

## **Role of Artificial Intelligence in Herbal Nano formulation: A Comprehensive Review**

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**ABSTRACT**

We explore the role of machine learning algorithms in optimizing the formulation of herbal products and in the discovery of bioactive compounds. These advanced computational techniques have potential to refine the design process, making it more efficient and targeted. This review delves into the various regulatory and ethical considerations that arise from the incorporation of AI technologies in the field of Nano herbal medicine, underscoring the importance of addressing these issues to ensure safe and effective practices.

**KEYWORDS** – Artificial Intelligence, Extraction, Herbal formulation, Nano technology, Drug Delivery System.

**INTRODUCTION**

Herbal medicine has played a crucial role in traditional healthcare systems for centuries, as numerous plants possess significant therapeutic benefits. Nonetheless, the effectiveness and safety of these herbal remedies may be compromised by issues such as inadequate bioavailability, inconsistent composition, and a limited comprehension of their pharmacological actions. The emergence of nanotechnology has facilitated the creation of innovative herbal formulations that enhance bioavailability and therapeutic efficacy. (1) AI has established itself as an essential technology within nano herbal medicine, supporting the analysis of vast datasets, the anticipation of bioactivity, and the optimization of formulation development.(2)

**ARTIFICIAL INTELLIGENCE IN MEDICINE;**

Artificial Intelligence, is defined as the combination of scientific research and engineering efforts focused on the creation of intelligent machines. By employing algorithms or a series of established rules, these machines are designed to emulate human cognitive functions, particularly in areas such as learning and problem-solving.(3) Artificial intelligence (AI) systems has the capacity to anticipate possible challenges or handle difficulties as they arise, enabling them to function with intention, intelligence, and adaptability.(4) Artificial intelligence's strength rests in its ability to examine large, multidimensional, and multimodal information and find patterns and connections within them. Artificial intelligence (AI) algorithms, for example, may distill a patient's whole medical history into a single number that represents a likely diagnosis.(5,6) Furthermore, AI systems are dynamic and autonomous, which enables them to keep learning and developing as new data is added.(7)

It is important to remember that artificial intelligence (AI) is a broad term that includes several subfields, such as machine learning and deep learning, rather than being viewed as a

single, all-encompassing technology. Whether applied separately or in combination, these subfields advance intelligence in a variety of contexts. In particular, machine learning (ML) focuses on creating algorithms that let computer systems improve on their own through experience learning.(8) Certain ingredients in herbal medicines are broken down considerably in the stomach's very acidic environment, while other ingredients are processed by the liver. As a result, the body may not absorb certain herbal medications to the appropriate degree. The medication cannot provide therapeutic benefits if it does not reach the affected region at the "minimum effective level." By avoiding obstacles like stomach acidity and liver metabolism, the use of nanocarriers in herbal remedies not only enables the transport of the ideal dosage to the intended location but also lengthens the drug's half-life in the bloodstream because of their small size. (9)

### **ARTIFICIAL INTELLIGENCE IN NANO HERBAL EXTRACTION**

Artificial intelligence algorithms, particularly those in the realms of machine learning and deep learning, have been utilized in the field of Nano herbal extraction to enhance extraction parameters such as temperature, pressure, solvent composition, and duration of extraction. These algorithms possess the capability to process extensive datasets and discern patterns that facilitate the prediction of ideal extraction conditions tailored to specific herbal extracts, which employed a machine learning algorithm to refine the extraction conditions for ginsenosides derived from ginseng, achieving a 25% improvement in extraction yield. (10).

### **SOLVENTS USED IN NANO HERBAL EXTRACTION**

In the process of Nano herbal extraction, various solvents, including water, ethanol, methanol, and acetone, are utilized. The kind of herb, the desired bioactive components, and the extraction procedure's specifications all influence the choice of solvent showed that, in comparison to conventional solvent extraction procedures, using a Nano-emulsion solvent system for the extraction of polyphenols from green tea resulted in a 30% increase in yield. (11)

### **BEST EXTRACTION SOLVENTS AND METHODS**

The selection of an extraction solvent plays a pivotal role in Nano-herbal medicine, significantly influencing both the yield and bioactivity of the compounds obtained. Research has identified several solvents that are particularly effective for the extraction of herbal constituents.

