INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Enhancing Cancer Therapy with Phytosomes: A Review of Mechanisms

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ARTICLE INFO

Published: 13 Dec. 2024
Keywords:
Phytosomes, nanoformulation, cancer, herbal formulation.
DOI:
10.5281/zenodo.14450759

ABSTRACT

Phytosomes, advanced delivery systems that enhance the bioavailability and efficacy of plant-derived compounds, have gained significant attention in cancer therapy. This review explores the mechanisms through which phytosomes enhance anticancer activity, including improved drug solubility, enhanced cellular uptake, and sustained drug release. We discuss their ability to overcome challenges in conventional therapies, such as poor bioavailability, systemic toxicity, and drug resistance, by encapsulating bioactive phytochemicals like curcumin, quercetin, and resveratrol. Moreover, we examine their role in modulating cancer pathways, such as apoptosis induction, inhibition of angiogenesis, and suppression of metastasis. Preclinical and clinical studies highlighting the synergistic effects of phytosome-based formulations with existing chemotherapeutics are also presented. By summarizing the current advances and challenges, this review underscores the potential of phytosomes as a promising strategy to optimize cancer treatment and improve patient outcomes. Phytosomes, an innovative drug delivery system, have emerged as a promising approach to enhance the therapeutic potential of plant-derived bioactive compounds in cancer therapy. These nanoformulations significantly improve the bioavailability, stability, and targeted delivery of poorly water-soluble phytochemicals, overcoming key limitations of conventional treatments. This review comprehensively examines the mechanisms by which phytosomes contribute to anticancer efficacy, focusing on their ability to enhance cellular uptake, promote controlled drug release, and protect bioactives from metabolic degradation. Specific phytochemicals, such as curcumin, quercetin, silymarin, and resveratrol, have shown enhanced pharmacokinetic profiles and amplified anticancer effects when delivered through phytosomes.

INTRODUCTION

The word “phyto” refers to a plant while “some” describes a cell. Phytosome, an advanced form of herbal formulation with the active phytoconsituents of the plant herb extract encircled and enclosed in fat globules. The majority of the bioactive compounds of phytomedicine are water-soluble natural products

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

such as flavonoids, glycosides, and terpenoids (flavonoids are widely acknowledged as the dominant bioactive ingredient most effective in a variety of therapeutics). However, due to the presence of a water-soluble herbal extract within an interior lipophilic layer, phytosomes exhibit impressive absorption on par with the commercial dosage forms of herbal extracted preparations. The novel geometry is achieved through a patented method, which utilizes standard plant extract or its components coated with phospholipids, specifically phosphatidylcholine, creating a lactone like structure. This high concentration of the odourless and thick viscous liquid phyto-phospholipid complex (phytosome) is designed to make microcells. Phytosomes are paradoxically encapsulated micro tissues of all the active ingredients of the herbal medicine and show significant improvement in pharmacokinetic and pharmacodynamic. (Nilesh J.et al, 2010)

How phytosomes beneficial?

Phytosomes are a relatively new development in the field of herbal medicine delivery systems and have shown potential in cancer treatment. Phytosomes are made by complexing plant extracts (phytoconstituents) with phospholipids to enhance their bioavailability and effectiveness. They improve the absorption and bioavailability of herbal compounds, allowing for better therapeutic outcomes.

Here's how phytosomes might be beneficial in cancer treatment:

1. Improved Bioavailability and Absorption Many herbal compounds that show anticancer properties have poor bioavailability when taken orally. This limits their therapeutic potential. Phytosome technology encapsulates these compounds in a phospholipid complex, enhancing their absorption into cells and tissues, which may improve their efficacy against cancer.

For instance, curcumin (from turmeric) is known for its anticancer properties, but it has low absorption in the body. Phytosome-formulated curcumin (like Meriva®) has been shown to enhance absorption by up to 29 times, making it more effective.

