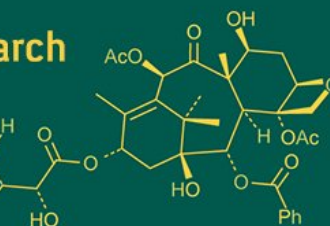
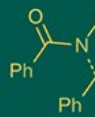


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Herbal nanomedications: A next generation approach to neurodegenerative diseases

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Abstract

Herbal nanomedications are the harness nanotechnology to overcome the longstanding barriers of natural products poor solubility, instability, rapid metabolism, and limited brain penetration thereby enhancing bioavailability, targetability, and multi-pathway neuroprotection in neurodegenerative diseases. Neurodegenerative disorders such as Alzheimer's disease (AD), Parkinson's disease (PD), and Huntington's disease involve convergent mechanisms including oxidative stress, neuroinflammation, mitochondrial dysfunction, protein aggregation, and impaired proteostasis, for which multi-target phytochemicals are well suited when delivered via nanocarriers. Nanoplatforms polymeric nanoparticles, nanogels, lipid-based carriers, and green-synthesized metal nanoparticles improve blood-brain barrier transport, sustain release, and enable surface functionalization for neuronal or lesion-site targeting. Exemplars include curcumin-loaded polymeric nanoparticles (e.g., PLGA or targeted Tet-1 conjugates) that disrupt A β aggregates, attenuate oxidative damage, and enhance brain delivery in AD models; similarly, nano-curcumin and plant-assisted gold nanoparticles leverage antioxidant and anti-inflammatory "nanozyme" activities relevant to PD pathobiology. Emerging evidence from comprehensive reviews indicates that nanoformulated phytochemicals (polyphenols, alkaloids, terpenoids) can modulate amyloidogenesis, tau hyperphosphorylation, synaptic dysfunction, and neuroinflammatory cascades in preclinical systems, with early clinical efforts beginning to address translational barriers of standardization, dosing, and safety. Future directions emphasize smart, stimuli-responsive and receptor-targeted systems; eco-friendly green synthesis that embeds bioactive plant coronas; and rigorously designed trials integrating pharmacokinetics, pharmacodynamics, and digital biomarkers to validate disease-modifying potential. By coupling the pleiotropy of botanicals with precision delivery, herbal nanomedications present a tractable path toward multi-modal interventions for complex neurodegenerative networks, with prospects for combination regimens and theranostic designs that unify imaging and therapy.

Keywords: Herbal nanomedications, neurodegenerative diseases, nanoformulations, nanoparticles, blood-brain barrier

Introduction

The progressive loss of neurons and their roles in the Central Nervous System (CNS) is a hallmark of a wide range of progressive disorders known as neurodegenerative diseases (NDs). Amyotrophic Lateral Sclerosis (ALS), Parkinson's disease (PD), Huntington's disease (HD), Alzheimer's disease (AD), prion disorders, and spinocerebellar ataxias are a few notable instances. Pathological pathways that lead to neuronal death and irreversible impairments in cognition, motor abilities, and behavior are shared by many disorders. Many mechanisms include aberrant protein aggregation, oxidative stress, mitochondrial dysfunction, neuro inflammation, and synaptic failure. Millions of people worldwide are impacted by NDs, which significantly increase death and disability. The biggest risk factor is still aging, but environmental and genetic factors also play a role in the development and course of disease. Due to extended life expectancies, NDs have a significant and growing global impact; by 2050, AD alone is expected to impact over 130 million people. As of 2021, neurological illnesses accounted for 443 million Disability-Adjusted Life Years (DALYs), making them the world's greatest cause of illness and disability. This highlights the serious public health and societal challenges they provide. The progressive loss of neurons and their roles in the Central Nervous System (CNS) is a hallmark of a class of severe illnesses known

