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The Nano-Herbal Revolution: Merging Traditional Botanicals with Modern Technology

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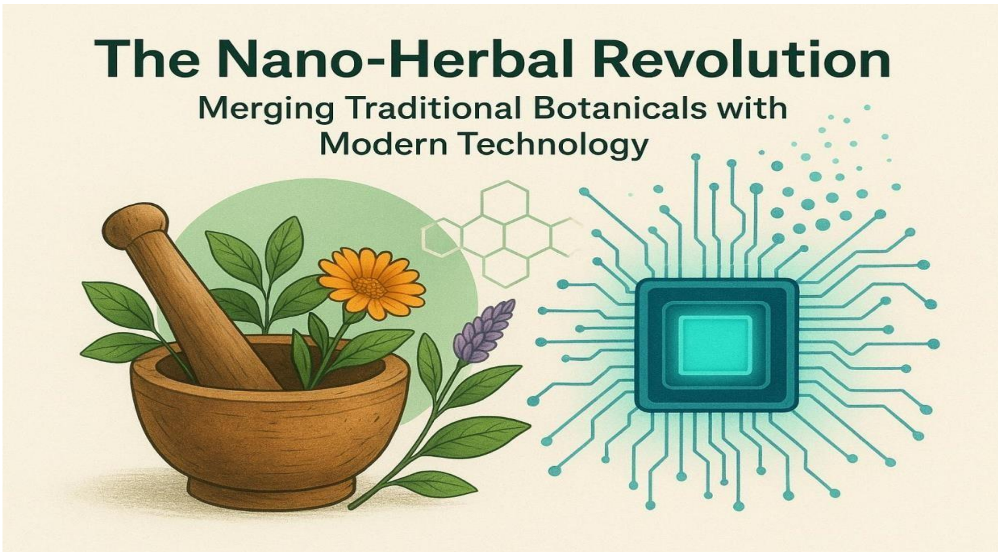

Abstract: *The integration of nanotechnology with plant-based medicinal compounds is bringing major improvements to modern drug delivery and treatment methods. Herbal medicines have been used for a long time because they are effective and usually cause fewer side effects. However, traditional herbal preparations often have limitations, such as poor absorption in the body, large particle size, and low availability of active compounds. Nanotechnology helps overcome these issues by enhancing absorption, increasing bioavailability, and allowing medicines to target specific areas in the body more effectively. Plant-based nanoparticles also provide an eco-friendly and sustainable solution, offering better drug release control and improved therapeutic performance. For example, nanoparticles like silver and gold produced using plant extracts have shown strong potential in fighting infections and cancer.*

Nanotechnology is helping herbal medicines work better in the body. By turning herbal compounds into very tiny particles, they become easier to absorb and more effective in treating problems like cancer, infections, and inflammation. These small carriers protect the medicine from being damaged in the stomach or broken down too early by the liver. This helps the herbal drugs reach the right place in the body and work more efficiently, making the treatment safer and more reliable.

Nanotechnology brings many benefits to herbal medicine by making treatments more effective and easier to use. It helps the medicine release slowly, so its effects last longer. It also allows the drug to work directly at the target site, which lowers side effects. This improves patient comfort and makes it easier to follow treatment routines. In addition, nanotechnology improves how well herbal medicines dissolve, get absorbed, and act in the body, while also increasing their safety. Because of this, patients often need smaller doses and do not have to take the medicine as frequently.

Nanomedicine is growing rapidly and is expected to play a much bigger role in the future. Nano-based herbal medicines have shown the potential to help in the treatment of different types of cancer, such as

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lung, liver, bone, and skin cancers. These advancements are opening new possibilities for improving the way plant-based medicines work in the body. However, while nanotechnology offers many benefits, it is important to understand its safety and long-term effects. More studies are needed to make sure these nano-formulations are safe and reliable for regular medical use. By combining traditional herbal medicine with modern nanotechnology, we can create more effective and advanced healthcare solutions. The growing use of nanoparticles in herbal medicine represents a new direction in developing safer, more efficient plant-based treatments and drug delivery systems.

Keywords*:* Nanoparticles, plant extracts, green synthesis, drug delivery, nanomedicine, Herbal drugs, nanotechnology, NDDS, Nanodelivery system, Liposomes, phytosome, solid lipid nanoparticles, Nanocarriers, Herbal remedies, Drug delivery system, Traditional knowledge, Botanical diversity, curcuma longa, Pharmacological activity

