesan R⁵

¹ Department of Pharmacology, Saveetha Medical College & Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai 602 105, Tamil Nadu, India.

²Department of Orthopaedics, Saveetha Medical College & Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai 602 105, Tamil Nadu, India.

³P.G. Department of Chemistry, Annai Vailankanni Arts and Science College (Affiliated to Bharathidasan University, Tiruchirappalli), Thanjavur 613 007, Tamil Nadu, India.

⁴Division of Phytochemistry and Drug Design, Department of Bioscience, Rajagiri College of Social Sciences (Autonomous), Kalamaserry, Kochi 683 104, India.

⁵Division of Entomology, Department of Bioscience, Rajagiri College of Social Sciences (Autonomous), Kalamaserry, Kochi 683 104,

*Corresponding Author
Dr.K. Dass

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Abstract: Cancer is a major cause of deaths. There are numerous therapies available to inhibit cancer cells, especially chemotherapy, radiotherapy, surgery, and hormone therapy etc., such treatments have many side effects. In this circumstance, we need to look for alternate therapies. In such a situation, it is necessary to go plant-based natural compounds. Researchers around the world are discovering naturally occurring phyto-compounds from various plants as potent drugs for different types of cancer. In addition, we discuss the problems and opportunities connected with medication delivery, combination therapy, regulatory barriers, and commercialisation. This review provides an in-depth look at natural phytochemicals such as alkaloids, organosulfur compounds, and polysaccharides potential as important resources for generating novel and effective cancer prevention and treatment strategies.

Keywords: Anticancer, Phyto-compounds, Alkaloids, Organosulfur compounds, Polysaccharides.

INTRODUCTION

Cancer is uncontrolled cell division, which is spreading to all nearby cells, tissues, organs, and various body parts. Cancer is considered one of the cruellest and most important diseases that cause human mortality (Wambua Mukavi et al., 2020). According to the World Health Organisation, the number of people affected by cancer every year is increasing, especially in India, with over 1.4 million cancer cases per year, with estimates of the number increasing to over 1.5 million cases by 2025. At present, Kerala is recognised as the cancer capital of India; 2,001,140 new cancer cases and 611,720 cancer fatalities occurred in the USA in 2024 (Bray et al., 2024; Siegel et al., 2024; WHO.2024). People are affected many types of cancer; of these, lung cancer, oral cancer, bladder cancer, bone cancer, colorectal cancer, kidney cancer (renal cell), pancreatic cancer, prostate cancer, and uterine cancer are common for males (Fig. 1). Females commonly experience cancers of the cervix, ovaries, uterus, vagina, vulva, fallopian tubes, breast, colorectal, lung, cervical, endometrial, and skin (Fig. 2) (Giaquinto et al., 2024; Hamdy et al., 2023; Murciano-Goroff et al., 2023)

Cancer is caused by a combination of intrinsic factor (genetic) and extrinsic factors (physical, chemical and biological). Intrinsic factors include

DNA repair, gene mutations, genetic errors or changes, cell division, apoptosis failure, heredity, and hormonal imbalance, whereas extrinsic factors include UV radiation, pollution (physical factors), tobacco smoke, alcohol consumption, drugs, aflatoxin (chemical factors), diet habits, bacteria, viruses, and parasites (biological factors) (Fig. 3)(Ledford, 2023; Muresanu & Khalchitsky, 2022; Wadgaonkar, 2024).

These include anti-cancer chemotherapeutic drugs, resistance to cancer cells, toxic effects, and non-target tissues. In this situation, we need to seek a new alternative to synthetic chemical-based drugs and active anti-cancer agents without side effects. In this scenario researchers believe plant phytochemicals have anti-cancer properties (Mandal et al., 2023; Rajasekar et al., 2023).

Over 37,000 plants contain bioactive compounds can stop cancer growth, including well-known treatments like vincristine, vinblastine, taxol, indicine-N-oxide, etoposide, camptothecin, allicin, ajoene, andrographolide, licochalcone, gossypol, and panaxadiol (Bozzuto et al., 2024; Chandra et al., 2023). This review describes the potential phytochemical namely alkaloids, organosulfur compounds, and polysaccharides as a valuable recourse for developing novel and effective strategies for cancer therapies.

MATERIAL AND METHODS

A literature review on the anti-cancer properties of different plant parts has been collected from the Internet, the World Health Organisation databases, and scientific publications, including Web of Science, Taylor & Francis, PubMed, Research Gate, Springer, Wiley, Google Scholar, and the National Cancer Institute database and relevant keywords cover cancer, phytochemicals, pharmacological potential, and anti-cancer effectiveness from 2010 to 2024.

3 Main text

3.1 Phyto-compounds as anticancer property

Phytochemicals are secondary metabolites, non-nutritive, and biologically active compounds naturally found in parts of the plants, including roots, stems, bark, leaves, fruits, flowers, seeds, etc. They provide health benefits to humans by acting as therapeutic agents. These compounds can be broadly classified into several major classes, each with unique chemical structures and mechanisms of action. These classes include flavonoids, alkaloids, terpenoids, and phenolic acids, among others. Each class offers a diverse range of health-promoting properties, such as antioxidant, anti-inflammatory, and antimicrobial effects, which contribute to the overall well-being of individuals (Shrihastini et al., 2021).

3.1.1 Alkaloids

An alkaloid is a naturally occurring organic compound that includes nitrogen and has a ring structure. It is basic and capable of accepting protons in reactions. Plants directly yield the majority of commercially available alkaloids, but some, like caffeine, can also undergo synthesis. Morphine, strychnine, quinine, ephedrine, and nicotine are some of the most well-known alkaloids. These compounds often exhibit significant biological activity, making them valuable in medicine and pharmacology. For instance, morphine is widely used for its analgesic properties, whereas nicotine is recognised for its stimulating effects on the central nervous system.