as neurodegenerative diseases (NDs). Amyotrophic lateral sclerosis, Parkinson's disease, Huntington's disease, Alzheimer's disease, prion disorders, and spinocerebellar ataxias are a few prominent examples. These conditions are similar in that they cause aberrant protein accumulation, oxidative stress, mitochondrial issues, brain inflammation, and nerve connection failure, which results in cell death and long-term memory, mobility, and behavior deficits. Millions are affected globally by NDs, which result in death and severe disability. Although aging is the primary risk factor, environmental and genetic factors also contribute. By 2050, Alzheimer's alone is predicted to touch about 130 million individuals. The burden of NDs is expanding quickly due to longer life expectancies. Since neurological illnesses caused 443 million Disability-Adjusted Life Years (DALYs) in 2021, they are now the biggest cause of illness and disability worldwide, placing a heavy strain on society and health systems. [Lamprey *et al.*, 2022] ^[6] [Selvam *et al.*, 2024] ^[7]. The limitations of existing treatments may be overcome by herbal nanomedicines. The beneficial effects of natural products on the brain, such as their anti-inflammatory and antioxidant properties, are well recognized. Nevertheless, a lot of plant chemicals have problems with instability, poor absorption, rapid breakdown, poor solubility, and trouble getting to the brain. Delivery technologies based on nanotechnology, such as lipid and polymeric nanoparticles, nanoliposomes, and nanoemulsions, aid in enhancing the physiological behavior of these herbal ingredients and more precisely delivering them to the brain. In addition to protecting the active substances, these nanocarriers increase solubility, regulate release, and facilitate blood-brain barrier

crossing. Herbal medicine and nanotechnology together provide a potent, secure new treatment option for neurodegenerative illnesses. [Moradi *et al.*, 2020] ^[8] [Panda and Mohapatra, 2024] ^[9].

What are neurodegenerative diseases

Neurodegenerative diseases (NDs) represent a group of chronic disorders in which nerve cells in the central nervous system (CNS) gradually deteriorate and die, leading to continuous decline in movement, memory, thinking, and overall daily functioning. Some of the most common examples include Alzheimer's disease (AD), Parkinson's disease (PD), Huntington's disease (HD), amyotrophic lateral sclerosis (ALS), spinal muscular atrophy, and spinocerebellar ataxia. Despite their different clinical presentations, these conditions share key biological features such as the build-up of misfolded proteins (like amyloid-beta plaques and tau tangles in AD), excessive oxidative stress, mitochondrial damage, chronic inflammation, excitotoxicity, and impaired communication between neurons. Together, these factors drive irreversible neuronal death. The development of NDs is influenced by multiple risk factors including advancing age, genetic vulnerability, and environmental triggers. Patients typically experience progressive symptoms such as memory impairment, movement difficulties, behavioral and emotional changes, and loss of automatic body functions, leading to significant disability, reduced quality of life, and a growing global healthcare and economic burden. [Goyal *et al.*, 2024] ^[11] [Bhattacharya *et al.*, 2022] ^[27].

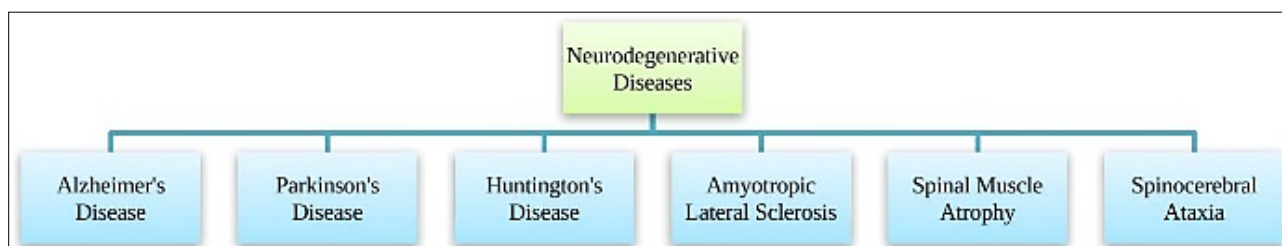


Fig 1: Neurodegenerative Disease

Herbal Nanomedications in Neurodegeneration

Herbal nanomedicines represent a novel and promising therapeutic strategy for addressing the complex pathogenesis and treatment challenges of neurodegenerative diseases (NDs). Neurodegeneration is driven by multiple molecular mechanisms, including oxidative stress, neuroinflammation, protein misfolding, mitochondrial dysfunction, and apoptosis. Conventional pharmacological treatments often face significant limitations, such as poor bioavailability, limited ability to cross the blood-brain barrier (BBB), off-target toxicity, and inability to simultaneously modulate multiple pathogenic pathways. Herbal-based nanomedicines integrate the neuroprotective properties of phytochemicals with the advantages of nanotechnology, including improved solubility, enhanced stability, targeted delivery, controlled release, and effective BBB penetration, thereby optimizing pharmacokinetic and pharmacodynamic profiles. [Moradi *et al.*, 2020] ^[8] [Panda and Mohapatra, 2024] ^[9]

