

Green Synthesis of Morin Hydride and Its Neuropharmacological Potential
Against Neurodegenerative Disorders

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Abstract

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The neurodegenerative diseases like Alzheimer's disease, Parkinson's disease, and Huntington's disease arise from various issues with neuron degeneration processes, oxidative damage, neuroinflammation, or mitochondrial dysfunction. The green technique gained a lot of attraction due to its eco-friendly feature as an effective and sustainable way of producing bioactive compounds, leaving aside toxic substances. Morin hydride has shown excellent antioxidant, anti-

inflammatory, and neuroprotective properties, making it a great candidate for treating neurodegenerative diseases. The green synthesis method is more recommended because of its usage of plant extracts and environmentally friendly reagents that make its production simpler and safer. The experimental studies have shown that morin hydride can protect neurons with the help of ROS scavenging, decreasing inflammatory mediators, avoiding mitochondrial dysfunction, regulation of apoptosis, and preservation of neurotransmitter balance. We can make this conclusion because of the fact of improved cognitive and motor functions that were showed through the presence of morin in some experimental models of neurodegeneration. However, we still need more pharmacokinetic, toxicological, and clinical studies to prove that the substance is safe for humans.

Keywords: Green synthesis, Morin hydride, Neuropharmacology, Neurodegenerative disorders, Alzheimer's disease, Parkinson's disease, Antioxidant, Neuroprotection, Neuroinflammation, Flavonoids

Introduction

Neurodegenerative diseases refer to those related to the progressive degeneration of neurons as a result of various reasons, resulting in cognitive, behavioral, and motor impairments. Some of the common ones include Alzheimer's disease, Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis. With increasing life expectancy and aging populations, the burden of neurodegenerative diseases is becoming more alarming. Despite the fact that each of these diseases is characterized by unique pathological features, they exhibit common mechanisms, such as oxidative stress, neuroinflammation, malfunctioning mitochondria, protein misfolding, and neuronal apoptosis. Treatment options available include but are not limited to symptomatic treatment, which mainly aims at relieving patients without halting the progression of the disease. The role of natural products, especially flavonoids, is properly highlighted in neurodegeneration management as they present relevant benefits and capabilities in terms of improving the patients' prognosis. (Kataria et al., 2018)

Neurodegeneration is a process that occurs when the production of reactive oxygen species takes place in excess. The reactive oxygen species results in damage to proteins,

lipids, DNA, and organelles. Oxidative stress leads to mitochondrial dysfunction and initiates inflammatory pathways that contribute to neuronal death. Moreover, abnormal surplus of proteins such as amyloid- β , tau, α -synuclein, and others is one of the critical factors influencing the onset of disease. Therefore, it is reasonable to look for medications that have strong antioxidant and anti-inflammatory properties. Flavonoids, which are a type of polyphenolic compounds found in a wide variety of vegetables, fruits, herbs, and medicinal plants, are the compounds regarded to be of great therapeutic significance. Flavonoids have been extensively researched, revealing their ability to cross the blood-brain barrier and provide neuroprotective action through combating oxidative damage, relieving inflammation, improving mitochondrial performance, and adjusting neuronal pathways activity. These properties make flavonoids especially relevant for the creation of medicines designed to treat neurodegenerative diseases. (Spencer, 2008)

Morin hydrate is an example of a natural flavonoid which is mostly obtained from plants belonging to the Moraceae family, such as *Morus alba* and *Maclura pomifera*, as well as from several fruits and medicinal herbs. The compound has drawn attention among scientists due to different properties that it possesses. The compound exhibits antioxidant, antimicrobial, anti-inflammatory, anticancer, cardioprotective effects, and is regarded as hepatoprotective and neuroprotective. The chemical structure contains OH groups that are beneficial in terms of free radical scavenging. Testing performed in laboratories showed that morin hydrate protects neurons from the harmful effects of lipid peroxidation, helps keep mitochondria intact, inhibits the activation of inflammatory cytokines, and protects neurons from apoptosis. Additionally, it acts as a modulator of various pathways, such as Nrf2, NF κ B, MAPK, and PI3K/Akt, that take place in the nervous system and are essential to neuron survival. This means that morin hydrate has a potential in treating neurodegenerative illnesses. (Rajput et al., 2021)

