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Overview of Cancer and Treatment Challenges: Harnessing the Anti-cancer Potential of Jasminum Sambac and its Nanoparticle Formulations

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ABSTRACT

Cancer research strives to discover effective treatment strategies that target tumour cells while minimising the negative effects of traditional chemotherapy. Studies conducted on plant-based leads have yielded promising therapeutic activities, prompting researchers to remain vigilant in exploring further plant-based studies. Research has shown that phytochemicals found in the roots, leaves, and flowers of Jasminum sambac (*J.sambac*) have demonstrated various active functions, including anti-inflammatory, antimicrobial, immunomodulatory, and anxiolytic effects. The progress made in nanoparticle drug delivery systems for cancer treatment is noteworthy as it allows for higher doses of medication to be delivered directly to cancer cells while minimising the negative impact on healthy cells. Various reports showcase the nanoparticle synthesis of *J.sambac* for screening multiple diseases. This review provides an overview of cancer and the challenges of available treatments while exploring the potential of *J.sambac* for its anticancer, cytotoxic, and antioxidant properties. Furthermore, it sheds light on the recent advances made in nanoparticle formulations of Jasminum sambac for cancer and other ailments. Disseminating these updates could encourage additional exploration into the potential anti-cancer properties of *J.sambac* and foster the development of nanoparticles for more effective cancer treatment.

KEYWORDS: Anti-cancer, Anti-oxidant, Cancer therapy, Cytotoxic, Jasminum Sambac, Nanoparticle.

INTRODUCTION

The complex and diverse nature of cancer, combined with its insidiousness and ability to evade detection until advanced stages, makes it a leading cause of death on a global scale.[1] It is alarming to know that in 2020, there were approximately 19.3 million new cancer cases globally and almost 10.0 million cancer-related deaths (excluding nonmelanoma skin cancer). Cancer cases are expected to rise by 47% from 2020 to 2040, reaching approximately 27.4 million new cases in 2040.[2] Despite the existence of numerous treatment options for cancer, the success rate of curing cancer remains low due to the significant adverse effects associated with these treatments. In addition, there is still a lack of effective drugs and treatment options to cure solid tumours, which poses a significant challenge.[3] Treatments like chemotherapy and radiation can be expensive, and some patients may find the side effects intolerable.[4] In light of this, researchers are continuously exploring alternative treatments with fewer side effects that may aid in developing more effective cancer therapies.

Medicinal plants have been the primary source of new drug molecules throughout history and hold a significant position in traditional medicine across cultures. Besides, screening natural plant resources for new cytotoxic compounds is essential, as over 60% of antineoplastic drugs have a plant origin, containing cytotoxic phytochemicals. Some reports suggest that certain plant chemicals can induce cell death or arrest the cell cycle by affecting cell-signalling pathways.[5] It is fascinating to know that various plants such as Abrus precatorius, Albizzia lebbeck, Asparagus racemosa, Euphorbia hirta, Anacardium occidentale, and Erthyrina suberosa have shown anticarcinogenic properties and encouraging results in studies conducted on fibrosarcoma in mice, ascites tumour cells, human epidermoid carcinoma, Freund virus leukaemia, hepatoma, and sarcoma respectively.[6] These findings have paved the way for further investigations into plant-based medicines, sparking hope for more effective and tolerable cancer treatments.

Among these, Jasminum sambac (*J.sambac*) stands out for its multifaceted pharmacological properties, encompassing antibacterial, anti-inflammatory, antioxidant, and, notably, anticancer attributes linked to its phytoconstituents, ranging from volatile oils to polysaccharides and flavonoids.[7] In tandem with these developments, nanomaterial-based cancer therapy has emerged as a cutting-edge approach, offering targeted drug delivery that mitigates the adverse effects associated with conventional chemotherapy. Integrating nanomedicines and synthesising nanoparticle formulations for herbal medications represent a dynamic frontier in cancer research, poised to revolutionise treatment strategies and enhance therapeutic outcomes.

This comprehensive review highlights the challenges inherent in current cancer treatment approaches while underscoring the potential of Jasminum

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sambac as a valuable player in the quest for alternative cancer therapies. The documented anti-cancer and cytotoxic properties and antioxidant effects position *J.sambac* as a promising avenue for future research and development. Exploring nanoformulations synthesised using *J.sambac* opens new possibilities for advancing cancer treatment modalities, offering hope in the ongoing battle against this formidable disease.