A number of natural product-derived nanoparticle carriers, often enriched with herbal extracts, have been thoroughly studied. Familiar herbal components found within these

nanosystems include curcumin, quercetin, resveratrol, piperine, ginkgolides from *Ginkgo biloba*, and thymoquinone from *Nigella sativa*. These formulations boast a variety of neuroprotective attributes ranging from antioxidant to anti-inflammatory, anti-apoptotic, and anti-amyloidogenic effects which are crucial for addressing neurodegenerative diseases. For instance, nanoparticles of curcumin have demonstrated increased brain uptake and have been shown to inhibit the aggregation of amyloid-beta in Alzheimer's disease models. Likewise, quercetin nanoparticles can help reduce oxidative stress and neuronal cell death. [Moradi *et al.*, 2020] ^[8] [Panda and Mohapatra, 2024] ^[9] [Nahar *et al.*, 2025] ^[3]

Nanoparticle carriers made from natural products or containing herbal extracts have been widely researched. Some commonly used herbal compounds in these nano systems are curcumin, quercetin, resveratrol, piperine, ginkgolides from *Ginkgo biloba*, and thymoquinone from *Nigella sativa*. These herbal nano formulations offer a range of protective benefits for the brain, such as fighting oxidative damage, reducing inflammation, preventing cell death, and stopping harmful protein buildup all important in

addressing neurodegenerative diseases. For example, curcumin nanoparticles show better ability to reach the brain and can inhibit the buildup of amyloid-beta plaques linked to Alzheimer's disease, while quercetin nanoparticles help lower oxidative stress and protect nerve cells from dying. [Izadi *et al.*, 2024] ^[4] [Bhattacharya *et al.*, 2022] ^[27]

While herbal nanomedicines hold great promise for treating neurodegenerative diseases, there are still some challenges to overcome. These include concerns about the potential toxicity of nanoparticles, uneven distribution in the brain, variations in the composition of plant extracts, and difficulties in producing these nanomedicines at a large scale. Current research focuses on improving the size, surface properties, and targeting capabilities of nanoparticles to increase their precision and safety, alongside using advanced methods for thorough analysis and clinical testing. [Moradi *et al.*, 2020] ^[8] [Panda and Mohapatra, 2024] ^[9] [Bhattacharya *et al.*, 2022] ^[27]

Nano carriers

Nano carriers are tiny delivery systems that play a vital role in getting medicines exactly where they need to go in the brain, especially for treating neurodegenerative diseases. They help make herbal medicines easier to dissolve, protect these medicines from breaking down too soon, help them pass through the blood brain barrier, and release the medicine right at the affected site. All these features are really important because neurodegenerative diseases are complex and need precise treatment. [Moradi *et al.*, 2020] ^[8] [Dhariwal *et al.*, 2025] ^[12]

Some nanocarriers are discussed below

- Polymeric Nanoparticles:** Polymer nanoparticles (PNPs) are tiny particles made from safe, biodegradable materials like Poly (lactic-co-glycolic acid), chitosan, and Polylactic Acid. They provide controlled, long-lasting drug release and can be customized on the surface to target specific areas. Their solid structure protects the medicine inside from breaking down too soon. [Moradi *et al.*, 2020] ^[8] [Panda and Mohapatra, 2024] ^[9] [Dhariwal *et al.*, 2025] ^[12]

- Liposomes:** Small round bubbles made of natural fat layers that can hold water-loving drugs inside their watery center or fat-loving drugs within their fatty walls. They are safe for the body and can carry various types of medicines.

- Solid Lipid Nanoparticles:** Made from solid fats, these particles are stable and release medicines slowly over time.

- Nanostructured Lipid Carriers:** An improved version of SLNs with a mix of different fats, helping carry more medicine and preventing it from leaking out.