3.1.1.1 Berberine

Berberine is an alkaloid that occurs naturally in various plants, including *Coptis chinensis*, *Berberis vulgaris*, and *Hydrastis canadensis*. This substance exhibits a range of pharmacological properties, such as anti-inflammatory, antioxidant, and anti-diabetic effects (Mana et al., 2023).

3.1.1.2 Brucine

Brucine was derived from *Strychnos nuxvomica*. Brucine exhibits a range of pharmacological activities, including anti-tumour, anti-inflammatory, and analgesic effects, as well as impacts on the cardiovascular and nervous systems (Jain et al., 2023).

3.1.1.3 Cathachunine

Cathachunine is a phytochemical derived from *Catharanthus roseus*, exhibiting a range of pharmacological properties, such as anti-microbial, anti-helminthic, anti-ulcer, diarrhoea-alleviating, anti-oxidant, memory-improving, wound-healing, anti-diabetic, and hypotensive effects (Sidhic et al., 2024).

3.1.1.4 Colchicine

Colchicine is derived from *Colchicum autumnale*. Colchicine is an anti-mitotic agent that interferes with cytoskeletal functions by inhibiting the polymerization of β -tubulin into microtubules. As a result, it inhibits the activation, degranulation, and migration of neutrophils (Ballacci et al., 2024).

3.1.1.5 Evodiamine

Evodiamine is an alkaloid derived from *the Evodia rutaecarpa*. This substance possesses a range of pharmacological properties, such as anti-inflammatory, anti-cancer, and neuroprotective effects (Panda et al., 2023).

3.1.1.6 Harmine

Harmine is an alkaloid found in *Peganum harmala*. It displays various pharmacological properties, including anti-inflammatory, antitumour, and antidiabetic effects (Akabli et al., 2025).

3.1.1.7 Neferine

Neferine is an alkaloid present in *Nelumbo nucifera*. It possesses several pharmacological activities, including anticancer, anti-inflammatory, and antioxidant effects (Bharathi Priya et al., 2021).

3.1.1.8 Roscovitine

Roscovitine or Seliciclib has been derived from *Ophioparma ventosa*. It is used to treat non-small cell lung cancer, leukaemia, HIV infection, herpes simplex infection, and the underlying mechanisms of chronic inflammation disorders (Meijer et al., 2016).

3.1.1.9 Skimmianine

Skimmianine is an alkaloid found in *Ruta macrophylla* and *Teclea simplicifolia*. This substance shows various pharmacological properties, including analgesic, antispastic, anti-inflammatory, sedative, antiplatelet aggregation, cytotoxic, and genotoxic effects (Zaman et al., 2024)

3.1.1.10 Solamargine

The *Solanum* species, specifically *Solanum nigrum* and *S. lycocarpum*, yield solamargine, a substance with antiviral, anti-inflammatory, and anticancer properties (Manoharan et al., 2024)

3.1.1.11 Solasonine

Solasonine has been derived from *Solanum carolinense*, *Solanum violaceum*, *Spinacia oleracea*, *Solanum mammosum*, and *Solanum sycophanta*. It exhibits properties such as antimalarial, antibacterial, antifungal, anthelmintic, cardiogenic, anticonvulsant, anti-inflammatory, and analgesic activities (Delbrouck et al., 2023)

3.1.1.12 Tylophorine

Tylophorine is an alkaloid derived from the *Tylophora indica*. It possesses a variety of pharmacological properties, such as anti-inflammatory, anti-cancer, and anti-bacterial effects (Mostafa et al., 2023).

3.1.1.13 Vincristine and Vinblastine: These alkaloids, isolated from the *Madagascar periwinkle* plant, is widely used chemotherapeutic agents for treating various cancers, including leukemia, lymphoma, and testicular cancer (Abdulwahid et al., 2024).

3.1.1.14 Camptothecin: This alkaloid, originally isolated from *Camptotheca acuminata*, and its derivatives are used to treat a variety of cancers, including ovarian, lung, and colorectal cancers (Odeniran et al., 2024).

3.1.1.15 Chrysophanol

Chrysophanol is a phytochemical, isolated from in several plants and herbs, including *Polygonum multiflorum*, *C. acutifolia*, *Rumex dentatus*, *Ageratina altissima*, *Aloe barbadensis miller*, *Senna folium*, and *Cassia semen*. It possesses various pharmacological properties, such as anti-inflammatory, anti-cancer, and anti-depressive effects (D. Liu et al., 2024)

3.1.1.16 Damnacanthal

Damnacanthal was first isolated from the roots of *Morinda citrifolia*. It shows a variety of pharmacological effects, including antioxidant, anti-inflammatory, anti-cancer, anti-hyperlipidemic, and antibacterial properties. These beneficial effects make Damnacanthal a subject of interest for further research in the field of traditional medicine and modern therapeutics. Ongoing studies aim to elucidate its mechanisms of action and potential applications in treating various health conditions (R. Li et al., 2022).

3.1.1.17 Emodin

Emodin isolated from *Polygonum multiflorum* and *Rheum palmatum*. Diuretic, antibacterial, antiulcer, anti-inflammatory, anticancer, and antinociceptive are only a few of the many biological properties of emodin (M. Luo et al., 2025).

3.1.1.18 Physcion

Physcion is a natural anthraquinone found in *Cassia occidentalis* and *Alternaria porri*. It has a range of pharmacological activity, including anti-inflammatory, antibacterial, antifungal, and anticancer properties (Pang et al., 2016)

3.1.1.19 Plumbagin

Plumbagin is present in the plants *Plumbago rosea* and *Plumbago zeylanica*. It possesses a range of pharmacological properties, such as anti-inflammatory, antioxidant, and anti-cancer effects (Sharma et al., 2024)

3.1.1.20 Punarnavine

The roots of the *Boerhaavia diffusa* plant are the source of punarnavine. It has several pharmacological qualities, such as analgesic, anti-inflammatory, and anti-proliferative (Das et al., 2023).