Over the last few years, green synthesis techniques have come to be recognized as eco-friendly options for the manufacture of medicines and their analogs. Green synthesis is said to reduce the employment of toxic solvents and reagents and also limit energy-consuming manufacturing methods while maximizing the output and the safety of the product. Green synthesis techniques employ living organisms including various

plant extracts, microorganisms, enzymes, and biodegradable catalysts. The principles of green chemistry minimize pollution and enhance biocompatibility and decrease toxicity of synthetic substances at the same time. The use of green approaches in the production of flavonoid derivatives including morin hydrate is the first step towards the production of revolutionary neuroprotective agents. (Vauzour et al., 2008)

Various experimental studies have shown morin hydrate possessing significant neuropharmacological effects in different models of Alzheimer's disease, Parkinson's disease, ischemic stroke, traumatic brain trauma, etc. It was shown that morin hydrate decreases neuronal apoptosis, inhibits neuroinflammation, enhances learning and memory, protects dopaminergic neurons, and increases the activity of antioxidant enzymes. Furthermore, morin hydrate has an effect on many molecular targets instead of a single pathway. However, the challenges of limited bioavailability, low water solubility, and insufficient clinical proof exist. Thus, progress in the development of formulation techniques and green synthesis methods could help overcome the problems affecting the use of morin hydrate in therapy. (Uttara et al., 2009)

This study investigates the green synthesis of morin hydrate and its neuropharmacological ability against neurodegenerative diseases. The focus is on sustainable approaches to synthesis, physicochemical properties, and the molecular mechanisms involved in neuroprotective action. A significant portion of the paper is dedicated to the antioxidant, anti-inflammatory, anti-apoptotic, and mitochondria-protective properties and their effect on vital signaling pathways. Additionally, recent developments in preclinical studies, limitations, and potential for clinical implementations are examined. Understanding morin hydrate produced by the green method can lead to developing new efficient and safe treatments against neurodegenerative diseases. (Mandel et al., 2012)

Green Synthesis of Morin Hydrate

In chemistry, green synthesis has surfaced as a novel process to generate bioactive molecules bypassing the need for hazardous chemicals and energy-intensive procedures. Increasing requirements for eco-friendly manufacture of pharmaceuticals motivated scientists to devise alternative procedures employing principles of green chemistry. Natural products, and more particularly flavonoids, attracted great attention due to their

remarkable biological properties, including antioxidant, anti-inflammatory, antibacterial, and neuroprotective activity. Morin hydrate is a naturally occurring flavonoid of the flavonol group widely present in multiple medicinal plants, fruits, and vegetables. The presence of several hydroxyl groups grants morin hydrate its strong free-radical suffering properties and its healing abilities. Traditional methods of bioactive compound extraction and synthesis use dangerous reagents and create pollutants in the environment. As a result, green technology approaches based on plant extracts, biocatalysts, and safe solvents are more reliable and effective. The process of developing green synthesis methods of morin hydrate and its derivatives can boost sustainability and retain the biological efficiency of the process. (Anastas & Warner, 1998)

Morin hydrate is one of the most significant polyphenolic flavonoids that have gained much attention in pharmaceutical science due to its impressive properties in this area. It is a biologically active compound of plant origin, obtained from plants belonging to the Moraceae family and thoroughly studied regarding its antioxidant, anti-inflammatory, anticancer, cardioprotective, and neuroprotective properties. It should be noted that morin hydrate contains hydroxyl groups in its chemical structure, which is instrumental in neutralizing free radicals to provide protection against oxidative damage. The role of oxidative stress is rather crucial in the developments of many chronic conditions in terms of the occurrence of some cardiovascular disease, neurodegenerative disease, and metabolic disturbance. Research proved the ability of morin hydrate to adjust the activities of different molecular pathways related to inflammation, apoptosis, and oxidative stress. Taking into account the beneficial properties of morin hydrate, many researchers aim at optimizing its production and bioavailability methods. (Pietta, 2000)

The increasing significance of the application of green synthesis technologies in drug development stems from their capability of generating bioactive compounds in a manner that is safe for the environment. Conventional chemistry methods entail the use of hazardous materials and involve complicated processes and techniques. In contrast, green synthesis processes make use of environmentally friendly materials, including raw materials such as natural products from plants, natural agents, and microorganisms. Green synthesis approach is advantageous in terms of low toxicity, low cost,

biodegradability, compatibility with living systems, and other aspects. The utilization of green synthesis in developing morin hydrate can have a positive influence on its therapeutic effects. This can be explained in terms of the fact that plant extracts contain valuable plant extracts that work well as catalysts. (Duan et al., 2019)