TUMORS AND CANCER: DRIVERS AND CHALLENGES

Challenge Of Targeting Cancer Stem Cells (Cscs) And Their Ability to Resist Treatment

Novel target-specific cancer treatments make the regression of the bulk of the tumour possible, yet these treatments cannot eradicate the cancer stem cell. There is still a considerable risk of tumour recurrence.[8] Gleevec (Imatinib), used in treating Chronic Myelogenous Leukemia (CML), blocks the binding site of the BCR-ABL fused protein, which possesses tyrosine kinase activity. The binding of Gleevec to the BCR-ABL binding site alters the growth signalling pathway in cancer cells. Gleevec prevents the transducer's signal from reaching its target protein as well. But, due to the drug's inability to target cancer stem cells, it has a limited curative potential.[9] Aldehyde dehydrogenase is a detoxifying enzyme that provides resistance to alkylating agents. In AML, CD34+ cells release aldehyde dehydrogenase.[10] CSCs are less affected by chemotherapeutic agents as they don't undergo vigorous cell division. They also display metabolic flexibility, which enables them to resist chemotherapy.[11]

The Need for Epigenetic Profiling And Improving The Specificity Of Existing Epi-Drugs

Cancer research has traditionally focused on identifying genetic anomalies, but only a few mutations have been linked to cancer.[12] Epigenetic knowledge could help understand the mechanisms behind tumour development. Methylation of tumour suppressor genes in the promoter CpG Island can cause genomic instability in cancer. DNA methyltransferase (DNMT) is responsible for CpG dinucleotide methylation and has become a therapeutic target to re-establish a regular methylation pattern in affected genes.[13] However, non-specific administration of these blockers could lead to genome-wide hypo methylation, randomly activating usually silenced genes. Cancer cells have hypo-methylated areas that activate previously silenced oncogenes. Selective epigenomic drugs targeting the hypermethylated area are necessary. Other mechanisms also dictate differential gene expression. There are observable differences in the modification patterns of histones depending on the type and stage of cancer.[14] Extensive research is essential to understand the epigenetic signature of different cancer types.

Biomarkers For Cancer Diagnosis and Prognosis

Biomarkers are vital for diagnosis and have significant predictive value. Developing specific markers can help monitor cancer progression and evaluate the effectiveness of chemotherapeutic agents in detail.[15] However, while clinical proteomics is very promising, the currently available biomarkers do not have the required specificity to enable early detection of cancer progress monitoring. Thus, further research, standardisation and validation are vital.[16]

Metastasis

The reason cancer is so hard to treat is due to its ability to spread to other parts of the body, known as metastasis. This becomes more challenging when there are multiple sites of metastasis or when micro-metastases occur, which are difficult to detect. While there are blood tests available to identify the occurrence of metastasis by detecting marker proteins released by specific types of cancer cells, most of these markers are still unidentified.[17]

CURRENT METHODS OF CANCER THERAPY AND THEIR LIMITATIONS

The most common cancer treatment methods include Chemotherapy, Radiation Therapy, Surgery, Hormone Therapy, Bone marrow Therapy, Immunotherapy and Targeted drug delivery.

Chemotherapy

Chemotherapy uses chemical agents that destroy dividing cells, including those involved in DNA synthesis. The drugs affect different phases of the cell cycle and are administered orally, intravenously, or through injection. The treatment is based on the principle that the fastest-dividing cells are most sensitive to medication. Chemotherapy terminates or slows down the rapid growth and division of tumour cells by inhibiting cell mitosis, thus minimising the pervasion of cancer and diminishing the symptoms. Chemotherapy can be used alone or in parallel with other therapies, such as radiation, hormonal therapies or even surgery.[18]

Methotrexate is a type of chemotherapy drug that is used in high concentrations to treat certain types of cancer. It works by inhibiting the dihydrofolate reductase enzyme in the uracil synthesis pathway, which can misincorporate bases and ultimately lead to cell death.[19] The drug is most effective against cells that divide rapidly, such as cancer cells, but certain tumours may resist it. As a result, methotrexate is often used in combination with other forms of therapy to increase its effectiveness.[20] Chemotherapy can adversely affect normal cells, resulting in hair loss, nausea, vomiting, diarrhoea, anaemia, loss of taste, fatigue, weakened immune systems, and an increased risk of infections. Improved understanding of cancer cell biology is necessary to address these limitations. However, chemotherapy may also cause long-term lung damage, sterility, cardiac problems, nephropathy, and recurrence of cancer. Chemotherapeutic drugs target cellular DNA or RNA to cell division, such as alkylating agents, alkaloids, antibiotics, and antimetabolites, which target purine or pyrimidine metabolic enzymes or the cytoskeleton and mitosis.[21]