**ETHANOL:** The extraction of herbal compounds, including flavonoids, alkaloids, and terpenoids, frequently employs ethanol as a solvent due to its effectiveness (12)

**METHANOL:** Methanol serves as a widely utilized solvent in the extraction of herbal constituents, especially in the isolation of phenolic compounds.(13)

**WATER:** Water is recognized as an environmentally sustainable solvent that has been

effectively used for the extraction of herbal constituents, particularly polysaccharides and glycosides. (14)

**ACETONE:** The use of acetone, a polar solvent, is prevalent in the extraction of herbal compounds, specifically in isolating flavonoids and phenolic acids. (15)

**DICHLOROMETHANE:** Dichloromethane serves as a non-polar solvent and is commonly employed in the extraction of various herbal constituents, such as terpenoids and alkaloids. (16)

## **BEST EXTRACTION METHODS FOR NANO-HERBAL EXTRACTS**

Achieving successful extraction of Nano-herbal extracts demands the use of specialized techniques designed to safeguard the delicate chemical profiles and Nano structural attributes of the plant material the most effective methods encompass:

### **SUPERCritical FLUID EXTRACTION (SFE)**

Supercritical fluid extraction (SFE) employs supercritical fluids, such as carbon dioxide, to selectively isolate specific compounds while preserving their structural integrity at the nanoscale level. With a co-solvent pump flow rate of 50 milliliters per minute, the process runs at a maximum extraction pressure of 300 bar and an extraction temperature of 600 degrees Celsius. This method has been successfully used to the extraction of bioactive ingredients from a variety of plants, such as *Panax ginseng* and *Ginkgo biloba*. (17)

### **MICROWAVE-ASSISTED EXTRACTION (MAE)**

Microwave-Assisted Extraction (MAE) utilizes the advantageous heating and mass transfer characteristics of microwaves to expedite the extraction process and improve the yield of nano-herbal extracts. This technique is especially proficient in extracting polar compounds and can markedly decrease the duration of the extraction process. The method operates within a broad thermal range of 100-150°C. It has been successfully employed to extract bioactive compounds from various herbs, including *Curcuma longa* and *Zingiber officinale* (18)

### **ULTRASOUND-ASSISTED EXTRACTION (UAE)**

By using high-frequency sound waves to disrupt plant cell walls, ultrasound-assisted extraction encourages the release of bioactive chemicals. Nano-scale extracts produced with this method are of higher quality. It is renowned for being effective, requiring less solvent, and producing higher extraction yields. In sonochemistry, the usual frequency range used is 20 kHz to 1000 kHz, with an expanded range up to 3000 kHz. Experiments have shown that this technique is useful for obtaining bioactive ingredients from plants such as *Thymus vulgaris* and *Rosmarinus officinalis*. (19)

## **NANOTECHNOLOGY-BASED DRUG DELIVERY SYSTEM FOR PHYTOCHEMICAL COMPOUNDS**

Research findings suggest that a significant 70% of the bioactive constituents extracted from plants are characterized as hydrophobic (20). The application of novel technologies has emerged as a strategic approach to enhance the bioavailability and bioactivity of phytochemical compounds. To advance the development of innovative nanotechnology-based therapies, it is crucial to create appropriate formulations for drug delivery. Effective delivery of phytochemicals is vital for the prevention and treatment of diseases. Among the various delivery systems, lipid-based and polymer-based systems show significant promise in augmenting the bioactivity of these phytochemical compounds. (21, 22) Advanced drug delivery mechanisms founded on nanotechnology have been established to facilitate the effective delivery of herbal pharmaceuticals (23)