3.1.1.21 Psoralen

Psoralen is a naturally occurring compound present in *Psoralea corylifolia*. Psoralen exhibits a range of pharmacological properties, encompassing anti-inflammatory, anti-cancer, and antiviral effects (Galiatsatos et al., 2024).

3.1.2 Organosulfur compounds

Organosulfur compounds, characterized by the presence of sulfur atoms, are found in garlic, onions, and cruciferous vegetables. These compounds exhibit antioxidant, anti-inflammatory, and anti-cancer properties. They have a significant role in promoting overall health and may help reduce the risk of chronic diseases.

Furthermore, ongoing research continues to explore their potential therapeutic applications in various fields of medicine (Bala et al., 2024).

3.1.2.1 Ajoene

The bioactive compound ajoene is isolated from the *Allium sativum* plant and has many medical uses, including fighting inflammation, boosting the immune system, killing bacteria, viruses, fungi, and parasites, and protecting the kidneys, the heart, and tumours (Talib et al., 2024a)

3.1.2.2 Allicin

Plants belonging to the *Allium* family, including *Allium cepa* and *Allium sativum*, contain the organosulfur compound allicin. Considering its wide range of pharmacological effects, it is useful as an antioxidant, anti-inflammatory, and antibacterial (Bhuker et al., 2024).

3.1.2.3 Aloe emodin

Aloe emodin is a phytochemical present in the roots and rhizomes of several plants, including *Aloe barbadensis miller*, *Cassia occidentalis*, and *Rheum palmatum*. Among its various medicinal qualities are anti-inflammatory, antibacterial, and anticancer activities (H. Luo et al., 2024).

3.1.2.4 Aloesin

Aloesin is obtained from *Aloe barbadensis miller* (Aloe vera). The extract of aloe vera has been documented to possess several advantageous effects, including immunomodulatory, wound- and burn-healing, hypoglycemic, anticancer, gastroprotective, antifungal, and anti-inflammatory characteristics (Catalano et al., 2024).

3.1.2.5 Diallyl disulfide

Diallyl disulfide is a bioactive compound present in *Allium sativum*, exhibiting many pharmacological properties. This organosulfur compound has anti-inflammatory, antioxidant, antibacterial, and anticancer properties.

3.1.2.6 S-allyl cysteine

S-allyl cysteine is a sulphurous amino acid present in old *Allium sativum* extract. It possesses several potential health advantages, encompassing antioxidant, anti-inflammatory, and anti-diabetic properties (Yudhistira et al., 2022).

3.1.2.7 Sulforaphane

This compound, which is plentiful in broccoli sprouts, strongly boosts antioxidant enzymes and has shown good results in early studies for fighting cancer. Additionally, it may also play a role in reducing inflammation and enhancing overall immune function, making it a valuable component of a healthful diet. Researchers continue to explore its mechanisms and potential applications in cancer prevention and treatment (Pogorzelska et al., 2024).

3.1.3 Polysaccharides

Polysaccharides are complex carbohydrates composed of long chains of sugar molecules. Certain plant-derived polysaccharides have been shown to possess immune-modulating and anti-tumour activities. These properties make them of particular interest in nutritional and medicinal research, as they could potentially enhance the body's defence mechanisms against various diseases. Additionally, their ability to influence gut health and microbiota composition further underscores their importance in promoting overall well-being (Zhao et al., 2023)

3.1.3.1 Lentinan

This polysaccharide, isolated from the shiitake mushroom, has been shown to enhance immune function and inhibit tumour growth in preclinical and clinical studies. Moreover, its potential therapeutic applications extend beyond oncology, as it may also play a role in managing various autoimmune disorders and improving overall health. Further research is necessary to fully understand its mechanisms and optimise their use in clinical settings (Zhou et al., 2024).

3.1.3.2 Schizophyllan

This polysaccharide, derived from the mushroom *Schizophyllum commune*, has demonstrated immune-stimulating and anti-tumour activities. Researchers have been particularly interested in its potential applications in cancer therapy because it appears to enhance the body's natural defence mechanisms. Furthermore, ongoing studies are investigating its effects on various immune-related conditions, highlighting its promise as a therapeutic agent (Gao et al., 2024).

RESULTS AND OBSERVATIONS:

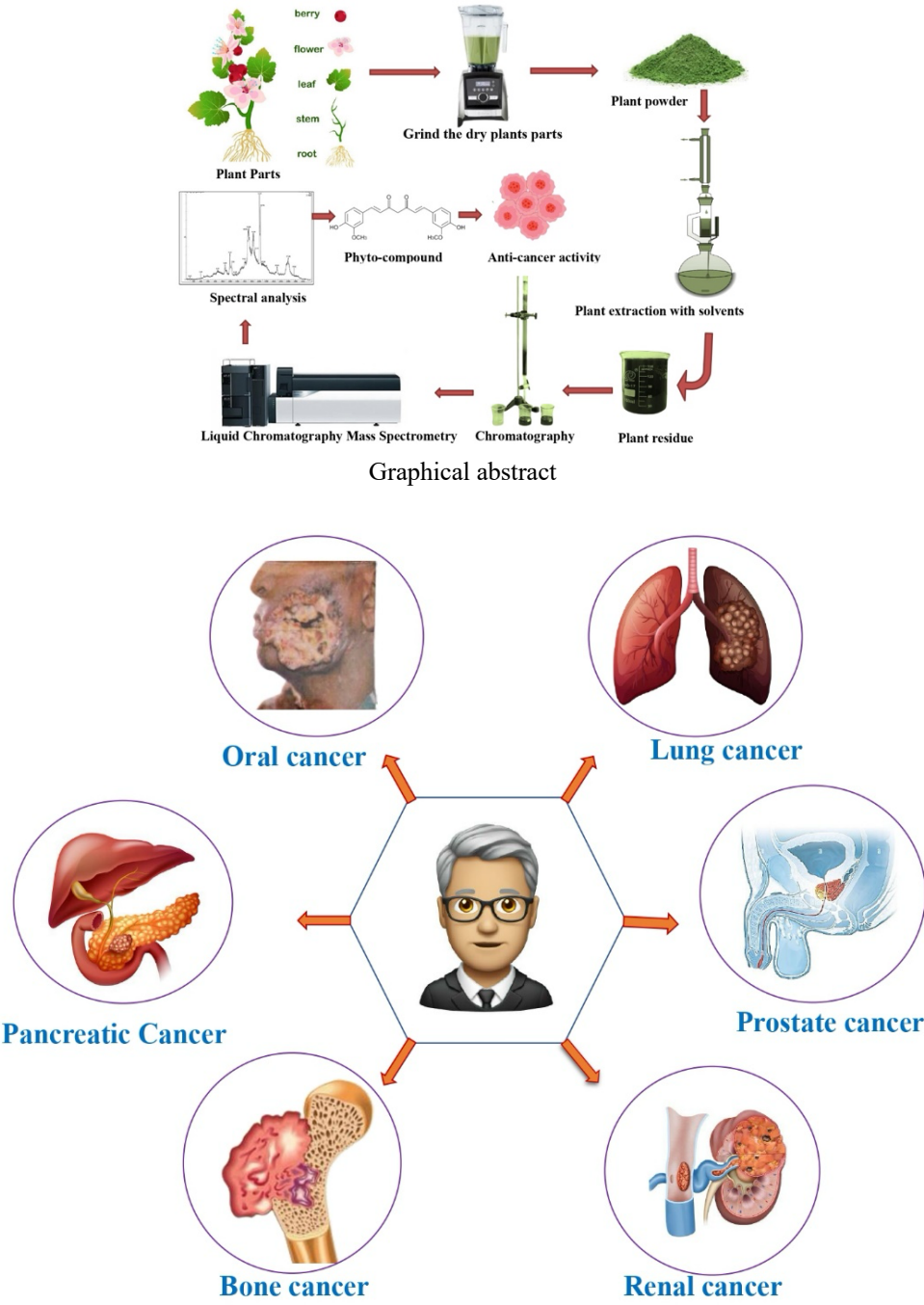


Figure.1. Diagnosed common cancer types in males

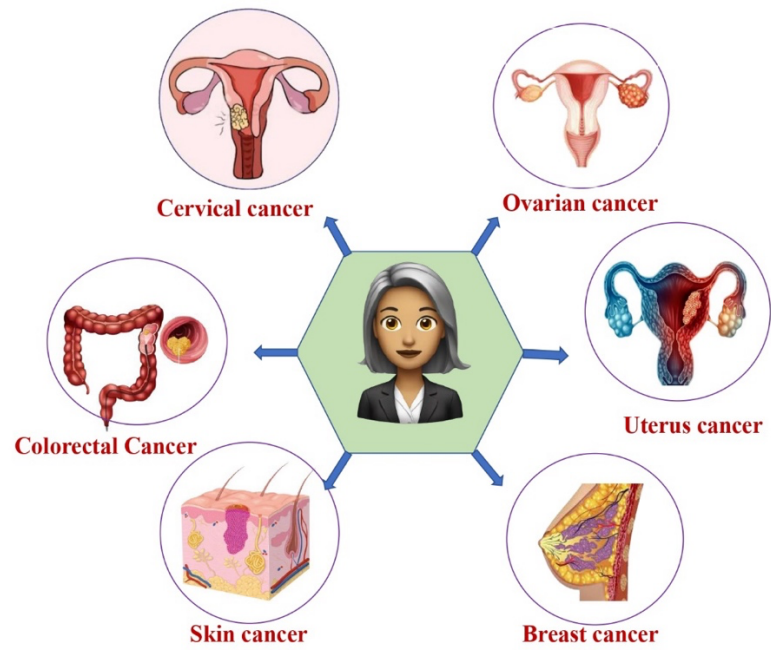


Figure.2. Diagnosed common cancer types in females

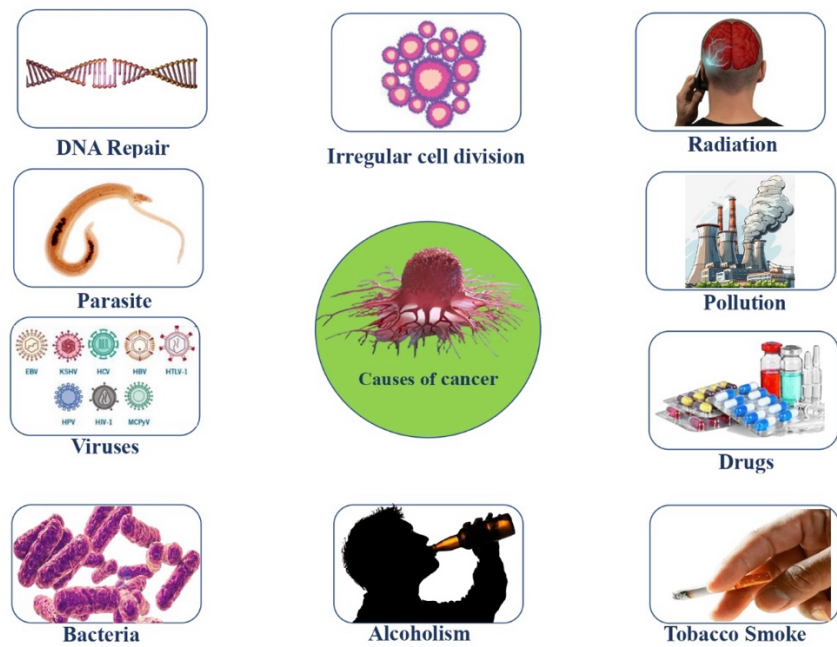
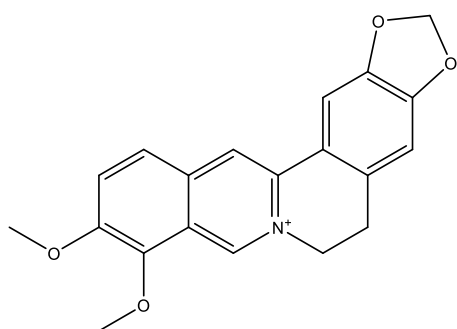
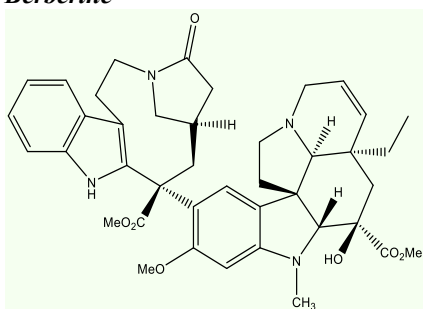