- Nanoemulsions:** Tiny droplets of oil dispersed in water using special stabilizers, which help dissolve medicines that do not mix easily with water. [Dhariwal *et al.*, 2025] ^[12] [Panda and Mohapatra, 2024] ^[9] [Izadi *et al.*, 2024] ^[4]

- Nanomicelles:** Nanomicelles are tiny, self-organizing structures formed from the amphiphilic molecules. Their unique design allows to carry drugs that don't dissolve well in water, making these drugs easier for body to absorb. Nanomicelles are an effective way to transport sensitive medications to where they are mostly needed in the body. [Moradi *et al.*, 2020] ^[8] [Bhattacharya *et al.*, 2022] ^[27]

- Inorganic Nanoparticles:** These types of nanoparticles are having special optical, magnetic and structural features that make them highly useful for medical imaging, targeted therapy and controlled drug release. [Panda and Mohapatra, 2024] ^[9] [Izadi *et al.*, 2024] ^[4]

- Phytosomes and Nanophytosomes:** these are the specialized form of lipid-based carriers, which are designed to boost both the absorption and stability of herbal extract. They form a complex between the phytochemicals and phospholipids. [Bhattacharya *et al.*, 2022] ^[27] [Izadi *et al.*, 2024] ^[4]

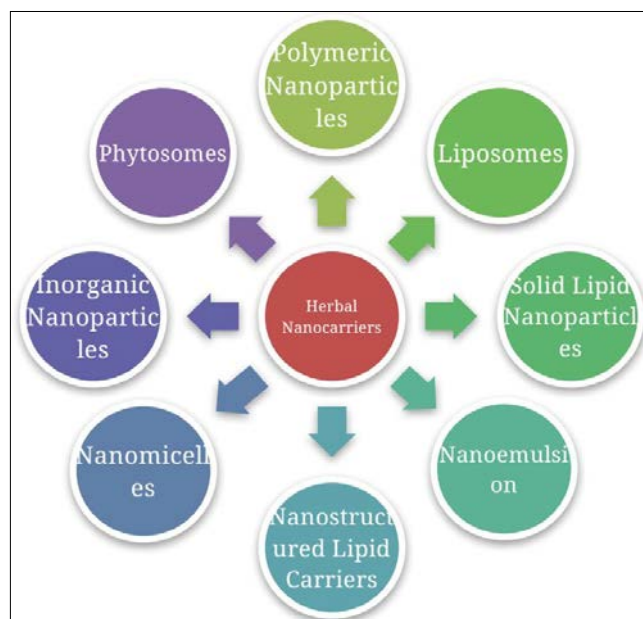


Fig 2: Herbal Nano carriers

Advantages of Herbal Nanocarriers

a) Bioavailability enhancement

Some herbal drugs are having poor water solubility and poor oral bioavailability, which limits their absorption and therapeutic activity. Nanocarriers increase the surface area and facilitate better dispersion, significantly improving absorption and bioavailability, help to reduce the toxicity risks. [Moradi *et al.*, 2020] ^[8] [Panda and Mohapatra, 2024] ^[9]

b) Improved Blood Brain Barrier (BBB) Penetration

Nano-sized carriers can easily cross the BBB and deliver active herbal ingredients directly to affected areas of the brain. That means they can work more effectively than the traditional herbal formulations. [Panda and Mohapatra, 2024] ^[9] [Bhattacharya *et al.*, 2022] ^[27].

c) Controlled and Sustained Drug Release

Nanocarriers release herbal compounds in a slow and steady way, which maintains therapeutic levels for longer time. It also reduces the frequent dosing [Moradi *et al.*, 2020] ^[8] [Izadi *et al.*, 2024] ^[4]

d) Reduced Toxicity and Side Effects

Herbal nanocarriers can reduce the unwanted effects on normal tissues and minimize the toxicity as they deliver drug at the target site. [Panda and Mohapatra, 2024] ^[9] [Izadi *et al.*, 2024] ^[4]

e) Synergistic Therapeutic Action

Nanocarriers can contain multiple phytochemicals, which can attack on different disease mechanisms and enhance neuroprotective action. [Nahar *et al.*, 2025] ^[3] [Moradi *et al.*, 2020] ^[8]