### **TYPE OF DRUG DELIVERY SYSTEM;**

- 1) Lipid based delivery system
- 2) Polymeric Nano carriers

### **LIPID BASED DELIVERY SYSTEM;**

- 1) Vesicular system;
  - Liposome
  - Phytosomes
  - Transfersome
  - Ethosome
  - Neosome
- 2) Lipid particulate
  - Solid-lipid nanoparticle
  - Nano structural lipid carrier (NLC)
- 3) Nano emulsion

### **POLYMERIC NANO CARRIERS;**

- Polymeric nanoparticle
- Dendzimer
- Polymersome
- Miscelles(24,25)

## **AI HERBAL NANO FORMULATIONS;**

### **1. NANOPARTICLES:**

Nanoparticles utilized in Nano formulation are minuscule entities, generally measuring between 1 and 100 nanometers that play a crucial role in the creation of sophisticated pharmaceutical formulations. Their diminutive dimensions facilitate enhanced drug delivery, increased bioavailability, and improved therapeutic effectiveness. The small scale of these particles enables superior penetration into tissues and cells, targeted delivery to designated areas within the body, and the controlled release of active compounds. Herbal nanoparticles have been synthesized from a variety of herbal extracts, such as turmeric, ginger, and cinnamon. These formulations have demonstrated enhanced bioavailability and diminished toxicity in comparison to traditional herbal extracts. (26)

### **2. LIPOSOMES:**

When used in Nano formulation, liposomes are spherical vesicles composed of one or more phospholipid bilayers that have the ability to encapsulate hydrophilic or hydrophobic medications. The size of these structures can vary from several micrometers to 50 nanometers. Liposomes are recognized for their high levels of biocompatibility and biodegradability. Within the context of Nano formulation, they serve to improve the pharmacokinetic and pharmacodynamic properties of drugs, leading to enhanced stability, reduced toxicity, and controlled release capabilities. Moreover, liposomes can assist in the targeted delivery of pharmaceuticals to specific tissues or cells, thereby increasing therapeutic efficacy while minimizing side effects. They have also been utilized to encapsulate herbal extracts such as resveratrol and curcumin, which enhances their solubility and bioavailability. (27).

### **3. NANOEMULSIONS:**

A notable development in Nano formulation is represented by Nano emulsions, which are fine water-in-oil or oil-in-water dispersions with droplet sizes generally between 20 and 200 nanometers. The purpose of these formulations is to improve the bioavailability and medication delivery. Their capacity to offer regulated and prolonged release, shield active components from deterioration, and enhance the solubility of hydrophobic medications are all facilitated by their thermodynamic stability. Because of their tiny size, the droplets are especially useful for intravenous, topical, and oral delivery because they improve absorption and penetration into biological tissues. Furthermore, essential oils targeted at topical applications, such eucalyptus and tea tree, have been used in the production of herbal Nano emulsions. (28)

**ADVANTAGES OF AI NANO-HERBAL FORMULATIONS:**

Nano-herbal formulations offer numerous benefits compared to conventional herbal medicines. These advantages encompass various aspects of efficacy and delivery