Radiation Therapy

Radiotherapy is a treatment that uses high-energy waves to target and shrink cancerous cells. It damages cancer cells' genetic information and inhibits cell division, leading to cell death.[22] It is used to cure or reduce early-stage cancer, reduce the risk of recurrence, and treat symptoms resulting from advanced cancer. However, it can also damage normal healthy cells, so efforts must be made to minimise the number of damaged healthy cells.[23] The responsiveness of cancer to treatment depends on the growth patterns of cancer cells.[24] Most carcinomas respond well to this treatment. Although radiation kills both normal and cancerous cells, the main objective is to increase the dosage of radiation that reaches the aberrant cancer cells and reduce exposure to the surrounding healthy cells.[25] Healthy cells, conversely, can maintain their function and generally tend to repair themselves faster than cancer cells.[26]

Radiation therapy has two techniques - fractionation protocol and intensity-modulated radiation therapy. The fractionation protocol technique enhances the survival advantage of normal tissues over cancer cells by repairing the damage from radiation in healthy cells, which is greater than cancer cells. Intensity-modulated radiation therapy is a potential new development that allows improved shaping of radiation dose profiles around the tumour and nodal regions while sparing surrounding typical tissue structures. This technique optimises dose distribution, opening up possibilities for lowering the overall toxicity profile of radiation treatment.[27-28] However, radiation therapy has the significant disadvantage of destroying regular cell genetic materials, which may lead to leukopenia, thrombocytopenia, and aplastic anaemia.[29] The cure rate of cancers is greater if treated early

before metastasis.[30] However, some cancers show a limited response to this treatment, even with combined therapy.

Radiotherapy is often combined with surgery and chemotherapy to address the possibility of tumour recurrence and to limit radiation exposure. However, patients who have undergone radiation therapy or have specific medical conditions may not be eligible for this treatment due to the significant harm it causes to normal tissue, which can increase the risk of developing secondary cancer.[31] Malignant cancers are often difficult to detect early and have a high growth rate. Radiation therapy is ineffective for treating metastasised cancers and tumours that have not been detected.[9] Surgery is necessary to alleviate the mass effect caused by the tumour pushing on surrounding tissue. Radiotherapy is also associated with poor wound healing and may not work in areas with inadequate oxygen supply.[32]

Surgery

For a long time, surgery used to be a first-line cancer treatment in cases of solid tumours. Partial or total removal was practised.[33] Surgical removal of the tumour reduced the volume of the tumour and, in turn, reduced the mass effect.[34] Surgery is now used only for tumours that cannot be treated with radiation or chemotherapy. Cancer surgeries carry several risks, including the possibility of recurrence due to microscopic remnants of cancer cells. Surgeons may need to remove a significant portion of healthy tissue surrounding the tumour to prevent this. Recovery can be prolonged, and there may be loss of function or removal of an entire organ. Age or other health concerns may make some individuals unable to undergo surgery, and infections following surgery can lead to significant problems.[35-36]

Surgery may not always be effective in removing cancer, especially in cases of metastasis or in areas of the body where tumours cannot be safely removed.[37] There is also a risk of minimal residual disease (MRD) developing after curative surgery, which can lead to perioperative tumour growth.[38] Cancer is a systemic illness, and tumour removal affects MRD development.[37]

Hormone Therapy

Hormone therapy involves using hormones or drugs to interfere with hormone production. Surgical removal of gland-producing hormones is another option. Trophic factor blocking is also used to prevent cell death.[39]

Hormone therapy successfully kills differentiated cells but cannot reduce the number of stem cells.[40] In cases where surgery and radiation are not feasible treatment options, hormone therapy can still be beneficial. The primary objective of hormone therapy is to reduce the size of the tumour, alleviate symptoms and improve life expectancy.