Involvement of Nanotechnology in Drug delivery

Neurodegenerative diseases like Alzheimer's, Parkinson's, and Huntington's remain difficult to treat because of their

complex nature and the protective blood-brain barrier (BBB), which prevents many drugs from reaching the brain. Conventional therapies often fail because of poor penetration, rapid breakdown, and unwanted side effects. Nanotechnology provides a promising solution by providing targeted, controlled, and efficient delivery of treatments directly to the affected brain areas. [Masoudi *et al.*, 2020] ^[13] [Dhariwal *et al.*, 2025] ^[12]

Nanomaterials have unique properties like nanoscale size (around 1-100nm), high surface area, and modifiable surfaces that enhance their interaction with biological membranes and improve therapeutic effects. Nanocarriers can target neurons or pathological protein aggregates via receptor-mediated or adsorptive transcytosis, increasing drug delivery to specific brain regions while reducing off-target

toxicity. For example, conjugation with transferrin or lactoferrin facilitates receptor-mediated transport across the blood-brain barrier, enhancing delivery efficiency. [Pinheiro *et al.*, 2021] ^[14] [Lopez-Espinosa *et al.*, 2024] ^[15].

Basically, nanotechnology makes it possible to combine treatment and diagnosis into one approach, known as theranostics (combination of therapy and diagnostics), which helps to improve how we monitor diseases and deliver therapies more precisely. Nanotheranostics uses nanoparticles paired with imaging agents like fluorescent dyes or MRI contrast materials, doctors can track the delivery of drugs and evaluate treatment effects in real time within the central nervous system. [Kumar *et al.*, 2020] ^[16]

Methods of preparation of Nanoparticles

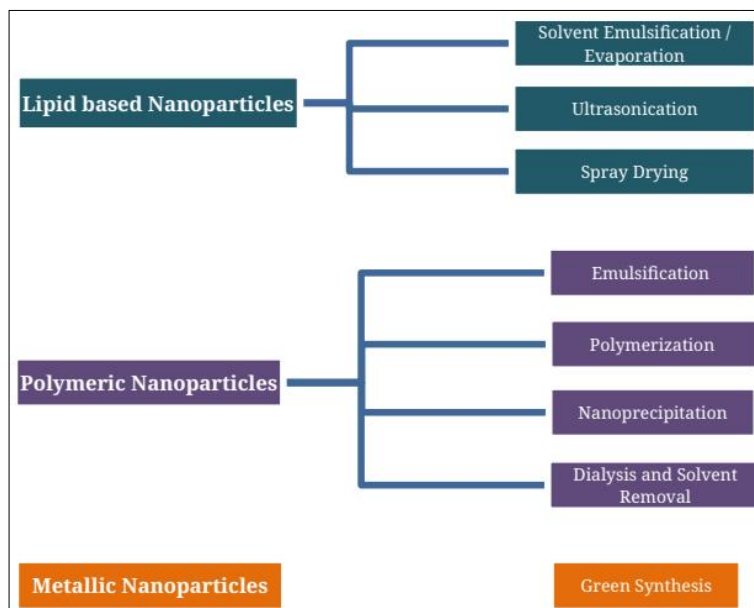


Fig 3: Methods of preparation of Nanoparticles

Table 1: Patented Herbal Nanomedications for Neurodegenerative Diseases

S. No.	Patent Title/Description	Nanostructure Types	Active Ingredients	Patent Holder/Inventor	Year	Patent Number	Reference
1	Curcumin-loaded Nanoparticles for CNS disorder	Polymeric Nanoparticles (PLGA, Other)	Curcumin	Various researchers/Institutions (e.g. Moradi <i>et al.</i>)	2019	PWO20182032 81A1	Moradi <i>et al.</i>
2	Ginkgo biloba extract nanoformulations	Niosomes, lipid nanoparticles	Ginkgo biloba flavonol glycosides, ginkgolides	Pharmaceutical research groups (e.g., Jin <i>et al.</i>)	2013	CN103795488 1A	Moradi <i>et al.</i>
3	Herbal Nanoparticles delivery for Neurodegeneration	Polymeric nanoparticles, lipid-based nanoparticles	Piperine, curcumin, quercetin, resveratrol	Panda & Mohapatra, Siksha o Anusandhan University	2024	IN2021470481 39	Panda & Mohapatra
4	Ayurveda-based herbal formulation by nanocarrier	Various nanostructure	Ayurvedic polyherbal mixtures	WO20120204 2A1 Patent holders	2011	WO201202042 3A1	[19]
5	Phytochemical green-synthesized nanoparticles	Green-synthesized metal nanoparticles	Various plant extracts	Various academic and industrial groups	2020 - 2024	US202103427 87A1	Izadi <i>et al.</i>
6	Nanoparticle formulations to enhance bioavailability	Polymeric nanoparticles, liposomes	Curcumin, resveratrol, quercetin, piperine	Multiple groups (various patents across 2015-2025)	2015 - 2025	EP3198584A1	Moradi <i>et al.</i>
7	Pomegranate oil nanoformulation for neurodegenerative disease treatment	Lipid nanoparticles, Nanoemulsion	Pomegranate oil and fractions	EP2844265A1 Patent holders	2013	EP2844265A1	[20]