2. Enhanced Antioxidant and Anti-inflammatory Effects Many phytosomes contain herbal compounds with strong antioxidant properties. In cancer treatment, antioxidants play a crucial role in neutralizing free radicals that can cause DNA damage and contribute to cancer development. Silymarin (from milk thistle), when formulated as a phytosome, exhibits improved antioxidant and anti-inflammatory properties. In cancer models, silymarin has demonstrated the ability to inhibit cancer cell growth and induce apoptosis (programmed cell death)

3. Targeting Cancer Cells Some studies suggest that phytosomes can help deliver herbal compounds more specifically to cancer cells. Phospholipids in phytosomes interact well with cell membranes, allowing better delivery of therapeutic compounds to cancerous tissues while potentially reducing side effects on healthy cells. For example, research on green tea polyphenols (EGCG) in phytosome form has shown improved uptake in cancer cells, enhancing its anticancer effects.

4. Reduced Drug Resistance Cancer cells often develop resistance to conventional chemotherapy drugs. Some herbal compounds delivered through phytosomes have been reported to reduce multidrug resistance (MDR) in cancer cells. Curcumin, delivered in phytosome form, has been studied for its ability to reverse MDR by inhibiting specific proteins (like P-glycoprotein) that cancer cells use to expel chemotherapy drugs, potentially increasing the efficacy of treatments.

5**. Synergistic Effects with Conventional Cancer Therapies** Phytosome formulations of herbal compounds can work synergistically with conventional chemotherapy and radiotherapy, enhancing their effectiveness and reducing

toxicity. For example, curcumin phytosomes have been studied in combination with conventional cancer drugs, showing promise in reducing side effects and enhancing the anticancer effects.(Lazzeroni M. et al, 2017)

Cancer persists as one of the world's leading causes of illness and mortality, and conventional treatment approaches, including chemotherapy, radiation, and surgery, often come with frequently have significant side effects and limited efficacy. Natural phytochemicals have showed promise in the prevention and treatment of cancer, and their investigation has been prompted by the search for safer and more effective therapeutic alternatives. Nevertheless, the low bioavailability and solubility of these bioactive substances usually prevent their clinical use, especially for hydrophilic phytoconstituents like flavonoids and polyphenols. As a result, there is a growing interest in alternative therapeutic strategies, particularly those involving natural products derived from plants. Among these, phytosomes have emerged as a promising drug delivery system that enhances the bioavailability and therapeutic efficacy of phytochemicals. (Kalita et al., n.d., pp. 2–3).

Phytosomes, a novel drug delivery system, have emerged as a promising solution to enhance the bioavailability and therapeutic efficacy of herbal extracts. This advanced formulation technology involves the Phytosomes are lipid-based nanocarriers formed by complexing phytoconstituents with phospholipids, such as phosphatidylcholine the unique structure of phytosomes not only improves the absorption of these compounds across lipid-rich biological membranes but also protects them from degradation by digestive enzymes and gut bacteria, thereby enhancing their pharmacokinetic and pharmacodynamic profiles. The ability of phytosomes to protect active compounds from degradation in the gastrointestinal tract and to promote their systemic circulation makes them particularly suitable for cancer therapy. (Choubey, n.d., p. 1,2).

Recent studies have demonstrated the potential of various phytosomal formulations in treating different types of cancer, including breast, colorectal, and liver cancers. For instance, phytosomal formulations of well-known phytochemicals such as curcumin, silybin, and luteolin have shown improved therapeutic outcomes in preclinical and clinical studies. Like phytosomal curcumin has shown significant anti-proliferative effects against breast cancer cell lines by modulating key signaling pathways Similarly, luteolin-loaded phytosomes have been reported to sensitize cancer cells to conventional chemotherapeutic agents, thereby enhancing their therapeutic efficacy. (Choubey, n.d., p.1, 2,3).

This review aims to provide a comprehensive overview of the various types of phytosomes and their applications in cancer treatment. We will explore the mechanisms by which phytosomes enhance the bioavailability of phytochemicals, discuss the therapeutic potential of specific phytosomal formulations, and highlight the challenges and future perspectives in the development of phytosomes based therapies for cancer. By elucidating the role of phytosomes in cancer treatment, we hope to contribute to the ongoing efforts to harness the power of nature in the fight against cancer. (Choubey, n.d., p. 4).