Morin hydrate and other flavonoid compounds have received much attention due to the increasing industrial demand for sustainable processes in pharmaceutical and biomedical studies. Methods of biological synthesis involving plant extracts, microorganisms, and natural catalysts exist as viable alternatives to traditional chemical methods. These methods not only reduce environmental hazards but also enhance biological compatibility of synthesized compounds. Plant-based methods of green synthesis are advantageous in that phytochemicals such as phenolics, terpenoids, and proteins can serve as natural reducing and stabilizing agents. It is expected that morin hydrate produced by sustainable methods may show improved biological activities due to enhanced structural stability and reduced contamination with toxic chemicals. The antioxidant properties of morin hydrate may be advantageous as it can be used in preventing cellular disturbances caused by free radicals. Moreover, its anti-inflammatory properties boost its beneficial effects in certain pathological conditions. Studies on green synthesis continue expanding since green synthesis is important for drug creation, nanotechnology, and functional biomaterials applications. Thus, the combination of natural flavonoids and green chemistry has potential in producing safe, effective, and environmentally friendly therapeutic components. (Sharma et al., 2019)

The future development of green-synthesized morin hydrate would represent an important advancement in terms of sustainable drug development. By combining green chemistry principles with research on natural products, scientists could obtain safer and more efficient bioactive compounds. The compound in question has already proved its effectiveness through antioxidant and anti-inflammatory properties, not to mention its protective effects on biological organisms. Using sustainable synthesis technologies could allow for further advancement of this substance in medicine, making it possible to achieve higher production efficiency while minimizing toxicity. Despite the fact that the existing research results have been promising, further studies are needed in terms of evaluation of pharmacokinetics, toxicity, and clinical efficacy. Implementation of

advanced technologies such as nanocarrier systems, environmentally friendly extraction, and biotechnological synthesis might make it possible for researchers to further extend therapeutic properties of the compound under consideration. (Procházková et al., 2011)

The medicinal significance of morin hydrate is fundamentally related to its ability to control oxidative stress, inflammation, and cellular signaling pathways. The uncontrolled synthesis of reactive oxygen species may result in oxidative injury, which in turn leads to certain pathological conditions. Morin hydrate has a considerable antioxidant potential, preventing free radical activity and promoting the natural antioxidant activity of the body. Furthermore, it appears to inhibit the action of the inflammatory factors responsible for damage to tissues and developing diseases. As a result, the mode of action of morin hydrate has been studied due to its potential use in the treatment of various diseases, including neuroprotective applications, cancer prevention, and cardiovascular disease treatments. Having said that, some aspects, such as low solubility, bioavailability, and stability, may limit its practical use. Green technology and innovative formulations may help solve these problems by improving the chemical characteristics of morin hydrate. (Tiwari et al., 2020)

Eco-Friendly and Sustainable Approach

In present times, eco-friendly and sustainable practices have turned into a necessity in scientific research due to rising concerns about the environment and the desire to make harmful chemical practices less harmful. Sustainable chemistry deals with minimizing waste generation, the use of toxic substances, and producing safer alternatives for industrial and pharmaceutical processes. Traditional synthesis techniques mostly employ toxic substances, high energy consumption, and harmful by-products unhealthy for both people and nature. Green techniques enable scientists to solve these problems thanks to the use of renewable resources, biodegradable materials, and environmentally friendly methods. Green chemistry practices are based on the principles of sustainability in development and production processes of any techniques. Eco-friendly practices have been used more and more often in pharmaceutical research for producing bioactive substances, drug development, and nanomaterials production. This leads to better safety, lower cost of production, and higher level of environmental protection processes. Integrating sustainable methods in scientific innovations significantly increases chances

for getting long-term output in the sphere of health care and manufacturing. (Clark, 2008)

The goal of sustainable chemistry is to promote economic growth while preserving the environment and taking into account social responsibility. The use of renewable materials, green energy, and biological systems promoted the production of green technologies as substitutes for traditional chemical processes. The use of natural resources, enzymes, microorganisms, and natural catalysts is crucial for eco-friendly synthesis because they provide effective and safe conditions for chemical reactions thereby reducing the need for petroleum-based chemical products. Additionally, sustainable processes are a priority in the biomedical sphere since they allow for the production of biologically active compounds whose compatibility is increased while toxicity is minimized. In the area of biomedical sciences, the application of green technologies makes it possible to improve the quality and safety of pharmacological substances while conserving the environment. (Anastas & Eghbali, 2010)