Table 2: Various nanoparticle-based drug delivery systems in neurodegenerative diseases

S. No.	Nano Particle type	Herbal drug	Neuro Disease target	Therapeutic Uses	Diagnostic Uses	Reference
1	Polymeric Nanoparticles	Curcumin	Alzheimer's disease (AD), Parkinson's disease (PD)	Improved brain bioavailability and anti-inflammatory, Prevents aggregation of amyloid- β plaques and τ proteins in AD, and α -synuclein proteins in PD. Protects against oxidative stress.	Not primary. Can be linked to imaging agents for research but not a primary diagnostic tool on its own.	Mathew <i>et al.</i> (2012) ^[5]
		Resveratrol	AD, PD, Huntington's disease (HD)	Enhanced brain bioavailability, anti-inflammatory and antioxidant effects, protects dopaminergic neurons.	Not primary	Nirale <i>et al.</i> (2023) ^[21]
		Ginkgo biloba extract	AD	Increased concentration of active compounds (flavonoids, terpenoids) in the brain. Reduces neuronal damage and improve cognitive function.	Not primary	Ghendov Mosanu <i>et al.</i> (2020) ^[22]
2	Lipid-Based Nanoparticles	Quercetin	AD, PD	Enhanced delivery across the blood brain barrier. Acts as a potent antioxidant and anti-inflammatory agent, reducing neuroinflammation.	Not primary	Modarai <i>et al.</i> (2011) ^[23]
		Berberine	AD	Improved brain uptake and stability. Inhibits acetylcholinesterase, a key enzyme in AD pathology and reduces oxidative stress.	Not primary	Alfieri <i>et al.</i> (2021) ^[24]
3	Inorganic Nanoparticles	Gold Nanoparticles with Terminalia arjuna extract	AD	Inhibition of $\alpha\beta$ fibrillation and disaggregation of preformed fibrils. Shows neuroprotective effects by inhibiting cholinesterase enzymes.	Can be used as a contrast agent in CT or MRI for in-vivo imaging of $\alpha\beta$ plaques when functionalized appropriately.	Suganthi <i>et al.</i> (2018) ^[25]
4	Dendrimers	Glycyrrhizin	PD	High drug-loading capacity and controlled release. Protecting against neurotoxin-induced neuronal cell death.	Not primary.	.
5	Nanocrystals/Nanosuspensions	Piperine	AD	Acts as a Bioenhancer, significantly improving the bioavailability of other herbal drugs like curcumin and resveratrol in the brain.	. Not primary.	Xu <i>et al.</i> (2018) ^[26]

Current status of Herbal Nanomedication

Herbal nanomedicines are emerging as highly promising options for treating neurodegenerative diseases (NDs), thanks to nanotechnology-driven improvements in delivery, stability, and therapeutic effectiveness of plant-derived compounds. Current research is especially highlighting nanoformulations of natural molecules such as curcumin, quercetin, resveratrol, and piperine, along with extracts from *Ginkgo biloba* and *Nigella sativa*. These compounds are important because they can reduce oxidative stress, control inflammation, and protect brain cells, which helps in managing the complicated causes of diseases like Alzheimer's and Parkinson's. [Moradi *et al.*, 2020] ^[8] [Liu *et al.*, 2023] ^[2]