Prostate and breast cancer can be treated by targeting androgens or estrogen. The removal of testes or injections of LHRH analogues with anti-androgen drugs is effective for prostate cancer. Tamoxifen is an anti-estrogen drug used for breast cancer treatment.[41]

Interferon-alpha and interleukin-2 are forms of hormonal therapy used to treat certain types of cancer. Interferon-alpha is effective against hairy cells and chronic myelogenous leukaemias, while interleukin-2 is used to combat metastatic renal cell carcinomas.[42] Both drugs promote cell growth and improve the immune response to cancer.

Cancer cells' resistance to hormone therapy is a threat, so researchers are testing intermittent use to avoid resistance. The specificity of the blocked trophic factor is also essential to prevent severe side effects and complications.[43]

Bone marrow Therapy

A bone marrow transplant is a medical procedure that involves replacing the defective bone marrow with functional new blood-forming stem cells. This method is often used in cancer treatment as it allows for larger doses of chemotherapy or radiation and provides new stem cells that can help kill cancer cells directly. Bone marrow transplants can be effective in various malignancies, including leukaemia, lymphoma, and myelodysplastic syndromes. The cells used in transplantation may come from the same body or another donor. However, bone marrow transplants can cause severe problems like infections, graft failure, and chemotherapy toxicity. Moreover, some studies show that bone marrow transplant recipients have an increased chance of developing new solid malignancies later on.[44]

Immunotherapy

Various immunological checkpoints regulate immune responses, maintain tolerance, and promote protective immunity. Co-inhibitory pathways of T cells help control the strength and duration of immune responses, which prevents autoimmunity, reduces immune-mediated tissue damage, controls inflammation resolution, and helps maintain tolerance. However, tumours use these co-inhibitory mechanisms to evade immune elimination. Recent studies have shown that cellular immunity, including T and NK cells and antibody-based methods, may have potent antitumor effects and potentially treat individuals with previously incurable cancers. Nonetheless, several challenges still need to be addressed.[45]

Targeted Drug Delivery - Impact of Nanotechnology in Cancer Therapy

Addressing the non-selective cytotoxicity associated with chemotherapeutic drugs is essential to minimise the undesirable side effects that occur during and after chemotherapy treatments. This lack of specificity can hinder the effectiveness of chemotherapy and negatively affect the control of tumour growth and metastasis.[46] Researchers have been drawn to the potential of nanotechnology in cancer treatment that offers targeted drug delivery. Nanocarrier-based drug delivery systems (NDDSs) that incorporate liposomes, micelles, and organic/inorganic nanoparticles mainly aim at targeted drug delivery, focusing on the tumour and its microenvironment.

This approach allows for higher doses of medication to be delivered directly to cancer cells while minimising damage to healthy cells, making it a promising option for cancer therapy. Adding targeting ligands to the nanocarrier's surface can further enhance the medication's effectiveness against tumour cells. Updated evidence also states nanoformulations have gained clinical approval for cancer chemotherapy.[1]

Targeted delivery on cancer cells can be accomplished through passive or active targeting. There are two main targeting strategies: passive and active targeting. Passive targeting drugs use leaky tumour vasculature to accumulate more drugs. The enhanced permeability and retention (EPR) effect allows larger macromolecules to accumulate in the tumour interstitial space. However, drug delivery through this method is problematic.

Active targeting delivers drugs to specific locations by attaching a homing molecule like a ligand or antibody. This method bypasses biological barriers and increases a drug's therapeutic index. Ligands such as proteins, peptides, vitamins, nucleic acids, and glycoproteins are commonly used for targeted drug delivery.[47-48]

Nanoformulations in cancer therapy have been attractive due to their exceptional physical and chemical properties. The unique fluorescent properties of some nanomaterials enable their use in Photodynamic therapy (PDT) and photothermal therapy (PTT), targeted delivery methods that utilise optical interference. The PDT approach involves using a photosensitiser that accumulates in the cancerous sites of the patient's body. Upon exposure to specific wavelength light, this

photosensitiser generates cytotoxic reactive oxygen materials, such as singlet oxygen, that cause apoptosis and necrosis. On the other hand, the PTT method utilises materials with a high photothermal conversion efficiency to increase the temperature of the targeted cancerous areas, thereby leading to cancer cell death.