I. INTRODUCTION

Herbal medicines have been used by people for centuries across different cultures. Traditional healing practices like Ayurveda, Traditional Chinese Medicine, and Unani have relied on natural plants and herbs to treat illnesses and maintain overall well-being. This long-standing use shows how deeply connected herbal medicine is to human history and healthcare traditions[1,2]. Herbal medicines are prepared products made from different parts of plants, such as leaves, roots, stems, or their combinations. In many developing regions, a large portion of the population depends on these natural remedies as their main source of healthcare, mainly because they are affordable, easily available, and deeply rooted in traditional practices[3]. These medicines are widely appreciated for their natural healing benefits and are usually considered gentler on the body, with fewer side effects compared to many modern treatments. This is why many people choose them as a safer and more natural option for their health needs[4]. Medicinal plants are full of natural compounds that support healing and help protect the body against inflammation, infections, oxidative damage, and even cancer. However, many of these beneficial compounds do not always work well in modern treatment because the body struggles to absorb them properly. They may break down too quickly, get poorly absorbed in the digestive system, or not dissolve well in water, which reduces their overall effectiveness[1,2,5]. To overcome the common problems seen with herbal medicines, advanced drug delivery methods like nanotechnology are being used. Nanotechnology works with extremely tiny particles and helps design better ways to carry medicines into the body. These tiny particles have special properties that allow them to protect the active ingredients and help them work more effectively. In herbal medicine, using nanotechnology improves how well plant-based compounds are absorbed and how long they remain active in the body. It also helps protect the compounds from breaking down too quickly, reduces possible side effects, and allows the medicine to be released gradually over time. This means smaller doses can be used while still achieving better results. Another advanced approach is phytosome technology, where plant extracts are combined with natural lipids. This makes the herbal compounds more compatible with the body, helping them enter cells more easily and improving their overall effectiveness[6,7] . Several traditional medicinal plants, including Boerhaavia diffusa, Rhododendron spiciferum, Caesalpinia bonducella, Capparis zeylanica, Luffa cylindrica, Withania somnifera, and Asparagus racemosus, are used to prepare different herbal formulations. These formulations are valued for their rejuvenating properties and their ability to support health and treat various conditions[8,9]. Various nano-delivery systems can be used to carry plant-based compounds more effectively throughout the body. These include tiny carriers like liposomes, polymer nanoparticles, nanoemulsions, nanospheres, and solid lipid nanoparticles. They help protect the herbal ingredients and improve how well they are absorbed and reach the areas where they are needed[10,11]. Although nanotechnology can be costly and raise safety concerns, it plays an important role in improving traditional herbal treatments for chronic diseases. By using nanocarriers, herbal medicines can work more effectively, release slowly, require smaller doses, and cause fewer side effects[12].

Table provides an overview of the several distribution methods for herbal nanoparticle[13],[14],[15],[16].

Formulations	Active Ingredients	Bilogical Activity	Method of Preparation
Curcuminoid solid lipid nanoparticles	Curcuminoids	Anticancer and Antioxidant	Micro-emulsion technique
Glycyrrhizic acid loaded nanoparticles	Glycyrrhizic Acid	Antihypertensive	Rotary-evaporated film Ultrasonication
Artemisinin nanocapsules	Flavonoids and Lignans	Hepatoprotective	Self Assembly
Berberine-loaded nanoparticles	Artemisinin	Anticancer	Ionic gelation

Table no. 01: Herbal Drug Nanoparticles

Nanocarrier Systems for Herbal Medicines

Nanocarriers are very tiny, specially designed systems that help carry active compounds and deliver them more effectively in the body. They are especially useful for improving the way herbal ingredients are protected, absorbed, and used by the body. Some commonly used nanocarriers for herbal compounds include liposomes, nanoemulsions, solid lipid nanoparticles, polymeric nanoparticles, phytosomes, metallic plant-based nanoparticles, and dendrimers. These systems help make herbal medicines more stable, easier to absorb, and more effective.

Here is a fully humanized version without any references:

Liposomes

These are tiny capsule-like structures made from natural lipids. They can carry both water-soluble and fat-soluble compounds, making them ideal for protecting delicate herbal ingredients and helping them stay stable in the body.

Nanoemulsions

These help oily plant compounds mix better with water by forming very fine droplets. This improves their stability and helps the body absorb them more easily.

Solid Lipid Nanoparticles and NLCs

These are fat-based carriers that help control how a drug is released and make it more stable. NLCs are a more advanced form that hold the drug more effectively and prevent it from leaking out too quickly.

Polymeric Nanoparticles

These are made from natural or synthetic materials and help release drugs slowly over time. They can also be modified to target specific parts of the body for better treatment results.

Phytosomes

In this method, plant extracts are combined with phospholipids to help them pass through cell membranes more easily, improving absorption and effectiveness.

Metallic Phytonanoparticles

These are metal-based nanoparticles prepared using plant extracts in an eco-friendly way. They are often explored for their potential in fighting infections and cancer.

Dendrimers

These are branched, tree-like structures that help carry drugs more precisely. They improve drug solubility and allow better targeting, making treatments more efficient[17,18].

Mechanisms of Improved Delivery & Bioavailability

Nanocarriers improve herbal drug performance through several mechanisms: protection from degradation (acidic pH, enzymes), increased aqueous dispersion of hydrophobic phytochemicals, enhanced permeation across biological barriers, targeted delivery (via ligands), and controlled/sustained release profiles.

How Nanocarriers Improve Herbal Bioavailability

-Nano-encapsulation protects actives from degradation (acid/enzymes).