1. **IMPROVED SOLUBILITY AND BIOAVAILABILITY:** Studies reveal that the solubility and bioavailability of herbal extracts may be markedly increased by Nano-formulations, leading to increased medicinal efficacy and decreased potential toxicity. (29)
2. **TARGETED DELIVERY:** The precision targeting of certain anatomical areas made possible by the creation of nano-herbal formulations maximizes the treatment's overall efficacy while helping to minimize the likelihood of adverse effects. (30).
3. **IMPROVED STABILITY:** By significantly lowering the rates of oxidation and degradation, nano- herbal formulations help to increase the durability of herbal medications. These herbal medications with Nano capsules might also lessen the likelihood of toxicity and unfavorable side effects that are frequently associated with traditional herbal goods. (31).
4. **IMPROVED EFFICACY:** Artificial intelligence (AI) has the ability to continually monitor clinical trial data, which helps with real-time efficacy validation and the early identification of safety risks. Furthermore, AI may greatly enhance the design and formulation of nano herbal medicines, resulting in increased effectiveness and less toxicity. Additionally, the use of AI to automate a variety of operations related to the creation and manufacturing of these formulations can improve productivity and lower total expenses. (32)
5. **ENHANCED SAFETY:** The use of artificial intelligence simulations and predictive modeling approaches can improve safety precautions by identifying potential adverse effects of nano-formulations before they are clinically evaluated. ( 33). Artificial intelligence (AI) has the ability to reduce the likelihood of adverse responses by identifying possible safety concerns related to nano herbal medicine compositions. (34).
6. **PERSONALIZED THERAPIES:** A substantial possibility to enhance individualized treatment techniques is provided by the integration of artificial intelligence with nano herbal medicine. Artificial Intelligence (AI) can help customize nano herbal medicines to meet the specific needs of each patient by evaluating large amounts of patient data, including genetic data, medical histories, and lifestyle variables. With this tailored approach, side effects are minimized and therapeutic advantages are optimized while also facilitating the administration of the safest and most effective therapies possible.

Additionally, artificial intelligence can help with the creation of customized nanoherbal medications that are tailored to the unique needs and traits of each patient. (35).

## 7. **PREDICTIVE ANALYTICS**

On the basis of past data, treatment reactions may be predicted thanks to AI's sophisticated predictive analytics capabilities. AI has the potential to give practitioners important insights on the likely responses of nanoherbal therapy by examining patterns from previous clinical studies and patient outcomes. This predictive component eventually contributes to improved patient care by helping to make better informed decisions. (36)

## 8. **INTEGRATION OF TRADITIONAL KNOWLEDGE AND MODERN SCIENCE**

Artificial intelligence in nano herbal medicine is a great advantage since it makes it easier to bridge the gap between traditional herbal remedies and contemporary scientific research. Artificial Intelligence has the potential to identify potent herbal combinations and bolster their scientific validation by analyzing vast datasets sourced from traditional medicine. This confluence helps to maintain the diversity of cultural legacy while also making herbal remedies more widely accepted in modern medicine. (37)

## 9. **IMPROVED FORMULATION AND DELIVERY SYSTEMS**

The utilization of nanotechnology markedly improves the solubility, stability, and bioavailability of herbal compounds. Furthermore, artificial intelligence can enhance these nanoformulations by predicting their performance in biological contexts, simulating interactions, and identifying optimal delivery methods. This has significant importance in the advancement of tailored treatments that seek to minimize adverse reactions while optimizing therapeutic benefits. (38)

## 10. **DRUG DISCOVERY AND DEVELOPMENT**

Artificial intelligence (AI) algorithms can process and analyze the chemical structures, biological activities, and pharmacological characteristics of herbal substances more quickly and efficiently than traditional methods. For example, machine learning models can accurately predict the activity of Nano formulated herbal compounds by analyzing their molecular signatures, which leads to a substantial reduction in the time and costs associated with drug discovery. This technique not only identifies viable candidates for further development but also streamlines the overall testing process. (39)

## **AI NANO HERBAL VACCINES;**

Artificial intelligence algorithms are more efficient than traditional methods in processing and analyzing the chemical structures, biological activities, and pharmacological properties of herbal substances. For example, by analyzing the chemical fingerprints of Nano formulated



herbal substances, machine learning models can predict their efficacy, significantly reducing the time and cost associated with medication discovery. This method streamlines the testing processes and makes it easier to identify candidates for further development.

### **MECHANISMS OF ACTION:**

The operational mechanisms of nano herbal vaccines are complex and encompass the activation of various immune cells, including dendritic cells and T cells, alongside the promotion of immune responses, which include both humoral and cellular immunity. The nanoparticles incorporated in these vaccines can be engineered to specifically target immune cells, particularly dendritic cells, facilitating the delivery of herbal extracts to the intended site of action. Subsequently, these herbal extracts can provoke immune responses, leading to the generation of antibodies and cytokines, thereby amplifying the activation of immune cells.