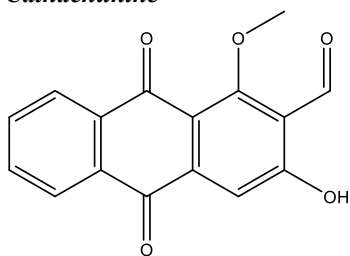
Figure.3. Major causes of cancer



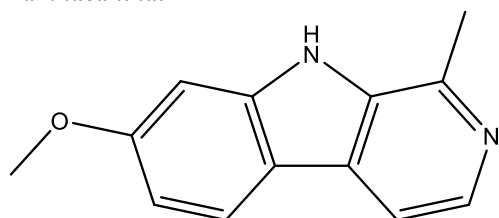
Berberine



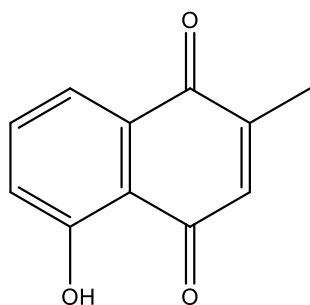
Cathachunine



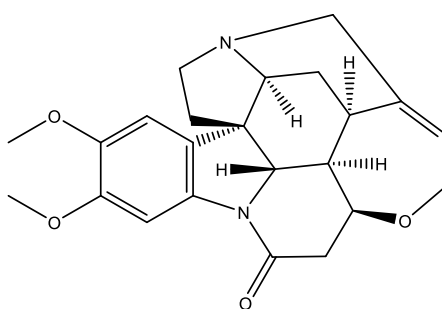
Damnacanthal



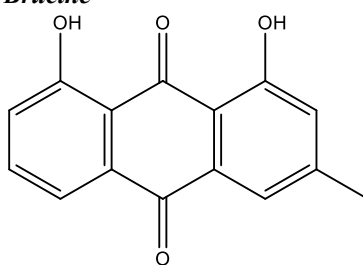
Harmine



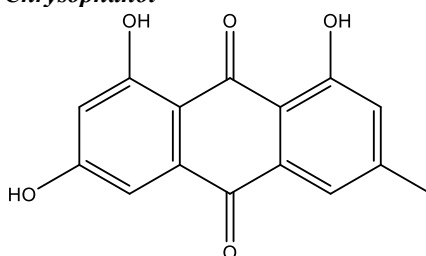
Plumbagin



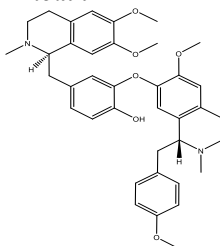
Brucine



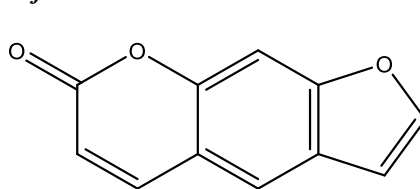
Chrysophanol



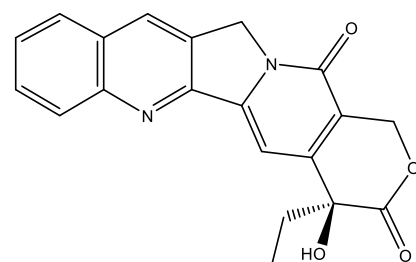
Emodin



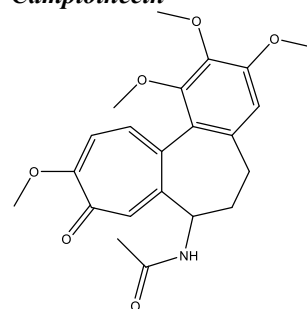
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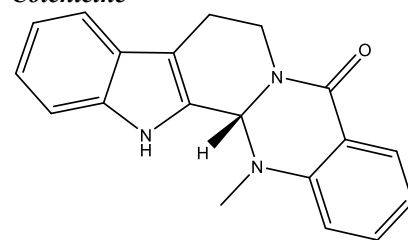
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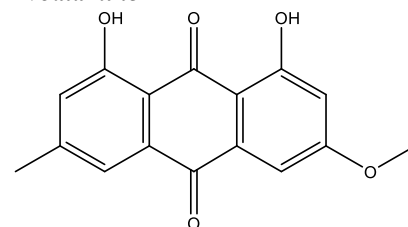
Camptothecin