-Improves aqueous dispersibility of hydrophobic phytochemicals.

-Promotes uptake via endocytosis or improved permeability (paracellular/transcellular).

-Controlled release profiles extend circulation time[19].

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Therapeutic Applications across the Disease areas

Cancer Treatment: Green-synthesized nanoparticles have the capability to stop the rise and advancement of carcinogenic cells by inducing cell loss. Additionally, they can increase the efficacy of radiation and chemotherapy. A major development in cancer nanomedicine is the targeted drug delivery capabilities of plant-derived nanoparticles, which minimises damage to healthy tissues while providing selective toxicity towards cancer cells.

Antimicrobial Therapy: These nanoparticles are a possible substitute for traditional antibiotics since they have powerful antibacterial, antiviral, and fungicidal activities against drug-resistant organisms.

Wound Healing: Green-synthesized nanoparticles can accelerate wound re-epithelialization, tissue regeneration, and infection-free healing. Silver nanoparticles synthesized using Litsea cubeba essential oil exhibited both antibacterial and wound healing effects.

Neurodegenerative Diseases: They may help manage neurodegenerative disorders by targeting key pathological mechanisms such as protein aggregation, inflammation, and oxidative stress. Zinc oxide nanoparticles synthesized using Acanthus ilicifolius demonstrated neuroprotective effects in Caenorhabditis elegans Alzheimer’s models.

Cardiovascular Diseases: Cardioprotection through antioxidant, anti-inflammatory, and gene-regulatory benefits, reducing oxidative stress, inflammation, and myocardial damage. Silver nanoparticles synthesized using Tribulus terrestris demonstrated significant cardioprotective effects in isoproterenol-induced myocardial infarction models.

Anti-inflammatory Therapy: Modulation of key immune pathways, suppressing proinflammatory cytokines, and reducing oxidative stress, offering a safe and plant-based alternative to conventional anti-inflammatory therapies. Green-synthesized silver nanoparticles showed notable anti-inflammatory activity in both UVB-induced HaCaT cells and acute inflammation models in Wistar rats.

Diabetes Management: Enhanced bioavailability, biocompatibility, and synergistic interactions with phytochemicals, improving glycemic control and reducing complications. Silver nanoparticles synthesized using a polyherbal extract demonstrated significant antidiabetic activity[20].

Benefits of Green Synthesis

Biocompatibility

Green-synthesized nanoparticles are biocompatible and non-toxic, reducing the risk of adverse reactions.

Eco-Friendliness

The green synthesis process minimizes energy consumption, toxic byproducts, and waste generation.

Improved Stability and Bioavailability

Therapeutic medicines' stability, solubility, and bioavailability can all be enhanced by green-synthesised nanoparticles.

Examples of Green-Synthesized Nanoparticles

Silver Nanoparticles

With their antiviral, antifungal, and antibacterial properties, silver nanoparticles may find use in antibacterial coatings, infection prevention, and wound healing.

Gold Nanoparticles

Showing promise in cancer therapy, gold nanoparticles can enhance the effectiveness of chemotherapy and radiotherapy.

Zinc Oxide Nanoparticles

Demonstrating antimicrobial and antioxidant activities, zinc oxide nanoparticles may be useful in biomedical applications[21].

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Fig.01: Tablets, Powder, Rhizomes of Turmeric

Synonyms

Indian Saffron, Haldi, Curcumin, Haridra.

Biological Source

It is the dried rhizome of Curcuma longa L. which belongs to Zingiberaceae family.

Geographical Source

It is widely grown in temperate climates and is native to southern Asia. Larger-scale cultivation occurs in China, India, Pakistan, Malaysia, and the East Indies.

Cultivation

Turmeric is a hardy plant that grows to about 60–90 cm in height. It has long, clustered leaves and a short stem, while the thick underground rhizomes are the part used for commercial purposes. The plant grows best in warm, humid weather with enough rainfall and soil that drains well. Loose, fertile soil such as loamy or alluvial soil is ideal for good growth. Before planting, the field should be properly prepared by deep ploughing to loosen the soil and mixing in organic manure. Turmeric is usually planted from April to August using small pieces of rhizomes taken from the previous harvest. Each piece should have one or two buds and is placed about 30–37 cm apart and around 7 cm deep in the soil. After about nine to ten months, when the lower leaves start turning yellow, the crop is ready for harvest. The rhizomes are carefully dug out, then cleaned and dried before further use.[22,23,24].