Enhanced Bioavailability and Efficacy

The enhanced bioavailability of phytosomes compared to conventional herbal extracts is attributed to several key mechanisms that facilitate the absorption and efficacy of phytoconstituents through several mechanisms:

1. Formation of Lipid-Compatible Complexes

Phospholipids, such as phosphatidylcholine, complex with phytoconstituents, like polyphenols, to form phytosomes. Lipid-compatible molecular complexes are produced by this interaction, and they easily incorporate into biological membranes

that are rich in lipids. The polar head of phospholipids and the phytoconstituents form a chemical bond that improves solubility and stability in the gastrointestinal tract, which increases absorption. (Choubey, n.d., p. 1; Kalita et al., n.d., pp. 2–3).

2. Improved Membrane Permeability

Phytosomes' unique shape allows them to pass through lipid-rich bio-membranes with more ease. More phytoconstituents can enter the systemic circulation because the phospholipid environment protects the active ingredients from being broken down by gut bacteria and digestive enzymes. (Choubey, n.d., p. 2). This is particularly important for hydrophilic compounds that typically struggle to penetrate lipid membranes.

3. Protection from Degradation

Because phytochemicals are encapsulated in phytosomes, they are shielded from deterioration caused by water. During passage through the gastrointestinal tract, this is essential for preserving the integrity and bioactivity of sensitive chemicals. (Choubey, n.d., p. 2). By preventing degradation, phytosomes ensure that a higher concentration of active ingredients is available for absorption.

4. Enhanced Solubility

Traditionally weakly soluble phytochemicals become more soluble thanks to phytosomes. The phytoconstituents' solubility profile is changed by the interaction with phospholipids, making it easier for them to dissolve in the lipid-rich gut lining environment. (Choubey, n.d., p. 3). This increased solubility directly correlates with improved absorption rates.

5. Targeted Delivery

It is possible to design phytosomes to specifically target particular tissues or cells, including cancer cells. This focused strategy increases therapeutic impact while reducing off-target consequences. Phytosomes' bioavailability at the site of action is increased by their capacity to elude the immune system and preferentially accumulate in target tissues. (Choubey, n.d., pp. 3–4).

6. Synergistic Effects with Phospholipids

When employed to prepare phytosomes, phosphatidylcholine has hepatoprotective properties in addition to acting as a carrier. The therapeutic advantages of the phytoconstituents may be increased by this synergistic action, especially in disorders impacting the liver. (Choubey, n.d., pp. 4–5). The presence of phospholipids can also improve the overall pharmacokinetic profile of the phytosomal formulation.

7. Increased Plasma Concentration

Comparing phytosomal formulations to their non-complexed counterparts, clinical research has demonstrated that the former can result in significantly higher plasma concentrations of active ingredients. For example, when olive polyphenols are given in a phytosomal form, their bioavailability has been found to be three to five times higher. (Choubey, n.d., p. 5). This increase in plasma concentration is crucial for achieving the desired therapeutic effects.

8. Facilitation of Cellular Uptake

Phytosomes improve the absorption of phytochemicals by resembling the structure of biological membranes. This resemblance enables phytosomes to merge with cell membranes more effectively, aiding in the movement of active compounds into cells. (Choubey, n.d., p. 7). The result is a more efficient delivery of therapeutic agents to target tissues.

Mechanisms of Action

Phytosomes enhance the pharmacokinetic and pharmacodynamic characteristics of herbal extracts by increasing their absorption across lipid-dense biological membranes. The establishment of chemical bonds between phospholipids and phytoconstituents leads to improved stability and solubility, which is essential for the successful delivery of these compounds to intended tissues.

(Choubey, n.d., pp. 1–2). The unique structure of phytosomes enables them to protect active ingredients from degradation by digestive enzymes and gut bacteria, thereby increasing their systemic availability. (Dave et al., n.d., p. 1; Jain et al., n.d., p. 1). The enhanced bioavailability of phytosomes is particularly beneficial in cancer therapy, where the effective concentration of therapeutic agents at the tumor site is crucial. For instance, studies have shown that phytosomal formulations of curcumin and luteolin can significantly inhibit the proliferation of various cancer cell lines, including breast and colorectal cancer cells. (Choubey, n.d., p. 4). The ability of phytosomes to target specific tissues, combined with their improved pharmacokinetic profiles, makes them a promising candidate for enhancing the efficacy of existing chemotherapeutic agents. (Choubey, n.d., p. 5,8).