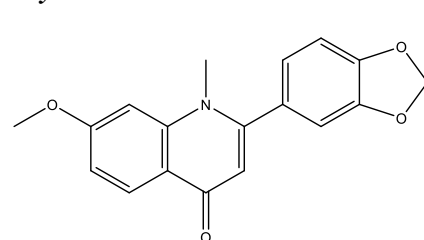
Colchicine



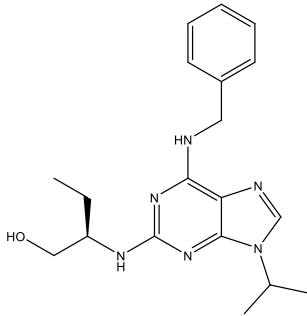
Evodiamine



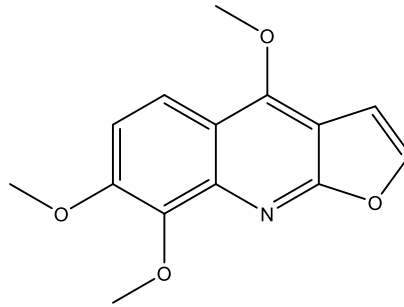
Physcion



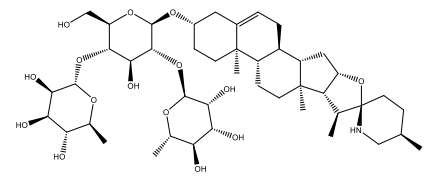
Punarnavine



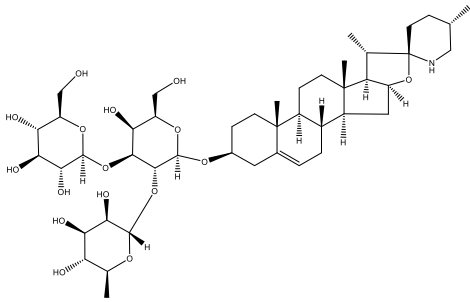
Roscovitine



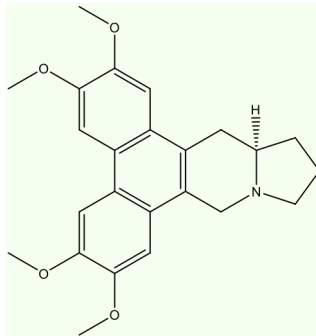
Skimmianine



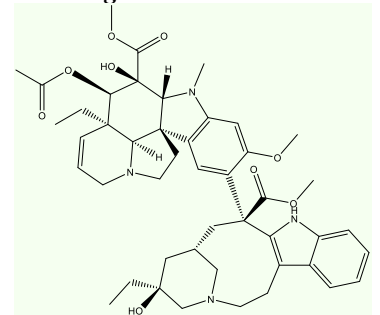
Solamargine



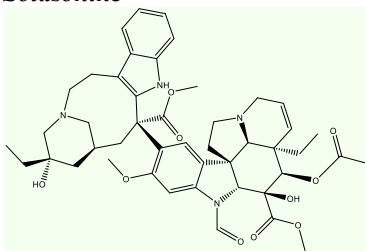
Solasonine



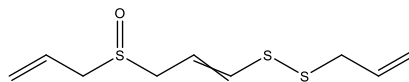
Tylophorine



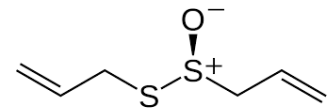
Vinblastine



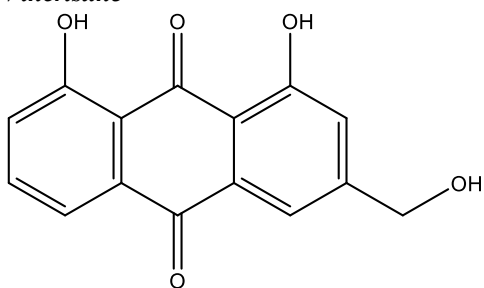
Vincristine



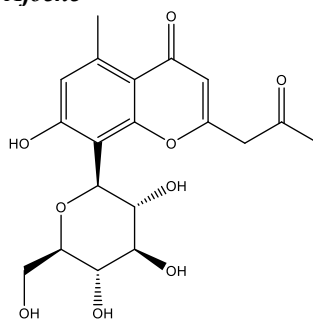
Ajoene



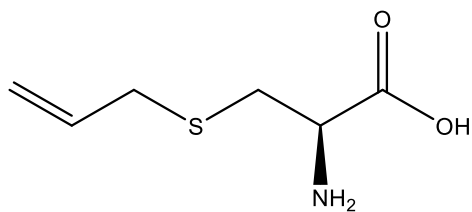
Allicin



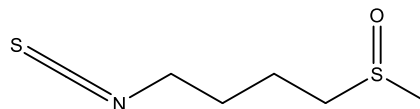
Aloe emodin



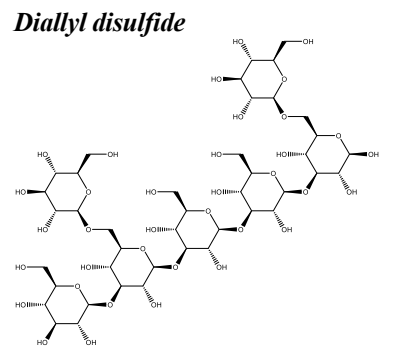
Aloesin



S-allyl cysteine



Sulforaphane



Lentianan

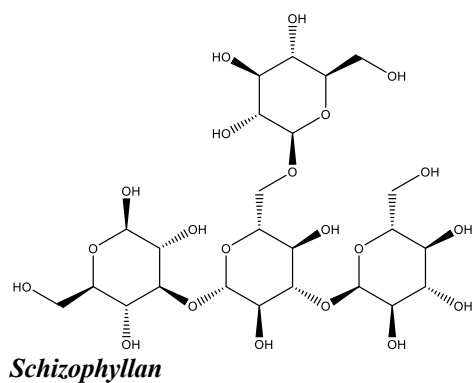


Figure.4. Alkaloids, organosulfur compounds, and polysaccharides phytocompounds evaluated their efficacy in anti-cancer activity.