The magnetic properties of nanoparticles have been studied for potential benefits, leading to the exploration of superparamagnetic iron oxide nanoparticles (SPION) for use in hyperthermia treatment for cancer. SPION's small size, ability to target specific areas, controlled release, and immune evasion properties.[46]

ARDUOUS RECOVERY

Cancer treatment often involves a long and challenging process that can take a toll on patients physically, emotionally, and financially. Even after treatment, the risk of cancer returning remains, which can further impact a patient's quality of life. In some cases, cancer cannot be fully cured and is instead treated as a chronic illness. To improve treatment effectiveness, shorten recovery times, reduce the risk of recurrence, and enhance patient quality of life, new therapies must be developed, or existing ones must be improved.

J.sambac - A PROMISE FOR TUMOUR AND CANCER

Jasminum sambac Linn (*J.sambac*), commonly known as Jasmine, belongs to the Oleacea family and is found to be cultivated in many Asian countries.[49] It is renowned for its fragrant flowers and is used in aromatherapy worldwide.[50] Due to its medicinal properties, the plant has been traditionally used to treat various conditions, including dermatitis, wound healing, and toothache. The flowers of *J.sambac* have also been used as a tonic to prevent breast cancer and stop uterine bleeding in folk medicine.[49] The medicinal properties of plants are usually a result of a combination of various phytochemical compounds present in the plant.[51] Studies have demonstrated that *J.sambac* possesses active components such as flavonoids, essential oils, and polysaccharides (Figure 2).[7] These components give it numerous pharmacological properties, including *antibacterial*, anti-inflammatory, antioxidant, antitumor, immune-modulating, and anxiety-reducing effects.[52] Our study focuses on exploring the potential of *J.sambac* in cancer research as an anticancer agent with cytotoxic and antioxidant properties.

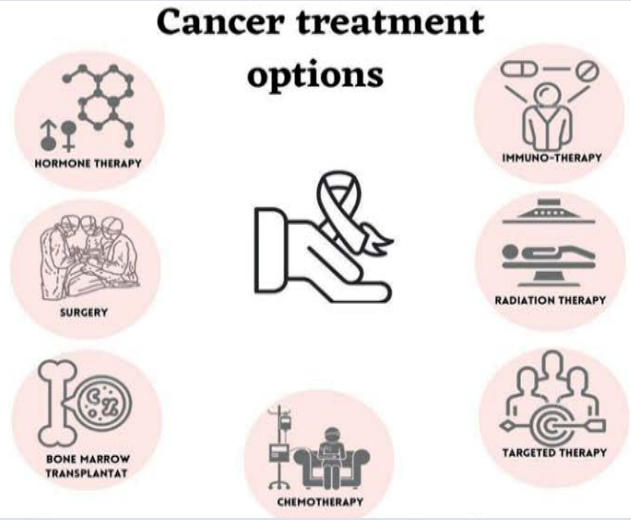

Figure 1: Different cancer treatment options, including Chemotherapy, Bone marrow transplant, Surgery, Radiation therapy, Hormone therapy, Immunotherapy and Targeted therapy

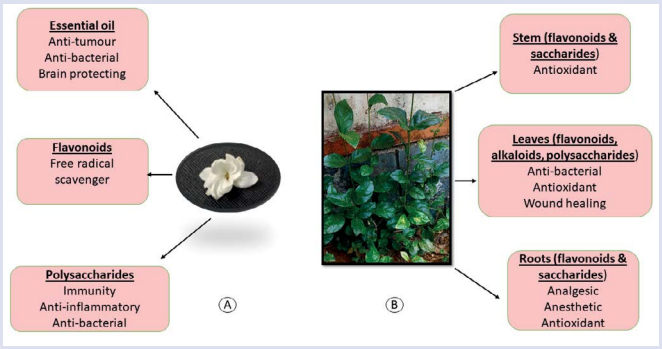

Figure 2: A. Flower of *J.sambac*. B. *J.sambac* plant. The main active components of the flower, stem, leaves and roots, along with their reported therapeutic effects.[6]