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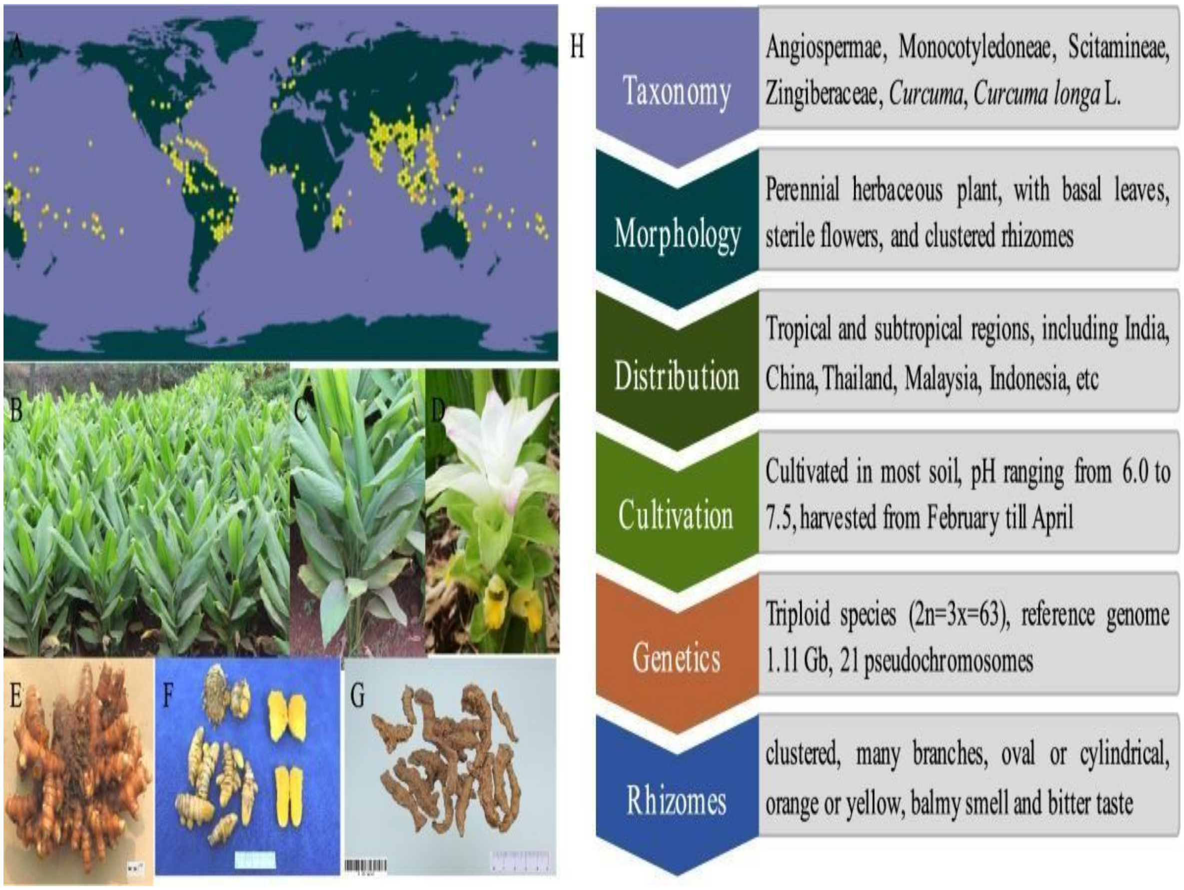

Fig.02: A. Botanical characteristics of turmeric, B,C. Global distribution of turmeric, D. Flower of turmeric, E,F,G. Rhizome of turmeric, H. Brief summary of botanical characteristics of turmeric.

Features

Turmeric rhizomes come in different shapes such as oval, pear-like, oblong, or cylindrical, and they usually have small side branches. The main, thicker rhizomes are known as bulb or round turmeric. The thinner side branches are called fingers; they grow sideways, are cylindrical, and taper at both ends. These finger rhizomes are often cut into smaller pieces, and the bulbs and fingers are separated during processing. After cleaning off the fibrous roots and soil, the rhizomes are dried and polished. As part of the curing process, the rhizomes, along with some leaves, are boiled in water until they become soft. Once cooked, they are cooled and then dried under the sun, while being turned regularly and rubbed on rough surfaces. The dried rhizomes show marks where the roots were attached and circular ridges formed by the leaf bases. Their color ranges from deep yellow to orange. When cut, the surface appears waxy and resin-like, and the broken surface is hard and glossy. The outer surface is wrinkled lengthwise and varies from dark yellow to brown. Turmeric has a strong, characteristic smell and a sharp, slightly bitter but aromatic taste[22,23,24].

Microscopy

When a turmeric rhizome is cut across, you can clearly see its internal layers. Most of it is made up of soft, round cells with thin walls. In between, there are special cells that contain oily, brown material. A few protective cork layers lie just under the outer skin, while the outer skin itself stays intact even after these layers form. Some parts of the tissue contain long, oval-shaped starch grains. There are also oil-containing cells filled with yellowish droplets. Inside, the plant's transport tissues are scattered throughout and form a partial ring near the center. Most of the water-carrying vessels show spiral patterns, giving the structure its typical internal appearance[22,23,24].