### **BENEFITS OF NANO HERBAL VACCINES:**

The application of nano herbal vaccines presents numerous advantages, such as.:

- 1) **IMPROVED EFFICACY:** Research indicates that nano herbal vaccines are capable of generating more robust immune responses and offering enhanced protection against infectious diseases when compared to conventional vaccine formulations
- 2) **ENHANCED SAFETY:** According to studies, nano herbal vaccines can boost immune responses and offer better protection against infectious diseases than conventional vaccination formulations.
- 3) **TARGETED DELIVERY:** The focused transport of herbal extracts to the action site is made possible by the smart formulation of nanoparticles to target certain immune cells. This can enhance the effectiveness of vaccinations and minimize their negative effects.
- 4) **STABILITY AND SHELF LIFE:** Nano herbal vaccines can be formulated to exhibit greater stability and an extended shelf life, which makes them ideal for application in areas with scarce resources. Given that they can be made to have longer shelf lives and better stability, nano herbal vaccines are perfect for use in resource-poor places. (40)

### **EXAMPLES OF NANO HERBAL VACCINES:**

A variety of studies have examined the potential of nano herbal vaccines for the treatment of different infectious diseases, including:

**INFLUENZA:** A study that was published in the Journal of Controlled Release has verified the efficacy of a liposomal formulation of a nano herbal vaccine that is intended to fight influenza and contains the herbal extract *Echinacea purpurea*. (41)

**HEPATITIS B:** Scientists have created a polymeric nanoparticle system that contains the herbal extract *Glycyrrhiza glabra* in order to create a nano herbal vaccination for hepatitis B. (42)

**MALARIA:** An efficient malaria-fighting nanoherbal vaccine that uses a liposomal formulation enhanced with the herbal extract *Artemisia annua* has been demonstrated by research published in the Journal of Nano medicine. (43)

## **APPLICATION OF AI NANO HERBAL MEDICINE;**

### **1. ENHANCED DATA ANALYSIS AND DRUG DISCOVERY**

Artificial intelligence algorithms are able to examine large datasets from clinical trials, chemical archives, and patient medical histories in order to identify potential herbal remedies for specific conditions. By employing machine learning methodologies, these algorithms can forecast the molecular interactions of these compounds, thereby facilitating the more efficient discovery of innovative nano herbal formulations. (44)

### **2. OPTIMIZING NANOPARTICLE DESIGN AND SYNTHESIS**

Artificial intelligence plays a significant role in the design and synthesis of nanoparticles. Through the application of machine learning algorithms, researchers are able to elucidate the structure-activity relationships of different nano-carriers, thereby optimizing their characteristics, including dimensions, surface charge, and stability, to enhance the effective delivery of targeted herbal compounds.(45)

### **3. PERSONALIZED MEDICINE APPROACH**

Customized herbal remedies may be developed more easily by using artificial intelligence to analyze patient data, including genetic composition, metabolic traits, and past treatment outcomes. This customized approach may increase therapeutic efficacy while lowering unfavorable side effects, which would eventually boost patient adherence and satisfaction. (46).

### **4. REAL-TIME MONITORING AND PREDICTIVE ANALYTICS**

Wearable technologies and smartphone applications may be used to track in real time how patients are responding to nanoherbal therapy thanks to artificial intelligence. AI systems can foresee results and suggest changes to treatment procedures by analyzing this data and producing recommendations. This allows for the development of adaptive therapeutic techniques. (47)

### **5. REGULATORY COMPLIANCE AND SAFETY ASSESSMENT**

Artificial intelligence have the capability to enhance the regulatory processes linked to nano botanical items by automating data analysis about safety and efficacy assessments. A thorough evaluation of clinical trial data may be accomplished by utilizing AI-driven approaches, which not only expedites the approval process but also strengthens the safety profiles of herbal pharmaceuticals (48).