ANTI-CANCER AND CYTOTOXIC ACTIVITY

J.sambac, traditionally used for its cancer-preventive properties, has been the focus of several studies demonstrating its remarkable anti-cancer effects. Earlier research reported that *J.sambac* flowers have anti-leukemic properties and can fight against leukaemia cells such as K562, P3HR1, Raji, and U937.[53.] A Subsequent study by Taleb and his colleague evaluated the anti-proliferative activity of 16 traditionally used anti-cancer plants on MCF-7, Hep-2, and Vero cell lines, where *J.sambac* flowers showed a mild cytotoxic effect against only MCF-7 and Hep-2 cancer cell lines.[54] In contrast, encouraging results were obtained from a study that evaluated the anti-cancer effect of Jasminum sambac flowers against Dalton's ascites lymphoma-induced Swiss albino mice in both in vitro and in vivo models. MTT (3-(4, 5-dimethyl-thiazole-2-yl)-2, 5-diphenyl tetrazolium bromide) assay was used to test the methanolic extract of *J.sambac* ability to inhibit proliferation in HeLa cell lines. The flower extract showed maximum cytotoxicity against cancerous (HeLa) cells and minimum cytotoxicity towards normal (mouse embryonic fibroblast) cells. Various concentrations of extract (25-400µg/ml) were tested, and an IC_{50} was recorded as 123.3 µg/ml for normal cells and 93.8 µg/ml for cancerous cells. Significant alterations in haematological parameters of tumour-bearing mice were observed using the in vivo method. The animal group treated with *J.sambac* (100 mg/kg) for 14 days proved its protective action on the hemopoietic system, reverting altered parameters to near normal. To add on, cancer biomarker enzymes like β-D-Glucuronidase, 5'Nucleotidase and γ-Glutamyl transferase were reduced ($p< 0.05$) in the animal group that received a methanolic extract of *J.sambac*.[55]

The same group of researchers investigated the anticancer potential of an ethanolic extract of Jasminum sambac flower (100 mg/kg) against Dalton's lymphoma ascites-induced lymphatic carcinoma. Anticancer potential against lymphoma was investigated using membrane-bound marker enzymes, biochemical data, and lipid profiles. In mice, induced tumours significantly lowered cholesterol, triglycerides, VLDL and LDL cholesterol levels. In contrast, HDL cholesterol was increased. The levels were brought to nearly normal by the administration of J. sambac. Moreover, plant extract treatment normalised and increased ATPase levels in Dalton's lymphoma ascites-induced mice. Also, ethanol extract treatment reduced DNA damage caused by lymphoma and normalised LDH-4 and LDH-5 levels in cancer-bearing animals. The antiproliferative effect of Jasminum sambac ethanol extract against Hep-2, MCF-7, and Vero cell lines was assessed in vitro. The extract showed significant antiproliferative activity against one or more cell lines.[49]

Following, another research group analysed the cytotoxicity of ethanolic extract of *J.sambac* using brine shrimp lethality bioassay. Leaf extracts were tested at 20-120µg/ml concentrations. The results

indicated mortality against brine shrimp nauplii in a dose-dependent manner with an IC_{50} 50µg/ml and IC_{90} 100µg/ml, suggesting potent cytotoxicity against brine shrimp Artemia salina.[56]

Later, R. Akter et al., on exploring cytotoxicity among Bangladeshi medicinal plants, found that leaf extracts of *J. sambac* exhibited significant selective cytotoxicity against (estrogen-dependent breast cancer cells) MCF-7 cell lines with an IC_{50} (0.007 mg/mL), which was nine times more than the cytotoxicity produced by cycloheximide (IC_{50} 0.061 mg/mL), thereby correlating with its traditional use to cure breast cancer. In addition, cytotoxicity screening of *J.sambac* leaf against gastric cancer cell (AGS) with (IC_{50} 1.25 mg/mL) was reported for the first time in this study.[57]

To assess the cytotoxicity of *J.sambac* essential oil (JEO), an anti-proliferative study was conducted by Lakshmi et al. in MCF-7 and MDA-MB-231 cells. The study attempted to evaluate the bio-active components of *J.sambac* essential oil against human breast cancer. The effectiveness of JEO in fighting cancer was tested on two different types of breast cancer cells - oestrogen-positive MCF-7 and oestrogen-negative MDA-MB-231. The results showed that the drug had varying sensitivity levels for each cell line. After 24 hours of treatment, the IC_{50} values (a measure of drug effectiveness) for MCF-7 and MDA-MB-231 were 326.26µg/ml and 158.39µg/ml, respectively. These findings indicate that compared to the control, the drug was more effective in reducing the growth of the MDA-MB-231 cells. To confirm the in vivo anticancer efficacy, the DMBA-induced breast cancer protocol was used simultaneously. After 45 days of treatment with 100mg/kg and 200mg/kg jasmine extracts in DMBA-induced breast cancer-bearing rats, significant anti-tumour properties were observed. A distinct reduction in tumour volume was recorded, with 46.96% and 54.61% for the 100mg/kg and 200mg/kg extracts, respectively, whereas the rats received the standard drug vincristine (5mg/kg) showed 75.77%. However, the group of animals treated with JEO (10mL/kg) displayed a tumour reduction of 60.94% and sustained healthy growth in the animals. These positive results indicate that the flower extract of *J.sambac* and JEO may have considerable tumour-controlling properties.[58]