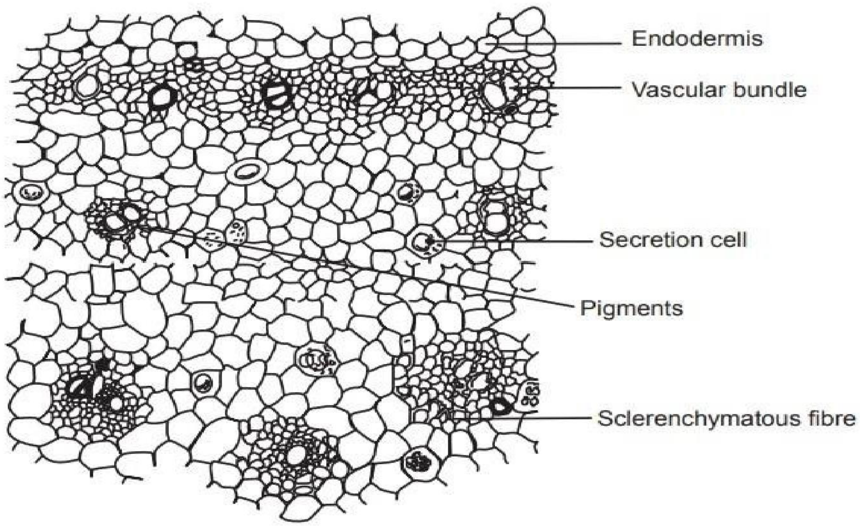

Fig.03: Turmeric Rhizome Transverse section

Chemical Tests

Turmeric contains curcumin, which shows clear colour changes when it reacts with certain chemicals. These reactions are commonly used to identify and test turmeric.

When strong sulphuric acid is added to curcumin or turmeric powder, the yellow colour changes to deep crimson.

If an alkaline solution is mixed with turmeric, the colour shifts from yellowish or reddish to violet.

When turmeric is treated with a mixture of strong sulphuric acid and acetic anhydride, it produces a violet colour, which appears as a bright red glow under ultraviolet light.

If turmeric extract is applied to paper and then treated with borax solution, the paper changes its colour to green.

In another test, filter paper soaked in turmeric extract is dried and then treated with slightly acidified boric acid. The paper turns pink or reddish-brown, and when an alkali is added, the colour changes to deep blue or blue-green.

These colour changes help confirm the presence of turmeric and its active compound in different samples[22,23,24].

Chemical Components of Curcumin

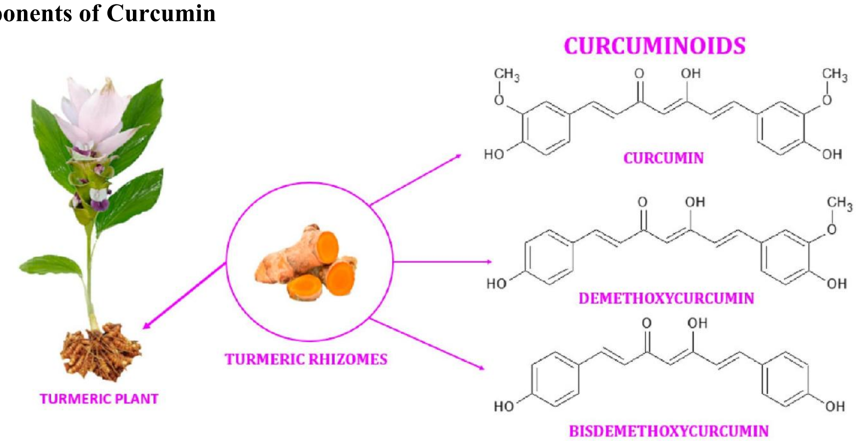

Fig.04: Chemical components of turmeric

The pharmacological activities

The pharmacological actions Turmeric has numerous properties. Figure provided a summary of the pharmacological actions.

Fig.05: The pharmacological activities of turmeric

Anti-inflammatory activity

Lowers pro-inflammatory cytokines such as IL-1β, TNF-α, MMP-1[25]

Mechanisms

Inhibition of inflammatory pathways

One important inflammation regulator inhibited by curcumin.

Decrease in pro-inflammatory cytokines

Curcumin lowers the levels of TNF-α, IL-1β, and IL-6.

COX-2 and iNOS inhibition

Curcumin lowers inflammation by blocking these enzymes.

Antioxidant Activity

The antioxidant qualities of curcumin aid in lowering inflammation and oxidative stress.

Potential Applications

Arthritis

Rheumatoid arthritis and osteoarthritis symptoms may be lessened with curcumin.

Inflammatory bowel disease

Curcumin's anti-inflammatory properties might help manage IBD.

Neuroinflammation

Curcumin's anti-inflammatory activity may contribute to its potential neuroprotective effects.

Research

Studies suggest curcumin's anti-inflammatory activity is comparable to some NSAIDs, but with potentially fewer side effects. Nevertheless, additional study is required to verify its effectiveness and the ideal dosage[26,27].

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Anti-oxidant Activity

15 SOD, CAT, GPx, and GR all rise.

Reduces oxidative damage through the NF-κB and Keap1/Nrf2/ARE pathways[28].

Mechanisms:

Free radical scavenging

Curcumin limits oxidative stress and deactivates ROS.