## **6. ENHANCED BIOAVAILABILITY OF HERBAL COMPOUNDS**

When encapsulated into nanoparticles, artificial intelligence can help identify formulations that enhance the bioavailability of herbal constituents. By applying techniques like deep learning, scientists can predict how changes in the composition of nanoparticles would affect their solubility and absorption, which will help in the creation of more effective delivery systems (49).

## **7. VIRTUAL SCREENING OF HERBAL COMPOUNDS**

Artificial Intelligence (AI) technology makes it possible to virtually examine large libraries of natural substances and find possible candidates for specific uses. This technique helps identify the most promising herbal compounds for further research and expedites the in vitro testing process greatly (50).

## **8. RECOGNITION OF HERBAL DRUG INTERACTIONS**

Artificial intelligence (AI) systems have the ability to examine patient data and detect possible interactions between conventional medications and herbal supplements. By enabling healthcare professionals to make well-informed decisions on treatment combinations, this analytical capacity helps to improve patient safety (51).

## **9. ACCELERATING CLINICAL TRIALS**

Applying predictive analytics to clinical trials, which may efficiently identify suitable patient groups, set objectives, and model possible outcomes, can benefit from artificial intelligence. This development not only gets nano herbal medicines onto the market more quickly, but it also makes clinical research procedures more efficient overall. (52).

## **10. METABOLOMIC PROFILING**

By making it easier to analyze biological samples from patients who have received treatment with nano herbal formulations, artificial intelligence can be a major asset to metabolomics studies. Researchers can uncover metabolic alterations and find biomarkers that indicate the efficacy of treatments by employing machine learning techniques. (53)

## **11. COMMUNITY DATA MOBILIZATION AND CROWDSOURCING**

Artificial intelligence has the potential to facilitate the efficient gathering and examination of empirical data by encouraging patient participation in data-sharing programs. Crowd sourced information about the efficacy and negative effects of herbal remedies can provide valuable insights into usage trends and improve comprehension of treatment results. (54)

## **12. ENVIRONMENTAL IMPACT ASSESSMENT**

Through the use of AI-enhanced analytics, herbal medicine practitioners may advocate for sustainable practices by gaining insights into the environmental effects of procuring herbal

resources for nano preparations. The implementation of this strategy is necessary to prevent the destruction of natural resources as a consequence of the development of herbal treatments (55).

### **13. TRAINING AND EDUCATION**

AI applications enable customized training programs and role-plays for pharmacists and other medical professionals, with an emphasis on safe nanoherbal product administration. The expertise and self-assurance of practitioners on alternative medicine are greatly enhanced by this endeavor. (56).

### **14)QUALITY CONTROL AND SAFETY**

Artificial intelligence technologies hold great potential to improve the quality assurance procedures involved in the production of herbal medicines. Analysis of production data and identification of abnormalities that can point to underlying quality issues are made possible by the application of machine learning techniques. Furthermore, through the analysis of past data, AI can evaluate the safety profiles of novel formulations, therefore reducing the possibility of unfavorable side effects. (57)

### **15)PREDICTIVE MODELING AND SIMULATION:**

AI-powered models are able to simulate how nano botanical components interact with biological systems. In order to reduce the requirement for comprehensive in vivo testing, this predictive skill is vital for getting insights into pharmacokinetics and pharmacodynamics. Research demonstrates how AI plays a critical role in modeling the behavior of nanoparticles, which helps develop more efficient medication delivery systems. Additionally, AI algorithms can be employed to forecast the efficacy and toxicity of nano herbal medicine formulations, thus diminishing the reliance on animal testing and clinical trials. (58)

### **16)HIGH-THROUGHPUT SCREENING:**

The integration of AI technologies into high-throughput screening of nano herbal formulations greatly accelerates the identification of viable treatments. AI algorithms can analyze thousands of nano herbal combinations in a fraction of the time that traditional screening methods would require. (59)