As part of an effort to identify new compounds that can be used to develop novel medications and therapeutic candidates, the chemical composition of *J.sambac* roots grown in Fujian Province was investigated. The roots of *J.sambac* yielded nine compounds, among which compounds (4-9) were isolated for the first time and some of which demonstrated significant cytotoxicity against MCF-7 cell lines. Out of all the compounds tested, compounds 3 and 4 showed remarkable cytotoxic effects against MCF-7 cell lines. The IC_{50} values for these compounds were 161.1 µM and 243.7 µM for 48 hours, respectively. [59]

ANTIOXIDANT EFFECT

Enzymes that act as free radical scavengers have been found to reduce oxidation damage in animals with cancer. Assays performed in DMBA-induced breast cancer rats indicated a decrease in enzymes like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase(GPx). Animal groups treated with *J.sambac* extracts (100 & 200 mg/kg) and jasmine essential oil (10mL/kg) were found to improve the values of said enzymes significantly and shows that jasmine extracts have a positive impact on helping treated animals overcome the difficulties of cancer. [58]

In the same period, Selfiani et al. conducted an experiment that demonstrated the antioxidant activity of ethanolic extract of *J.sambac* leaves through DPPH assay with IC_{50} (56.05 mg/ml), which was attributed to the presence of secondary metabolites like alkaloids, flavonoids and saponins.[60]

Balkrishna et al. reviewed the antimicrobial and antioxidant potential of Jasminum Species. They revealed that 80% of the methanolic leaves extract of *J.sambac* (Arabian nights) possessed DPPH radical scavenging activity with an IC_{50} of 130.7µg/mL, which may be correlated to its flavonoid content of 39.2 µgQE/mg and phenolic content of 47.3 µg GAE/mg.[61]

As powerful antioxidant sources, Nurul Fatin et al. looked into novel anti-oxidative components from the twigs and leaves of Jasminum sambac. Isoamyl nitrite and benzophenone were identified as the antioxidative components extracted from the DCM extract of *J. sambac* twig; benzophenone was also present in the DCM extract of *J. sambac* leaves. As a result, *J. sambac* is a promising source of bioactive chemicals with strong antioxidant qualities that can be used as a foundation point for treating medical conditions. The DPPH assay was used to measure the crude extract's antioxidant capacity. Compared to ascorbic acid, the standard with the maximum scavenging action with an IC_{50} of 2.90 ppm, dichloromethane (DCM) extract from twigs and leaves scavenged DPPH radicals with an IC_{50} of 6.24 ppm and 5.22ppm respectively.[50]

A Malaysian study by K M Khidzr et al. proved that the anti-oxidant activity of extracts from *J.sambac* grown in Malaysian settings is worthy of attention. Methanol extracts from *J.sambac* flowers showed DPPH free radical scavenging activities with IC_{50} 208 µg/ml.[62]

Another attempt to test the hydroalcoholic extract of Jasminum sambac leaves for its antioxidant potential was performed using a DPPH assay and the scavenging of hydrogen peroxide and nitric oxide. In comparison to ascorbic acid, Jasminum sambac showed a moderate scavenging effect on DPPH radicals [122 µg/ml], hydrogen peroxide [125µg/ml] and nitric oxide [173.94 µg/ml]. The study evaluated the extract's total antioxidant capacity as 155.40 µg/ml due to its phytochemical constituents like alkaloids, flavonoids, and glycosides.[63]

An earlier study evaluated the antioxidant activity of *J.sambac*'s essential oil and methanol extract and obtained significant results. The IC_{50} values of the essential oil and methanol extract in the DPPH test were 7.43 and 2.30 µg/ml, respectively. The RAA values of the essential oil and methanol extract were 96.6% and 93.9%, respectively, in the β-carotene-linoleic acid system. [64]

NANOPARTICLE FORMULATIONS OF *J.sambac*

Using biological synthesis to create nano-formulations of plants with anti-cancer potential could significantly reduce chemotherapy-induced adverse effects in cancer patients. Green synthesis of nanoparticles using natural plant extracts offers several benefits, such as avoiding chemicals that may cause toxicity and optimising the nanoparticles' biological activity. It's worth exploring the research that has evaluated the effectiveness of *J.sambac* in nanoparticle formulations for treating cancer and other illnesses, as it highlights the potential of using nanotechnology to achieve safer and more robust results.