Recent studies are exploring that, advanced carriers like lipid-based nanoparticles, polymeric nanocarriers, and eco-friendly metal nanoparticles, which make it easier for herbal compounds to cross the blood-brain barrier, remain stable, and reach their target efficiently. For example, curcumin

packed in polymeric nanoparticles or liposomes shows better brain absorption and controlled release, making it promising for future clinical use. Similarly, liposomal forms of resveratrol improve its stability and absorption, helping to overcome issues like quick breakdown and low solubility of the natural compound. [Nahar *et al.*, 2025] ^[3] [Liu *et al.*, 2023] ^[2]

Both preclinical and clinical studies have shown encouraging neuroprotective benefits, such as lowering amyloid-beta buildup, protecting mitochondria, and reducing brain inflammation. Still, there are challenges in turning these findings into real treatments, including ensuring consistent quality of herbal extracts, developing large-scale production methods, proving safety, and meeting regulatory requirements. Progress in analytical tools, smarter nanocarrier designs, and combined treatment approaches is helping to overcome these barriers, bringing herbal nanomedicines closer to practical clinical use. [Kaspute *et al.*, 2025] ^[17] [Mu *et al.*, 2025] ^[18]

Future Prospectives

Some important futuristic approaches are given below

Smart and Stimuli-Responsive Nanocarriers: New types of nanocarriers are being developed which are responsive to endogenous stimulation (pH, enzymes) or external factors (light, temperature) for controlled drug release in affected brain portions. [Dhariwal *et al.*, 2025] ^[12] [Bhattacharya *et al.*, 2022] ^[27]

Multi-Targeted and Combination Therapies: Designing tiny, advanced systems that contain various natural components (phytochemicals) or even blend with conventional drugs. This can tackle several causes of neuro diseases at once and makes the therapy more effective. [Nahar *et al.*, 2025] ^[3] [Panda & Mohapatra, 2024] ^[9]

Green and Sustainable Nanotechnology: Plant-mediated synthesis techniques can be widely used for producing safer nanoparticles which will minimize the environmental impact. [Izadi *et al.*, 2024] ^[4]

Personalized Nanomedicine: Creation of disease profiles and customization of nanocarrier according to each patient will help to get precise therapy and improve clinical outcomes. [Dhariwal *et al.*, 2025] ^[12]

Clinical Translation and Regulatory Harmonization: Comprehensive preclinical and clinical investigation confirm the safety, effectiveness and the drug's activity in our body. It also makes the easier path toward regulatory approval and successful commercialization. [Kaspute *et al.*, 2025] ^[17] [Panda & mohapatra, 2024] ^[9].

Nanocarrier Surface Engineering: Improvement in specific targeting by the use of ligand or antibody conjugation, which will ultimately increase BBB crossing and neuron-specific delivery. [Dhariwal *et al.*, 2025] ^[12]