### **17)OPTIMIZATION OF NANOFORMULATIONS:**

The process of designing and synthesizing nanoparticles that encapsulate herbal extracts presents significant complexities. Artificial intelligence methodologies, such as genetic algorithms and neural networks, enhance these processes by forecasting the most effective combinations of materials and conditions to achieve the desired characteristics. Furthermore, AI can be employed to refine the formulation and design of nano herbal medicines, thereby maximizing their therapeutic efficacy while minimizing potential toxicity. (60)

**18) PHYTOCHEMICAL ANALYSIS:**

Artificial intelligence (AI)-enhanced methods, such as deep learning and machine learning, have been used to analyze the phytochemical content of herbal extracts. This makes it possible to identify bioactive substances and forecast the pharmacological effects of such chemicals. (61)

**19) TARGETED DELIVERY AND PERSONALIZED THERAPY:**

Artificial intelligence (AI) algorithms are able to assess distinct patient parameters, such as genetic profiles and illness features, in order to create personalized nano herbal remedies. (62) Artificial intelligence (AI)-powered smart drug delivery systems can precisely target pathological tissues, improving the bioavailability of nano herbal remedies while reducing the likelihood of adverse effects. (63).

**20) PHARMACOKINETIC AND PHARMACODYNAMIC MODELING:**

Nano herbal medications have better bioavailability and a lower risk of adverse effects because to AI-enhanced smart drug delivery systems that can precisely identify and target sick tissues. (64)

**21) NANO CARRIER SYSTEM IDENTIFICATION:**

The integration of artificial intelligence can support the identification of effective nano carrier systems for herbal formulations, leading to enhanced bioavailability and therapeutic outcomes. A study conducted utilized a neural network to predict the loading efficiency of a nano carrier system for a particular herbal extract, achieving an accuracy of 95.6%. (65)

**CASE STUDIES AND REAL-WORLD APPLICATIONS****CASE STUDY 1: ANTI-CANCER NANO HERBAL FORMULATIONS**

A research investigation employed artificial intelligence to discern the anti-cancer attributes of nano-formulated curcumin, a compound sourced from turmeric. The AI model revealed synergistic interactions with various phytochemicals, thereby improving the bioavailability and anti-tumor efficacy of curcumin. (66)

**CASE STUDY 2: AI IN ENHANCING BIOAVAILABILITY**

The research highlighted the implementation of artificial intelligence to improve the bioavailability of nano- encapsulated ginseng extract. Through the use of optimization algorithms, the study identified the most advantageous nanoparticle compositions, resulting in a fourfold enhancement in bioavailability in contrast to conventional methods. (67)

## CONCLUSION

The integration of artificial intelligence with nano herbal medicine has opened up new avenues for improving the efficacy, accuracy, and customization of natural plant-based treatments. By utilizing AI's strengths in rational design, targeted delivery, predictive modeling, and quality assurance, the realm of nano herbal medicine is set to provide more effective and tailored therapies for various health issues. As advancements in this area progress, it is vital to confront the challenges and fully exploit the transformative potential of this technology to enhance human health. The advantages of merging AI with nano herbal medicine are significant, leading to improvements in drug discovery, personalized therapies, formulation enhancements, predictive analytics, quality management, and the amalgamation of traditional and contemporary knowledge. As research in this sector advances, Using these technologies to their full potential will be essential for all stakeholders, including academics, medical professionals, and legislators. The long-term impacts of these advances on patient outcomes and the healthcare system as a whole should be the main focus of future research.

## DISSCUSSION

This review also addresses the regulatory and ethical issues associated with the integration of AI in nano herbal medicine. AI has established itself as an essential technology within nano herbal medicine, supporting the analysis of vast datasets, the anticipation of bioactivity, and the optimization of formulation development. As research in this sector advances, it is imperative for all stakeholders, including researchers, healthcare professionals, and policymakers, to adopt these technologies to maximize their benefits. Future investigations should focus on the long- term effects of these innovations on patient outcomes and the overall healthcare system

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