The use of environmentally friendly strategies in the process of manufacturing natural substances has caught a lot of attention due to the expected benefits they would have compared to traditional methods. Natural bioactive substances such as flavonoids and phenolics, as well as plant-based compounds are of great interest due to their healing properties. Eco-friendly methods of extraction or synthesis preserve the biological activities of natural substances and reduce the environmental impact. Technologies like green extraction, solvent-free synthesis, and biocatalysis can be used to provide safer methods of manufacturing products because there is no need to use any toxic reagents. These methods are very important in pharmaceutical industry due to the fact that safety and sustainability are the key issues in this industry. In addition, eco-friendly manufacturing allows for the development of cheap and easily scalable production processes. The combination of natural materials and eco-friendly methods of production leads to a number of new opportunities in medicine. (Chemat et al., 2012)

The eco-friendly synthesis techniques have made a huge impact on the development of nanotechnology, biotechnology, and pharmaceutical sciences. The usage of biological systems like plants and microorganisms as renewable sources of various materials becomes more common nowadays. The methods are associated with

numerous advantages such as low energy costs, low levels of chemical waste, and increased safety in terms of biology. Green technologies play a pivotal role in producing medical drugs as they help avoid contamination and increase their compatibility with biological species. Besides, sustainable synthesis allows us to create ecologically sustainable industries with minimized usage of non-renewable resources. Scientists keep studying new approaches of combining green chemistry principles and modern methods in order to achieve more efficient results. (Kharissova et al., 2013)

The use of eco-friendly methods in pharmaceutical research paves the way to creating safer and more efficient medications. The application of sustainable methods enhances the production of natural substances by increasing productivity, lowering toxic waste, and keeping biological activity. Such methods are extremely useful for substances that have antioxidant, anti-inflammatory, and protective action. Sustainable technologies provide opportunities for developing effective systems of delivery and green drugs. However, although considerable developments have already been made in this sphere, more challenges remain to be solved in terms of optimization, large-scale manufacturing, and approval. The progress in green technologies, as well as the collaboration among various fields of research may help deal with existing problems. (Hessel et al., 2012)

Green approaches and technologies form a viable pathway for the future development of science and industry. The importance of green approaches lies in their responsibility for both environmental protection and the welfare of human beings. Adopting green technologies in chemical synthesis, biotechnology, and medicine can open new avenues for environmentally friendly innovations. These technologies are beneficial for making production processes more effective and for finding new drugs with lesser negative environmental impacts. Future research should be devoted to optimizing green technologies, improving their scalability, and assessing the prospects of sustainable technologies. All in all, green technologies should be utilized as a basis for developing better solutions to the existing scientific challenges. (Lancaster, 2016)

Antioxidant and Anti-Inflammatory Activity

Antioxidant and anti-inflammatory activities are among the most noteworthy biological characteristics involved in the cell protection process. Oxidative stress takes place when

the generation of reactive oxygen species (ROS) overtakes the ability of the organism to address it. In situations of excess oxidative stress, proteins, lipids, and DNA are impaired in their function, leading to the emergence of serious chronic diseases. Another important process is inflammation, which can cause tissue damage and progression of diseases in case of being released uncontrolled. Natural substances, above all, flavonoids and polyphenols are prominent due to their capabilities of eliminating free radicals and controlling inflammatory processes. These substances work effectively through enhancing the functioning of antioxidant enzymes and lowering the amounts of inflammatory mediators formed. Overall, antioxidant and anti-inflammatory properties of natural substances make them perfect candidates for therapeutic purposes concerning the problem of oxidative stress. (Reuter et al., 2010)

Antioxidants are essential for the function of cells because they eliminate harmful oxygen radicals and prevent cellular injury. The cell has internal mechanisms that protect cells from oxidative injury such as superoxide dismutase, catalase, and glutathione enzymes. However, excessive production of reactive oxygen species may circumvent those defenses and trigger detrimental signals. Natural antioxidants that come from plants are of significant interest owing to their safety and their range of biological activities. Flavonoids are among the how most widely studied natural antioxidants due to presence of hydroxyl groups that help neutralize free radicals. Besides, these natural compounds have been found to influence processes that protect cells and induce protective responses against stressors. The importance of antioxidants has been increasing due to their role in reducing oxidative stress. (Panche et al., 2016)