The improved absorption of phytochemicals like flavonoids and terpenoids through the gastrointestinal tract results in increased plasma levels, which can greatly enhance therapeutic effectiveness. (Babazadeh et al., 2018, p. 1; Patel et al., n.d., p. 2). For instance, studies have shown that curcumin phytosomes exhibit superior bioavailability compared to free curcumin, leading to enhanced anticancer effects in various cancer models. (Gaikwad et al., 2023, p. 12). Similarly, luteolin-loaded phytosomes have been reported to sensitize breast cancer cells to doxorubicin, indicating their potential in combination therapies. The mechanisms by which phytosomes exert their anticancer effects are multifaceted. Phytosomes have been shown to enhance the pharmacokinetic profiles of their constituent phytochemicals, leading to increased plasma concentrations and prolonged therapeutic effects (Gaikwad et al., 2023, p. 1; Kalita et al., n.d., p. 4). Additionally, phytosomes can facilitate targeted delivery to cancer cells through passive targeting mechanisms, such as the enhanced permeability and retention (EPR) effect, which allows for the accumulation of nanoparticles in tumor tissues (Babazadeh et al., 2018, p. 1; Gaikwad et al., 2023, p. 2). Furthermore, phytosomes can also enhance the cytotoxic effects of conventional chemotherapeutic agents. For instance, studies have indicated that luteolin-loaded phytosomes can sensitize breast cancer cells to doxorubicin, thereby improving the overall efficacy of the treatment (Gaikwad et al., 2023, p. 10; Kalita et al., n.d., p. 4). This synergistic effect highlights the potential of phytosomes to not only serve as standalone therapies but also as adjuncts to existing cancer treatments.

Types of Phytosomes and Their Applications

The application of phytosomes in cancer treatment represents a significant advancement in the field of herbal medicine and drug delivery systems. Phytosomes, which are lipid-based nanocarriers formed by complexing phytoconstituents with phospholipids, have demonstrated enhanced bioavailability and therapeutic efficacy compared to conventional herbal extracts.

1. Curcumin Phytosomes: Curcumin, a well-known anti-inflammatory and anticancer agent, has been formulated into phytosomes to enhance its bioavailability. Clinical studies have demonstrated that curcumin phytosomes can improve the safety and efficacy of conventional chemotherapy agents like gemcitabine in pancreatic cancer. (Gaikwad et al., 2023, p. 1,12). The patented formulation Meriva™ is a notable example of curcumin phytosomes that has shown promising results in clinical settings. (Allam et al., 2015, p. 2; Gaikwad et al., 2023, p. 12).

2. Silybin Phytosomes: Silybin, derived from milk thistle, has demonstrated hepatoprotective and anticancer properties. Silybin phytosomes have been shown to enhance the bioavailability of silybin, leading to improved therapeutic effects against liver cancer (Babazadeh et al., 2018, p. 6; Tiloke et al., 2018, p. 8). The combination of

silybin with other anticancer agents in phytosomal formulations has also been explored, showing synergistic effects (Babazadeh et al., 2018, p. 6).

3. Luteolin Phytosomes: Luteolin, a flavonoid with antioxidant properties, has been encapsulated in phytosomes to enhance its anticancer activity. Research indicates that luteolin-loaded phytosomes can inhibit the growth of breast cancer cells and enhance the efficacy of doxorubicin (Gaikwad et al., 2023, p. 1). This highlights the potential of phytosomes in combination therapies, where they can improve the effectiveness of existing chemotherapeutic agents.