In 2019, EL Hawary evaluated the ethanolic leaf extracts of two cultivars of Jasminum sambac L. (Ait), namely Arabian Nights (JSA). The goal was to use the extracts as reducing agents for the green synthesis of AgNPs and assess their cytotoxicity against MCF-7 breast cancer and 5637 bladder cancer cell lines. Chemical profiling showed that JSA is an excellent source for synthesising AgNPs with optimal characteristics. The enhanced activities selective to MCF-7 and 5637 cell lines could be attributed to the secoiridoids. Notably, they had low toxicity to healthy cells, making them safe to use as a cytotoxic agent.[65]

It was succeeded by the biosynthesis of silver nanoparticles (AgNPs) using leaves of Iraqi Jasminum sambac (L.) Aiton by A K Bidan and Z S Abdullah Al Ali has shown significant bioreduction and capping properties. The biogenic nano-formulation of Jasminum sambac-

AgNPs is considered a safe and economical option with antibacterial and anticancer therapeutic applications. AgNPs exhibit antibacterial properties against gram-positive (Staphylococcus aureus) and gram-negative (Escherichia coli) bacteria. The MTT assay shows cytotoxicity (IC_{50} at 222.6µg/mL) against the breast cancer MCF-7 cell line. AgNPs also have genotoxicity, which results in fractured DNA of MCF-7 by comet assay, emphasising apoptotic cells in the cell cycle flow cytometry-based analysis.[66]

Research by Babu Viashnavi shows the antimicrobial properties of silver nanoparticles synthesised with *J.sambac* leaf extract using low-cost, eco-friendly, plant-assisted synthesis. The antibacterial effect of the synthesised silver nanoparticles was evaluated against eight clinically significant Gram-positive and Gram-negative bacterial pathogens and four fungal pathogens, and the nanoparticles showed promising antimicrobial activity against all tested pathogens. The study also concluded that silver nanoparticles exhibit a higher activity than leaf extract. According to the research, a concentration of 60µl of the silver nanoparticles displayed the highest bactericidal activity and fungicidal activity.[67]

An earlier study reported the synthesis of Au, Ag, and Au-Ag alloy nanoparticles (NPs) using corresponding metal precursors and extract from Jasminum sambac leaves as capping and reducing media under microwave irradiation. This green chemical strategy was utilised to test the invitro anti-microbial activity against four different pathogens. When combined with antimicrobial agents, the nanoparticles of *J.sambac* demonstrated increased antimicrobial activity (1-4 times increase in the zone of inhibition) against test strains. Therefore, the photosynthesised NPs may be potent growth inhibitors against various microbes.[68]

In 2023, Manish Khandelwal conducted research in India on the effectiveness of Copper oxide nanoparticles using a biogenic synthesis process involving Jasminum sambac flower extract as a capping and stabilising agent. The successful synthesis process provided appropriate particle shape, size, and morphology. The study found that different copper salt precursors significantly influenced the nanoparticles' structural, optical, and morphological behaviours. The CuO nanoparticles were found to have remarkable antibacterial activity against both Gram-negative and Gram-positive bacterial strains. The antibacterial activity of the nanoparticles was attributed to the presence of phytochemicals found in *J. sambac* flower extracts, such as flavonoids, steroids, phenolics, cardiac glycosides, coumarins, and saponins. The research concluded that a sustainable nanoparticle protocol was successfully developed using Jasminum sambac flowers.[69]

CONCLUSION

Our research aims to investigate the potential of Jasminum sambac as a herbal source with both anticancer and antioxidant properties. We also focus on nanoparticle formulation studied using *J.sambac* as a treatment against cancer and other illnesses while highlighting the challenges present in current cancer therapies. The study would promote the development of nanoparticles using different parts and active components of *J.sambac* that have been reported to have anti-cancer effects and their evaluation through various in vivo and in vitro studies. However, further research on the mechanism of *J.sambac's* anticancer activity and the development of more advanced tumour-targeted nanomedicine formulations is crucial to broadening our understanding of this topic.

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CONFLICTS OF INTEREST

None.

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