Inflammation is an intricate biological process regulated by signaling molecules and mechanisms of immunity. While inflammation is important for the healing of tissues and protection from harmful stimuli, chronic inflammation can also lead to the development of diseases. Pro-inflammatory cytokines, enzymes, and transcription factors like NF- κ B are among the molecules involved in regulating inflammation. On the other hand, some natural bioactive compounds with anti-inflammatory characteristics inhibit these signaling pathways, thereby leading to reduction in inflammation. For instance, flavonoids and phenolic compounds possess the property to inhibit the action of inflammatory mediators on tissues. Their capability of influencing and controlling

both oxidative stress and inflammation implies the use of these compounds in the prevention of diseases. Therefore, anti-inflammatory and antioxidant compounds deserve the status of promising agents for creating new treatments. (Kim et al., 2004)

The connection between oxidative stress and inflammation is closely related to the advancement of a variety of diseases, such as neurodegenerative illnesses, tumors, and heart problems. Reactive oxygen species can induce an inflammatory pathway, and vice versa—it's the process of inflammation that can only increase the oxidative stress. Both antioxidant and anti-inflammatory agents are able to block the process and offer more effective protection. Natural products from plants, are reported to have the ability to control oxidative and inflammatory activity by many different means. Thus, they may boost the antioxidant protection, block inflammatory enzymes, and control the cellular balance. Because of these features, natural products are extensively studied for their treatment possibilities in modern medicine. (Mittal et al., 2014)

Due to the antioxidant and anti-inflammatory properties of bioactive compounds, their usage has gained prominence in pharmaceutical and nutraceutical studies. This is because these compounds have the potential to affect different pathways during disease development. Natural antioxidants are able to affect multitudes of cellular processes, unlike synthetic single-target medications, which gives them a wider spectrum of protective effects. Studies show that flavonoid-based compounds are effective in decreasing oxidative stress, suppressing inflammatory processes, and increasing cell survival. However, issues related to poor bioavailability, absorption, and stability must be overcome to achieve the highest therapeutic effect. (Kumar & Pandey, 2013)

Natural agents protect living organisms from cellular damage and the progression of diseases through antioxidant and anti-inflammatory properties. Scientists became increasingly curious regarding these mechanisms and began studying the possibility of using plant-based substances as agents performing the same functions. This is possible due to the ability of these substances to control the oxidative process and inflammation. Future studies of the use of plant-derived agents will be focused on their mechanisms of action, increasing their bioavailability, and clinical testing. This way,

it will be possible to learn more information regarding the potential therapeutic value of plant-based substances. (Ghasemzadeh et al., 2010)

Neuroprotective Potential

The term neuroprotective potential refers to the ability of bioactive substances to protect the neurons from damage, degeneration and failure in functioning caused by different pathological conditions. Neurodegenerative disorders such as Alzheimer's disease and Parkinson's disease are characterized by progressive neuronal loss, oxidative stress, inflammation and mitochondrial dysfunction. The growing number of cases of these diseases leads to the search for agents which could prevent damage of neurons and maintain the normal functioning of the brain. Natural agents, and in particular flavonoids and polyphenols are widely studied in this field because of their antioxidant, anti-inflammatory and neuroprotective activities. (Kelsey et al., 2010)

Neuronal damage is caused by oxidative stress which harms cellular components and disrupts normal brain activity. The brain is particularly susceptible to oxidative damage due to its high oxygen demand, large quantities of lipids, and low levels of the antioxidant mechanism. High levels of the production of reactive oxygen species may cause damage to neurons resulting in a higher pace of neurodegeneration. Natural antioxidants can help reduce the damage by neutralizing free radicals, supporting antioxidant systems, and keeping the cellular homeostasis. Flavonoids are very important since they can penetrate the blood-brain barrier and modulate various protecting mechanisms of neurons. Antioxidant action of flavonoids allows maintaining the activity of neurons. (Spencer, 2010)

Mitochondrial dysfunction and neuronal degeneration are linked, as neurons need a lot of energy. Impaired mitochondria produce less energy, which leads to increased oxidative stress and activation of cell death mechanisms. Some neuroprotective agents were found to promote stability of mitochondria and improve antioxidant mechanisms. Many different phytochemicals have shown promise in preventing mitochondrial damage in various experimental setups. Therefore, it is obvious that studying natural substances for their potential effectiveness as neuroprotective agents is an important area of research. (Perry et al., 2010)