4. Moringa Oleifera Phytosomes: Moringa oleifera has gained attention for its antiproliferative effects against various cancer cell lines. Phytosomal formulations of Moringa extracts have shown enhanced bioavailability and therapeutic efficacy, making them a promising candidate for cancer treatment (Gaikwad et al., 2023, p. 12; Tiloke et al., 2018, p. 8).

5. Thymoquinone Phytosomes: Thymoquinone, an active compound from Nigella sativa, has shown significant anticancer potential. Phytosomal formulations of thymoquinone have been developed to improve its solubility and bioavailability, demonstrating enhanced cytotoxic effects against lung cancer cells. (Gaikwad et al., 2023, p. 11; Tiloke et al., 2018, p. 8). As research continues to evolve, phytosomes may play a crucial role in the future of cancer treatment, providing hope for improved therapeutic outcomes for patients worldwide.

Moringa

1.Improved Absorption with Encapsulation: Mopping, containing flavonoids and tannins and other polyphenols, were encapsulated in phytosomes for improved bioavailability. The lipid-compatible phytosomes enable the smooth transfer of polyphenols across the cell membranes towards the target cells.

2. Sustained drug release: MoP is the formulation for controlled and sustained release of polyphenols. In this form, an initial burst followed by a timed and gradual release of polyphenols to the cells prolongs the time necessary to maintain therapeutic levels inside the cells.

3. Antiproliferative Activity: The MoP preparation showed a great capacity for inhibiting the proliferation of the 4T1 cells, which is an in vitro model for the growth of breast cancer cells. This is due to the interference between cell growth and cell division caused by polyphenols, thus an efficient reduction in the rate and extent of spread and proliferation of cancerous cells. The IC50 values measured for MoP toward the 4T1 cells were less than the one for free polyphenols, which makes the latter more effective.

4. Low Toxicity Towards Normal Cells: MoP compound compared to conventional drugs prepared using doxorubicin is more selective because there was a higher selectivity index. This is indicated to be more toxic than on normal cells, increasing its selectivity towards malignantly transformed cells to inhibit proliferation and minimize adverse reactions against normal cells. (Jecinta W. et al, 2022)

Silymarin

• Antioxidant Activity: Silymarin scavenges free radicals and increases intracellular glutathione levels and has been shown to provide some protection against oxidative damage in cells. Though a chemical antioxidant, it appears selectively toxic to malignant cells and is effective in its ability to treat cancer(review S).

• Cell Proliferation Inhibition: It is characterized by cell cycle arrest often at the G1 phase through the modulation of proteins such as CDKs and upregulation of cell cycle inhibitors including p21 and p27. This results in lower cancer cell proliferation.

• Induces Apoptosis: The compound triggers apoptosis through the intrinsic as well as the

extrinsic pathway, especially in the p53-positive cancerous cells. There is a rise in the amount of pro-apoptotic proteins as well as its reduction by anti-apoptotic proteins; therefore more mitochondrial cytochrome c is released and caspases become activated(review S).

• Anti-inflammatory Activity: It reduces overexpressed levels of inflammation mediators COX-2 as well as NF-kB, which have been usually found to be over-expressed in cancers, this further inhibits the progression as well as survival of these cancerous cells.

• Antimetastatic Activity: Silymarin suppressed metastasis through the inhibition of proteolytic enzymes, i.e. MMP2 and MMP9 that are involved in tissue invasion and metastasis, while it inhibited the motility of the cancer cell through the signal transduction pathways like Wnt/β-catenin and PI3K/Akt.

•Anti-angiogenesis : It repressed the levels of the vascular endothelial growth factor (VEGF) for breaking the nutrient supply lines that are imperative for tumour growth so it results in less v ascularity in the tumours.(Tomas K. et al,2021)

Green tea

• Bioavailability and Tissue Penetration: The lecithin-based formulation enhances the bioavailability of EGCG, thereby facilitating its penetration into breast cancer tissue at higher concentrations compared to the normal tissue in the surrounding.

• Anti-Proliferative Action: Plasma levels of free EGCG were found to be positively correlated with a decrease in the Ki-67 marker, an indicator of reduced proliferation of cancer cells in tumor tissues.