Antioxidant enzyme induction

Curcumin boosts the synthesis of glutathione peroxidase, catalase and superoxide disputes (SOD)

Preventing the peroxidation of lipids

Curcumin reduces oxidative damage to lipids and cell membranes.

Chelating metal ions

Curcumin binds to metal ions, reducing their pro-oxidant effects.

Potential Benefits

Protection against chronic diseases

Curcumin's antioxidant activity may help prevent or manage ailments such as cardiovascular disease, cancer, and neurodegenerative diseases.

Reducing inflammation

Curcumin's antioxidant properties contribute to its antiinflammatory effects.

Supporting cellular health

Curcumin's antioxidant activity helps maintain cellular homeostasis and lessen oxidative damage.

Research

Research indicates that the oxidation inhibitor activity of curcumin is comparable to several well-known Antioxidants like vitamins C and E. However, additional study is required to verify its effectiveness and ideal dosage[29].

Antidiabetic Activity

Helps with blood glucose, insulin sensitivity, islet integrity.

Impacts inflammatory cytokines and gut microbiota[30].

Mechanisms

Improving insulin sensitivity

Curcumin enhances insulin signaling and glucose uptake in cells.

Reducing glucose production

Curcumin inhibits glucose production in the liver.

Increasing the uptake of glucose

Curcumin increases the uptake of sugar in adipose tissue and muscles

Possible Advantages

Controlling blood sugar levels

Curcumin may help lower HbA1c and fasting blood sugar levels

Helping with diabetes complications

Curcumin reduce issues like nerve and kidney damage caused by diabetes.

Improving lipid profiles

Curcumin could decrease triglycerides and bad cholesterol levels.

Research

Curcumin may help manage type 2 diabetes, according to studies, but further investigation is required to determine its effectiveness and ideal dosage. According to certain investigations, Enhanced glucose metabolism and insulin sensitivity Decreased inflammation and oxidative stress Reduced chance of complications from diabetes[31].

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Anti-tumor Activity
Inhibits tumor proliferation, invasion, metastasis, and angiogenesis.
Acts on PI3K/Akt, JAK/STAT3, PPARγ pathways[32].
Mechanisms
Inhibiting cancer cell proliferation
Curcumin causes apoptosis (cell death) and prevent the growth of cancer cells
Inhibiting angiogenesis
Curcumin reduces creation of newly formed blood vessels providing tumours.
Inhibiting metastasis
Curcumin reduces cancer cell migration and invasion.
Potential Benefits
Preventing cancer development
Curcumin may help prevent certain cancers, like colon, breast, and lung cancer.
Enhancing cancer treatment
Curcumin may complement conventional cancer therapies, like chemotherapy and radiation.
Reducing cancer recurrence
Curcumin influences pathways that are implicated in the genesis and progression of cancer.
Research
Cancer can affect different parts of the body. Examples include the colon, breast, lungs, prostate, and pancreas[33].

Neuroprotective Activity
Reduces Aβ aggregation and α-synuclein accumulation.
Increases SOD, CAT, GPx.
Impacts pathways like TLR4/NF-κB[34]
Mechanisms
Reducing oxidative stress
Curcumin's Antioxidant qualities aid to prevent oxidative damage in the brain.
Inhibiting inflammation
Curcumin's anti-inflammatory effects help reduce neuroinflammation.
Reducing amyloid-beta aggregation
Curcumin may help reduce amyloid-beta plaques associated with memory loss disease.
Modulating signaling pathways
Curcumin modulates neuroprotection pathways.
Potential Benefits
Neurodegenerative diseases
Curcumin may aid in the treatment of disorders like Paralysis, hereditary chores, and Alzheimer's.
Cognitive function
Curcumin may improve cognitive function and memory.
Neuroprotection
Curcumin's neuroprotective effects may help prevent or slow neurodegeneration.
Research:
Studies suggest curcumin's neuroprotective activity, including:
Decreased tau protein phosphorylation.
Enhanced mental performance and decreased oxidative stress in in Parkinson's models
Anti-inflammatory and antioxidant effects in neurodegenerative disease models[35].

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Hepatoprotective Activity
Helps with liver oxidative injury, NAFLD Activity Scores.
Impacts inflammation, intestinal flora, lipid metabolism[36].
Mechanisms:
Antioxidant effects
Curcuminlowers lipid peroxidation and oxidative damage in the liver.
Anti-inflammatory effects
Curcuma longa inhibits inflammatory pathways, reducing liver inflammation.
Inhibiting fibrosis
Curcumin may reduce liver fibrosis and scarring.
Modulating liver enzymes
Curcumin affects liver enzymes involved in detoxification and metabolism.
Potential Benefits
Liver protection
Curcumin may help protect against liver damage from toxins, alcohol, or viral infections.
Reducing liver fibrosis
Curcumin's anti-fibrotic effects may help manage liver fibrosis. Supporting liver health Curcumin's hepatoprotective effects may support overall liver health.
Research
Studies suggest curcumin's hepatoprotective activity, including:
Reduced liver damage and inflammation in models of liver injury
Antioxidant and anti-inflammatory effects in liver illness models; enhanced liver function and decreased fibrosis in liver fibrosis models[37].