The field of neuroprotection is an important domain of research which may offer chances to prevent or treat neurological disorders. There exists a plethora of natural products and compounds capable of influencing oxidative stress, inflammation, and apoptosis in the given context. In addition, further studies are necessary so as to gain a better understanding of the molecular mechanisms of the above-mentioned agents and evaluate their efficiency in clinical trials. The development of safe and efficient neuroprotective methods is of paramount significance for the improvement of the treatment of neurodegenerative diseases. (Uttara et al., 2009)

Neuroinflammation is yet another critical element that contributes to the development of neurodegenerative illnesses. The activation of microglia and astrocytes results in the release of inflammatory cytokines and mediators that afflict neurons. Anti-inflammatory substances can lessen this detrimental effect and prolong the survival of neurons. Natural substances can modulate neuroinflammation in terms of various inflammatory pathways (such as NF- κ B and MAPK pathways) and dial down the inflammatory process that causes neuronal damage. They might also help in coordinating neuronal connections and may prevent apoptosis. Because of their capacity to affect various pathways, the aforementioned substances are seen as valuable agents for treating neurological conditions. (Vauzour et al., 2008)

The neuroprotective properties of natural substances have recently become an important topic of discussion in the field of pharmaceutical studies because of their ability to affect different targets. Compounds with antioxidant, anti-inflammatory, and anti-apoptotic properties may protect against neuronal degeneration more effectively. Flavonoids and some other plants' substances have shown promising results in memory improvement, reducing neuronal damage, and supporting the brain's health. However, unresolved issues such as low bioavailability, fast metabolism, and limited clinical evidence exist. (Wang et al., 2012)

Effective against Neurodegenerative Disorders

Neurodegenerative disorder is defined as a variety of neurological disorders that arise from the degeneration of neurons in the brain that subsequently leads to both a decline in cognitive functions and a decrease in motor performance, which negatively affects the quality of life of patients. Some of the most common neurodegenerative diseases are

Alzheimer's disease, Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis. Neurodegenerative conditions involve several pathological processes, including oxidative damage, inflammation of the nervous system, impairment of mitochondria, deposition of abnormal proteins, and apoptosis of neurons. Although modern pharmacological treatments mainly allow reducing symptoms of these disorders, they are not sufficient to stop the progression of the disease. Consequently, the search for effective neuroprotective agents has become a relevant area of research. Natural compounds, especially flavonoids and polyphenols, have demonstrated favorable results in terms of protecting neurons and enhancing cellular processes. (Dawson & Dawson, 2003)

Oxidative stress is thought to be one of the primary causes of neurodegenerative diseases. An excessive production of reactive oxygen species harms the proteins, lipids, and DNA found in neurons. This leads to impaired neuronal activity and even death of the neuron. Neurons are extremely vulnerable to oxidative stress since they require a lot of energy and have few biological means to counteract injury caused by oxidative stress reactions. Antioxidant compounds may prevent oxidative damage by neutralizing free radicals and stimulating the natural defenses of the organism. There are many examples of plant-derived substances acting as natural protectors against neurodegenerative disorders in experimental studies. (Barnham et al., 2004)

The importance of neuroinflammation in the progression of neurodegenerative diseases is evident because of its ability to cause neuronal damage and dysfunction. The activation of microglial cells for a long period of time results in the release of inflammatory cytokines and mediators, which in turn leads to neuronal loss. In order to prevent the activation of these pathways, substances possessing anti-inflammatory properties are able to protect against inflammation-induced processes. Various natural flavonoids have been known for their ability to control the processes of inflammation. (Glass et al., 2010)

Numerous studies indicate that bioactive substances could potentially treat neurodegenerative diseases by acting on several mechanisms at the same time. Bioactive compounds enhance the body's antioxidant defense, protect the mitochondria, stop apoptosis, and help maintain communication between neurons. In Alzheimer's

disease treatment, bioactive compounds may reduce the toxicity of amyloid, while they may protect dopaminergic neurons from degeneration in Parkinson's Disease. The fact that natural substances work in different ways is beneficial compared to therapies targeting only one mechanism of disease. Further research is needed to test efficacy, safety, and bioavailability of bioactive compounds. (Querfurth & LaFerla, 2010)