• Tissue Selective Localization: EGCG concentration was significantly higher in tumor tissues than in the adjacent non-cancerous tissues, thus the formulation targeted selectively and localized more importantly within the cancerous cells.(Matteo L. et al, 2017)

Curcumin

• Curcumin stimulates autophagy in a dose and time-dependent manner. The curcumin stimulates the degradation of the protein kinase Akt. This is through the action of AMPK, which curcumin activates.

• PI3K/Akt Signaling Inhibition: The Akt protein is one of the proteins that mediate the PI3K/Akt signaling pathway; it is implicated in cell proliferation and survival in cancer cells. Curcumin inhibits the signaling process that would normally enhance proliferation and migration of cancer cells by degrading Akt.

• Cell Proliferation and Migration Suppression: Curcumin's action of inhibiting Akt reduces the rate of cell proliferation and inhibits cancer cell migration, hence curcumin useful for inhibition of cancer growth.

• Autophagy-mediated Selective Targeting: This type of autophagy mediates selective targeting of cancer cells, as the inhibition of autophagy or AMPK considerably reduces curcumin's anticancer activity, which further confirms the role of autophagy in curcumin's action.(Feng G. et al, 2016)

Quercetin

• The phytosomal formulation increased uptake at the cellular level; thus, cytotoxicity to MCF-7 was increased. The free drug combination had a lower IC50 value than either drug alone and hence exhibited higher potency.

• Induction of Apoptosis: QRT-PHM-SV caused marked induction of apoptosis by enhancing the levels of caspase-9 and Bax protein while suppressing the level of anti-apoptotic protein Bcl-2. It disrupted the MMP, a typical feature of apoptosis.

• Cell Cycle Arrest: The formulation caused an increase in S phase cell cycle arrest which restricts DNA synthesis and results in the prevention of multiplication of cancerous cells from further multiplying.

• Inflammatory Marker Modulation: Treatment with QRT-PHM-SV decreased NF-κB activity and increased levels of TNF-α, promoting further pro-apoptotic signaling. (Nabil A. et al, 2021)

Challenges and Limitations

Despite the promising applications of phytosomes in cancer therapy, several challenges remain. The pH sensitivity of phytosomes structures can affect their stability and bioavailability, posing a significant hurdle for industrial-scale production (Babazadeh et al., 2018, p. 8; Gaikwad et al., 2023, pp. 13–14). Additionally, the complexity of formulating phytosomes with various phytoconstituents requires careful optimization to ensure consistent quality and efficacy (Gaikwad et al., 2023, pp. 13–14).

Additionally, while the production of phytosomes is relatively straightforward, scaling up these processes for industrial applications poses challenges. The need for consistent quality and stability in large-scale production is critical, and any variations can impact the therapeutic efficacy of the final product (Gaikwad et al., 2023, pp. 13ΓÇô14).

Moreover, the regulatory landscape for phytosomal products is still evolving. As phytosomes are a relatively new technology, there is a need for comprehensive studies to establish their safety and efficacy in clinical settings (Gaikwad et al., 2023, p. 13) and in development and commercialization of phytosomes for cancer therapy. One significant hurdle is the pH sensitivity of phytosomes structures, which can affect their stability and bioavailability (Gaikwad et al., 2023, pp. 6–7). Furthermore, the large-scale production of phytosomes poses logistical challenges, as the manufacturing processes must ensure consistency and quality across batches (Gaikwad et al., 2023, p. 7,9-10).

Another concern is the limited number of clinical studies validating the efficacy and safety of phytosomal formulations in cancer patients. While preclinical studies have shown promising results, more extensive clinical trials are necessary to establish the therapeutic potential of phytosomes in diverse cancer types (Gaikwad et al., 2023, pp. 10–11). Additionally, regulatory hurdles related to the approval of novel drug delivery systems can slow down the translation of phytosomes technology from the laboratory to clinical practice (Gaikwad et al., 2023, p. 11).