RESEARCH ARTICLE

 Table.1. Isolated alkaloids, organosulfur compounds, and polysaccharides anti cancer phyto-compounds in
various plant species.

Species	Part(s) used	Phytocompound(s)	Major classification of Phytocompound(s)	Type of cancer	Reference
 Alliaceae					
<i>Allium</i>	Bulbs	Ajoene	Organosulfur Compounds	Breast, colon and gastric cancer	(Talib)
<i>Allium</i>	Bulbs	Z-ajoene	Organosulfur Compounds	Breast, colon and gastric cancer	
<i>Allium</i>	Bulbs	Allicin	Organosulfur Compounds	Breast, colon and gastric cancer	
<i>Allium</i>	Bulbs	S-allyl cysteine	Organosulfur Compounds	Breast, colon and gastric cancer	
<i>Allium</i>	Bulbs	Diallyl disulfide	Organosulfur Compounds	Breast cancer	Sujath
 Vinaceae					
<i>Vinca roseus</i>	Leaves	Vinblastine	Alkaloids	Ovary, cervix, hodgkin's, rhabdomyosarcoma, liver, malignant lymphoma, leukemia, neuroblastoma, colon, testis, rectum, and breast cancer	(Kegl)
<i>Vinca roseus</i>	Leaves	Vincristine	Alkaloids	Ovary, cervix, hodgkin's, rhabdomyosarcoma, liver, malignant lymphoma, leukemia, neuroblastoma, colon, testis, rectum, and breast cancer	
<i>Vinca roseus</i>	Leaves	Cathachunine	Alkaloids	Human leukemia cells	(Wang)
<i>Vinca indica</i>	Leaves	Tylophorine	Alkaloids	Breast cancer	(Lauri)
 Liliaceae					
	Leaves	Aloe emodin	Organosulfur Compounds	Leukemia, stomach cancer, and neuroectodermal tumors	(El-S)
	Leaves	Aloesin	Organosulfur Compounds	Leukemia, stomach cancer, and neuroectodermal tumors	
 Berberidaceae					
<i>Berberis vulgaris</i>	Root	Berberine	Alkaloids	Leukemia, prostate, breast, and liver cancer	(Man)
 Brassicaceae					
<i>Brassicaceae</i>	Aerial part	Sulforaphane	Organosulfur compounds	Prostate cancer	(Cipo)
<i>Brassicaceae</i>	Aerial part	Sulforaphane	Organosulfur compounds	Breast cancer	(Castr)
<i>Brassicaceae</i>	Aerial part	Sulforaphane	Organosulfur compounds	Breast cancer	(Rong)
<i>Brassicaceae</i>	Leaves	Roscovitine	Alkaloids	Lung and breast cancer	(Garc 2021)
<i>Brassicaceae</i>	Leaves	Sulforaphane	Organosulfur compounds	Breast cancer	(Saav 2022)
<i>Brassicaceae</i>	Leaves	Sulforaphane	Organosulfur compounds	Breast cancer	(Cao)
 Colchicaceae					
<i>Colchicum autumnale</i>	Flower	Colchicine	Alkaloids	Solid tumors, hodgkin's lymphoma, and chronic granulocytic leukemia	(Atkin)
 Rutaceae					
<i>Rutaceae</i>	Seed	Brucine	Alkaloids	Breast cancer cell Line mda-mb-231	(Xu et)
 Leguminosae					
	Leaves	Neferine	Alkaloids	Liver cancer	(Yoon)
<i>Leguminosae</i>	Roots	Sucrose	Polysaccharides	Cerebral glioma cells (u251)	(WU)
<i>Leguminosae</i>	Stem	Resveratrol	Stilbenoids	Gastric cancer	(Reza)
 Berberidaceae					
<i>Berberis</i>	Root	Berberine	Alkaloids	Breast, pancreatic cancer	(Barz)
 Melastomataceae					
<i>Melastomataceae</i>	Aerial part/Stem/Root	Skimmianine	Alkaloids	Liver cancer	(Muk)
 Simarubaceae					
<i>Simarubaceae</i>	Fruit	Evodiamine	Alkaloids	Breast cancer cells, mcf-7 And mda-mb-231 cells	(Wang)

aceae					
<i>igrum</i>	Leaves	Solamargine	Alkaloids	Liver, skin, lung, and breast cancer	(Al Si
<i>igrum</i>	Leaves	Solasonine	Alkaloids	Liver, skin, lung, and breast cancer	(Kim
<i>ecopersicum</i>	Fruit /flower	A-tomatine	Alkaloids, Terpenoids	Mouse colon cancer cells	
<i>ecopersicum</i>	Fruit /flower	A-tomatine	Alkaloids, Terpenoids	Mammary adenocarcinoma in mice	(Tom
ae					
<i>inensis</i>	Leaves	Theabrownin	Alkaloids	Lung cancer	(Wu e
nyllaceae					
<i>armala</i>	Leaves/ rhizome	Harmine	Alkaloids	Breast cancer	(Ayoc

DISCUSSION

Phyto-compounds as anticancer activity various phyto-compounds derived from different plant parts have been studied for their anti-cancer activity. Table 1, expressed plants phytochemicals namely alkaloids, organosulfur compounds, and polysaccharides have anti-cancer properties for various target cancers. *Allium sativum* (Amaryllidaceae) chemicals like ajoene, allicin, and diallyl disulphide can stop the growth of breast, colon, and stomach cancer cells, which might lead to better cancer treatments. Furthermore, research indicates that these compounds can enhance the efficacy of conventional therapies, potentially leading to better patient outcomes. Continued investigation into the synergistic effects of phyto-compounds alongside standard treatments may pave the way for more holistic cancer care strategies (Talib et al., 2024b).