Antimicrobial Activity
Anti-bacterial (e.g., Staphylococcus aureus).
Anti-viral (e.g., influenza viruses)[38].
Mechanisms
Stopping the growth of microorganisms
Curcumin prevents viruses, fungi, and bacteria from growing.
Cell membrane disruption
Curcumin causes microbial cell death by rupturing their cell membranes.
Inhibiting biofilm formation
Curcumin reduces biofilm formation, making microbes more susceptible to treatment.
Potential Benefits
Antibacterial effects
Curcumin shows activity against bacteria like Staphylococcus aureus and E. coli.
Antifungal effects
Curcumin inhibits fungal growth, including Candida species.
Antiviral effects
Curcumin shows activity against viruses like influenza and herpes simplex.

Research
Studies suggest curcumin's antimicrobial activity, including:
Inhibition of bacterial growth and biofilm formation
Antifungal effects against Candida and other fungi
Antiviral effects against influenza and other viruses[39].

Other Activities

Anti-nematicidal (e.g., Aedes aegypti).

Anti-diarrheal, affects stool frequency.

Anti-aging, impacts β-tubulin protein.

Anti-nematicidal activity

Curcumin shows activity against nematodes, which can cause diseases in plants and animals.

Anti-diarrheal activity

By lowering intestinal inflammation and enhancing gut health, curcumin may help control diarrhoea.

Anti-aging activity

Curcumin's antioxidant qualities may support healthy ageing by lowering oxidative stress.

Dermatological benefits

Curcumin's properties may help treat skin disorders like vitiligo, psoriasis, and acne.

Benefits for the respiratory system

Curcumin's natural anti-inflammatory effects may help people with breathing problems like asthma and COPD.

Research

Studies point to curcumin's possible advantages in these domains, although further investigation is required to validate its effectiveness and ideal dosage[40].

Traditional Indian (Ayurvedic) formulations

Turmeric has been part of traditional healing for thousands of years and has always been valued for its wide range of uses in daily life and medicine.

People used to apply a paste made from turmeric and water on cuts, burns, and skin problems to help clean the area and speed up healing. In some cases, turmeric was mixed with burned cloth and placed on wounds to protect them and support the healing process.

For internal health, turmeric was often added to warm milk and taken as a home remedy. This drink was believed to strengthen the body, calm throat irritation, and improve digestion. A pinch of black pepper was sometimes added because it helped the body absorb turmeric better.

Turmeric was also used to support digestion by reducing gas and stomach discomfort. It helped in maintaining liver health and improving overall gut function. For breathing problems like cough or asthma, turmeric was commonly used to give relief.

In skincare, turmeric paste was applied to make the skin clearer and brighter. It was also used during traditional ceremonies to give a natural glow to the skin.

For joint pain and stiffness, turmeric was traditionally consumed to reduce discomfort. It was also considered a rejuvenating herb, believed to support long life and maintain overall health and energy.

Part A- shows the progression from Curcuma longa plant to turmeric rhizomes to turmeric powder.

Part B- displays various turmeric products including slices, drugs (capsules), oil, and different packaged powders[41,42,43].

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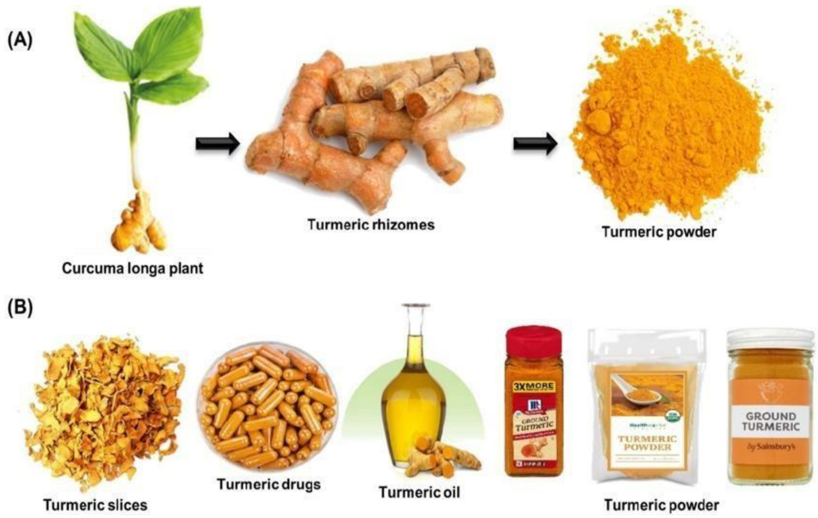

Fig.06: Traditional and Modern formulations of turmeric

History and Conventional Uses

Turmeric has been part of human life for thousands of years and has a strong place in traditional medical systems and daily culture, especially in Asia. Although its exact origin is not clearly known, it has been used in India since ancient times as both a medicine and a spice. As trade routes expanded, turmeric gradually spread to different parts of the world and became popular in many regions. People began using it in cooking, for its natural color, and for its health benefits. Over time, it reached Africa, Europe, and other parts of the world. Today, turmeric is widely available across the globe and is used in medicines, health products, dietary supplements, cosmetics, and food. Its long history and natural healing properties continue to make it an important part of modern life[44,45,46]