Future Perspectives

Looking ahead, the future of phytosomes in cancer therapy appears promising. Ongoing research is focused on optimizing phytosomal formulations to enhance their stability, bioavailability, and therapeutic efficacy. The potential for combining phytosomes with other nanocarrier systems, such as liposomes or solid lipid nanoparticles, may further enhance their delivery capabilities and therapeutic outcomes (Babazadeh et al., 2018, p. 1,8). Advances in nanotechnology and drug delivery systems may lead to the development of more sophisticated phytosomal formulations that can deliver multiple phytoconstituents simultaneously, thereby maximizing therapeutic effects (Gaikwad et al., 2023, p. 12). Furthermore, the exploration of active targeting strategies, such as the conjugation of ligands to phytosomes, could improve the specificity of drug delivery to cancer cells, thereby minimizing off-target effects and enhancing treatment efficacy (Babazadeh et al., 2018, p. 8). Moreover, the integration of phytosomes with other therapeutic modalities, such as immunotherapy and targeted therapy, could provide synergistic effects that improve patient outcomes (Gaikwad et al., 2023, p. 13). As research continues to evolve, it is essential to address the existing challenges and explore innovative strategies to enhance the clinical applicability of phytosomes in cancer therapy.

DISCUSSION

The application of phytosomes in cancer treatment represents a significant advancement in drug

delivery systems, particularly for herbal medicines. Phytosomes, which are complexes formed by the interaction of phospholipids with phytoconstituents, enhance the bioavailability and therapeutic efficacy of various bioactive compounds. One of the primary advantages of phytosomes is their ability to enhance the bioavailability of hydrophilic phytochemicals, which are often poorly absorbed in their native forms. For instance, studies have shown that phytosomal formulations of curcumin, a well-known anticancer agent, exhibit significantly higher absorption rates compared to conventional formulations. (Gaikwad et al., 2023, p. 12; Kalita et al., n.d., p. 4). This enhanced absorption is attributed to the ability of phytosomes to cross lipid-rich biological membranes more effectively, thereby increasing the concentration of active compounds in systemic circulation. (Gaikwad et al., 2023, p. 1; Kalita et al., n.d., p. 1).

Moreover, the encapsulation of phytochemicals in phytosomes not only improves their solubility but also protects them from degradation by digestive enzymes and gut bacteria (Kalita et al., n.d., p. 2; Patel et al., n.d., p. 2). This protective mechanism is crucial for maintaining the integrity and efficacy of the active compounds, particularly in the gastrointestinal tract, where many phytochemicals are susceptible to degradation (Jain et al., n.d., p. 1; Patel et al., n.d., p. 2).

Clinical trials have corroborated these findings, demonstrating that patients receiving phytosomal formulations of silybin and curcumin experienced improved therapeutic outcomes compared to those receiving standard formulations (Kalita et al., n.d., pp. 3ΓÇô4). For example, the use of silybin phytosomes in patients with chronic liver disease resulted in faster normalization of liver function tests compared to conventional silymarin. (Jain et al., n.d., p. 4; Kalita et al., n.d., p. 3).

CONCLUSION

The processes that enhance the bioavailability of phytosomes are complex, involving better solubility, protection against degradation, and precise delivery. These elements work together to improve the pharmacokinetic and pharmacodynamic characteristics of phytosomal formulations, positioning them as a promising option for increasing the effectiveness of herbal medicines in cancer therapy and various other medical uses. As ongoing research progresses, the opportunities for utilizing phytosomes in drug delivery systems are likely to grow, paving the way for innovative treatment strategies. (Choubey, n.d., p. 7). Moreover, the integration of phytosomes with other therapeutic modalities, such as immunotherapy and targeted therapy, could provide synergistic effects that improve patient outcomes (Gaikwad et al., 2023, p. 13). As research continues to evolve, it is essential to address the existing challenges and explore innovative strategies to enhance the clinical applicability of phytosomes in cancer therapy.

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HOW TO CITE: Pratiksha Hajare, Mahesh Reddy, Vedashree Dhumekar, Yogesh Somwanshi, Enhancing Cancer Therapy with Phytosomes: A Review of Mechanisms, Int. J. of Pharm. Sci., 2024, Vol 2, Issue 12, 1889-1899. https://doi.org/10.5281/zenodo.14450759