In this review we analysed 31 phyto compounds from 19 plant species, representing 14 families. All the plants analysed had cancer-inhibiting properties. These findings suggest a remarkable potential for developing new cancer therapies based on natural products. Further research is needed to isolate the specific compounds responsible for these effects and to understand their mechanisms of action.

Annona squamosa, which belongs to the family Annonaceae, has seeds containing an essential active compound called bullatacin that has been shown to have anti-cancer properties against breast cancer (Pardhasaradhi et al., 2005). *Catharanthus roseus* (Apocynaceae) alkaloids and phytochemicals, such as cathachunine, vinblastine, and vincristine, are considered new anti-cancer compounds tested against ovary, cervix, breast cancer, etc. These findings highlight the potential of natural compounds derived from plants to develop novel cancer therapies, emphasising the importance of further research to fully understand their mechanisms of action and efficacy in clinical settings. As the search for effective treatments continues, integrating such phytochemicals into therapeutic regimens could offer new hope for patients battling various forms of cancer (Keglevich et al., 2012; Wang et al., 2016a).

The medicinal plant *Arisaema flavum* (Araceae) two bioactive compounds, such as hexadecanoic acid ethyl ester and 5-oxo-19-propyl-docosanoic acid methyl ester, were isolated, and the anti-cancer activity examined against the human breast cancer cell line MCF-7 using an MTT assay (Nisa et al., 2022; Velsankar et al., 2020). *Panax ginseng* (Araliaceae) active phytochemicals panaxadiol and anaxatriol have anti-cancer properties against the HCT-116 cell line of human colon cancer, demonstrating significant cytotoxic effects in vitro. Additionally, studies have demonstrated that these compounds can boost the effectiveness of conventional chemotherapeutic agents, indicating a potential for synergistic treatment approaches in cancer therapy (Du et al., 2013).

Aloe barbadensis miller (Asphodelaceae) three anthraquinone compounds, such as aloe emodin, aloesin, and barbaloin, were effectively controlling leukaemia, stomach cancer, and neuroectodermal tumours (El-Shemy et al., 2010). A natural phytochemical, Lappaol F, found in *Aedidium lappa* (Asteraceae) seed, this compound inhibits the cell cycle of cervical, colorectal, breast, and prostate cancer. According to his study, the mechanisms of this phenomenon are still not clear and require further investigation to fully understand how these phytochemicals exert their effects on cancer cells. Additionally, exploring the synergistic potential of these natural compounds could lead to more effective therapeutic strategies in cancer treatment Li et al., 2021).

The clinical success of podophyllotoxin and its fascinating method of action sparked a significant deal of interest in further modifying PPT to improve anticancer efficacy. Researchers began exploring various analogues and derivatives, aiming to enhance the drug's potency while minimising its side effects. This innovative approach led to a more profound understanding of its mechanisms, paving the way for potentially more effective treatments in oncology. As a result, several promising candidates emerged from preclinical studies, demonstrating improved selectivity towards cancer cells. These advancements not only hold the potential for better patient outcomes but also encourage further investigation into the broader

applications of podophyllotoxin derivatives in cancer therapy Liu et al., 2015).

Sulforaphane (SFN) is a potential phytochemical derived from *Raphanus sativus* with various anticancer properties. The metabolome and microbiome provide an inadequate understanding of SFN's effects on breast cancer (Cao et al., 2023). These investigations, though still modest in number compared to in vitro testing, confirm the importance of phyto-compounds in cancer treatment; those phyto-compounds are shown in Fig. 4. These compounds not only exhibit significant anti-cancer activity, but they also play a crucial role in modulating the body's metabolic pathways. Further research is needed to elucidate the precise mechanisms through which SFN influences breast cancer progression and to identify potential synergies with other therapeutic agents.

CONCLUSIONS

This review concludes that the phyto-compounds, as an alternative to synthetic chemicals, have proven to be an effective agent against cancer cells. So far, around 3500 plant biochemicals exhibiting anti-cancer properties have been reported on in various studies. Phytochemicals represent a valuable source of potential anticancer agents, offering a natural and potentially less toxic approach to cancer prevention and treatment. While challenges remain in translating promising research findings into clinically approved therapies, ongoing research, technological advancements, and a collaborative approach hold promise for unlocking the full potential of these natural compounds in the fight against cancer. Most researchers are focusing on controlling cancer cells with biochemicals. In this context, many failures are observed owing to the challenge of identifying the active compounds, a lack of characterisation, and difficulty in understanding. In the future, there will be a greater concentration on the production, growth and development, and deployment of natural anticancer properties to address various difficulties. To aid in the product's commercial further efforts in the manufacturing, formulation, and delivery of plant-derived active chemicals are required. As the quest for effective cancer control continues, the exploration of biochemicals stands at a pivotal juncture, marked by both obstacles and opportunities. The journey to harness these potent compounds is fraught with challenges, such as the identification of active ingredients, their characterisations, and a comprehensive understanding of their mechanisms. However, the future beckons with promise as researchers shift their focus towards enhancing the production and development of natural anticancer properties. To realise the full potential of plant-derived active chemicals, concerted efforts in manufacturing,

formulations, and delivery systems are essential. By overcoming these hurdles, we can pave the way for innovative therapies that combat cancer more effectively and integrate seamlessly into existing treatment paradigms, offering hope for improved patient outcomes.

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K.D: Writing - Original draft, Validation, Supervision, Methodology, Investigation,

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S.S: Conceptualization, literature review and Editing

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S.P: Visualization, Editing, Data analysis.

R.M: Validation.

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