Table 3: Some herbal nanomedications that are present in the market

S. N	Type of Nanostructure	Trade name/Product	Active Ingredient(s)	Indication/Use	Company/Manufacturer	Reference
1.	Polymeric Nanoparticles	Nanocurcumin	Curcumin	Alzheimer's disease, neuroprotection	Sabinsa, C3 Nano	Moradi <i>et al.</i> (2020) ^[8]
2.	Polymeric Nanoparticles	Nano-ashwagandha	Withania somnifera	Stress and neuroprotection	Ayurveda and herbal supplementary firms	Moradi <i>et al.</i> (2020) ^[8]
3.	Polymeric Nanoparticles	Nano-green tea extract	Epigallocatech in gallate	Antioxidant, cognitivesupport	Nutraceutical companies	Moradi <i>et al.</i> (2020) ^[8]
4.	Polymeric Nanoparticles	Nano-ginger extract	Zingiber officinale	Neuroprotection, Anti-inflammatory	Herbal supplement companies	Panda & Mohapatra (2024) ^[9]
5.	Liposomal nanoparticles	Nanoliposomal turmeric-curcumin	Curcumin and turmeric extract	Neuroprotection, Oxidative stress	Nutraceutical companies	Panda & Mohapatra (2024) ^[9]
6.	Liposomal carriers	Ginkgosome \$^{\wedge}\{TM\}\$	Ginkgo biloba extract	Cognitive impairment, Dementia	Liposome Company	Panda & Mohapatra (2024) ^[9]
7.	Liposomal formulation	Nano-bacopa	Bacopa monnieri	Memory enhancement	Herbal product companies	Panda & Mohapatra (2024) ^[9]
8.	Lipid nanoparticles	Nano-resveratrol	Resveratrol	Neuroprotection, anti-aging	Various nutraceutical companies	Moradi <i>et al.</i> (2020) ^[8]
9.	Lipid nanoparticles	Nanosomal piperine	Piperine	Bio enhancer, neuroprotection	Nutraceutical companies	Moradi <i>et al.</i> (2020) ^[8]
10.	Lipid nanoparticles	Nanolipid Ginseng extract	Panax ginseng	Cognitive and physical performance	Traditional herbal medicine companies	Panda & Mohapatra (2024) ^[9]
11.	Lipid nanoparticles	Nano-pomegranate polyphenols	Punicalagins	Antioxidant, neuroprotection	Phytopharmaceutical manufacturers	Izadi <i>et al.</i> (2024) ^[4]
12.	Lipid nanoparticles	Nanolipid Gotu Kola	Centella asiatica	Brain health, neuroprotection	Herbal formulations	Panda & Mohapatra (2024) ^[9]
13.	Nanomicelles	CurcuWIN	Curcumin	Brain health, anti-inflammatory	Omniactive health technologies	Panda & Mohapatra (2024) ^[9]
14.	Solid lipid nanoparticles	NanoHerb (HerboNano)	Ayurvedic extracts (Aswagandha, Bacopa)	Neurodegenerative support	Various Indian Ayurvedic firms	Izadi <i>et al.</i> (2024) ^[4]
15.	Solid lipid nanoparticles	Nano-turmeric	Turmeric extract	Anti-inflammatory, neuroprotection	Nutraceutical companies	Panda & Mohapatra (2024) ^[9]
16.	Metal nanoparticles (Gold)	Svarna Bhasma	Ayurvedic gold Bhasma	Neurodegeneration (traditional)	Indian Ayurvedic pharmaceutical companies	Bhattacharya <i>et al.</i> (2022) ^[27]
17.	Polymer-lipid hybridnanoparticles	Nano-mixed flavonoids	Quercetin, Apigenin	Neuroprotection	Research-based nutraceuticals	Parvin <i>et al.</i> (2025) ^[28]
18.	Phytosome	Curcumin phytosome	Curcumin	Cognitive function enhancement	Indena, Naturex	Panda & Mohapatra (2024) ^[9]
19.	Polymeric and lipid nanoparticles	Herbal nano complex (multiple herbs)	Combination of neuroprotective herbs	Neurodegeneration management	Ayurvedic and nutraceutical companies	Izadi <i>et al.</i> (2024) ^[4]
20.	Nanoemulsion	Herbal nanoemulsion blends	Various multiple herbs	Cognitive health, neurodegeneration	Nutraceutical manufacturers	Moradi <i>et al.</i> (2020) ^[8]

Conclusion

Neurodegenerative diseases are the growing global health challenge with complex mechanisms, which limit current treatment options. Herbal nanomedications offer new hope by combining the natural power of plant-based compounds with advanced nanotechnology. This approach improves drug absorption, helps medicines to cross the blood-brain barrier, ensures targeted delivery, and allows controlled release accelerating the effectiveness while reducing side effects. Nanocarriers like polymeric, lipid-based, and green-synthesized nanoparticles have been used to deliver herbal compounds such as curcumin, resveratrol, and ginkgolides. These show strong antioxidant, antiinflammatory, and anti-amyloid effects that may slow down the progression of disease. The increasing number of patents and clinical studies highlights the growing interest and potential in this field. In future, developments can be done by including smart, responsive nanocarriers, AI-assisted design, and eco-friendly production methods. To achieve real-world use, challenges like regulatory approval, safety testing, and large-scale manufacturing must be handled with proper planning. Overall, herbal nanomedications mark a major step toward safer, more effective, and proper brain therapies, blending traditional plant wisdom with cutting-edge science to fight neurodegenerative disorders and improve quality of life.

Conflicts of Interest

The authors report no financial or any other conflicts of interest in this work.

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Author Contributions

All authors made substantial contributions to the conception and design of the review, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit it to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All authors are eligible for authorship as per the requirements/guidelines of the International Committee of Medical Journal Editors (ICMJE).

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