Prospects for the Future

Turmeric is likely to become even more important in the future because of its natural healing and protective properties. As research continues, it may lead to the development of more effective treatments for conditions like inflammation, diabetes, cancer, and brain disorders. Modern technologies are also helping make turmeric more easily absorbed by the body, which can improve its overall effectiveness. In the food industry, turmeric will continue to be used as a natural coloring and health-boosting ingredient. In cosmetics, it is expected to be used more widely in skincare and beauty products due to its benefits for the skin. Turmeric also holds potential in agriculture, where it could be used in developing natural alternatives to chemical pesticides. Overall, turmeric has a bright future as a natural solution in healthcare, food, cosmetics, and sustainable product development[47,48].

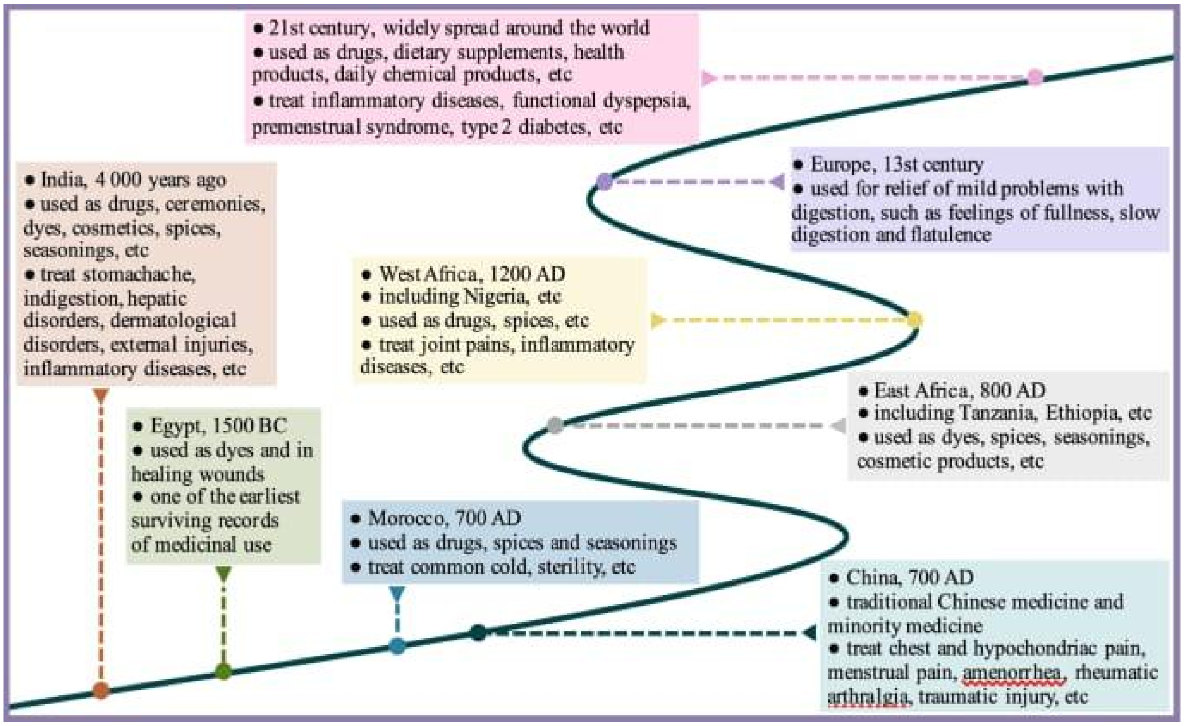

Fig.07: Evalution and Worldwide use of Turmeric

II. CONCLUSION

The nano-herbal revolution is reshaping herbal medicine by combining traditional plant remedies with modern nanotechnology. Many herbal treatments face challenges like poor absorption, low water solubility, and quick breakdown in the body. Nanotechnology offers a solution: tiny carriers called nanocarriers that help herbal compounds be absorbed more effectively, remain stable longer, and reach specific parts of the body where they are needed. Different types of nanocarriers—such as liposomes, nanoemulsions, solid lipid nanoparticles, and phytosomes—protect herbal compounds from stomach acid or enzymes and help them pass through the body's natural barriers to reach their targets. This approach shows promise in treating a variety of health issues, including cancer, infections, slow-healing wounds, brain disorders, and heart problems. For example, turmeric's active compound, curcumin, is known for its anti-inflammatory, antioxidant, and healing properties, but the body doesn't absorb it easily. Nanotechnology improves its effectiveness by enhancing absorption and stability. Going forward, more research is needed to ensure that nano-herbal products are safe for long-term use. Clear guidelines for manufacturing and regulation will be important to make these advanced herbal medicines safe, effective, and widely accessible.

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