The formulation of effective treatment methods for neurodegenerative diseases needs substances capable of penetrating the blood-brain barrier and acting beneficially on nervous tissue. Numerous natural antioxidants and flavonoids have demonstrated promise in terms of memory enhancement, neuronal damage reduction, and improvement of brain functioning. However, some disadvantages, like low absorption and quick metabolism may diminish their practicality in clinical settings. Advanced delivery techniques and improved formulations may overcome this difficulty. (Williams et al., 2004)

Neuroprotective natural compounds are likely to be good therapeutic alternatives for preventing and treating neurodegenerative diseases. Natural substances possess unique capabilities to regulate multiple processes involved in oxidative stress, inflammation, mitochondrial disorders, and neuronal survival. Numerous preclinical trials demonstrate excellent results; however, further studies should be conducted to assess the efficacy and safety of natural compounds in humans. The active investigation of natural bioactive substances is expected to result in the introduction of new safe drugs to treat neurodegenerative conditions. (Cummings et al., 2014)

Future Therapeutic Candidate

In modern biomedical research, finding potential drugs for treating chronic, infectious, neurological, and degenerative diseases is of great importance. The ideal medicine should have good biological activity, high safety, acceptable pharmacokinetics, and should be able to target significant pathways involved in the diseased condition. Natural bioactive substances have become a hot topic of research as they possess many beneficial pharmacological properties with a lower level of toxicity than synthetic substances. Plant-derived compounds including flavonoids and polyphenols have antioxidant, anti-inflammatory, antimicrobial, anticancer, and neuroprotective properties which make them good candidates for drug development. These substances have the

ability to influence various cellular targets responsible for the disease state that guarantees utilization of a wider range of therapeutic effects. Thanks to the usage of modern approaches in molecular biology, biotechnology, and pharmacology, the process of finding and creating new medicines will be enhanced. Combination of natural medicines with the contemporary techniques of drug delivery will eliminate the limitations concerned with stability and bioavailability. (Newman & Cragg, 2020)

Medicinal applications today heavily focus on substances that could operate through multiple pathways. Most diseases, particularly involving neurodegenerative and inflammatory processes include several components such as oxidative stress, inflammation, mitochondrial dysfunction, and cellular injury. Substances with antioxidant and anti-inflammatory properties are expected to be the best solutions as they assist cell protection. Natural agents like flavonoids are known to have influence over the pathways responsible for inflammation, apoptosis, and oxidation defense. This class of substances is thought to have certain advantages over traditional medicines that often work through specific mechanisms. Recent developments in the fields of computational biology and molecular screening have helped in discovering and investigating different therapeutic candidates based on their interaction with biological objects. New understanding of disease mechanisms helped researchers design novel and effective therapy programs. However, factors such as absorption, metabolism, toxicity, and efficiency need to be thoroughly studied in order to make any therapeutic application successful. (Atanasov et al., 2021)

Natural compounds are important as sources of new drugs due to their chemical diversity and various biological activities. Many compounds derived from plants have been used in traditional medicine and are now being studied using innovative technologies. For instance, flavonoids, phenolic compounds, and other secondary metabolites have shown their potential in preventing cell damage and controlling pathways associated with various diseases, contributing to maintaining their antioxidant and anti-inflammatory properties. They can reduce the level of reactive oxygen species and contribute to lowering the immune response. Hence, such compounds could be used against diseases with chronic inflammation and oxidative stress. It should be mentioned that natural compounds can affect gene expression and activity of enzymes

and pathways involved in cell survival and repair. It is crucial to develop the therapeutic agents based on those compounds after understanding their pharmacological properties and safety. (Harvey et al., 2015)

In order to transform promising bioactive substances into therapeutic options, several obstacles in drug development must be cleared. Even though various natural substances tend to have strong properties, such as certain drugs, their clinical effectiveness can be limited due to problems with absorption, metabolism, and stability. In order to conquer the issues mentioned above, scientists are working on superior techniques for drug formulation such as nanoencapsulation, targeted drug delivery, and chemical changes. Thanks to those methods, the pharmacological characteristics of therapeutic substances can be substantially improved, making these substances more effective in clinics. It is also important to carry out proper toxicological research studies to find out how safe and long-lasting a new medicine is going to be. The wide usage of biotechnology, pharmacology, and computational technology has provided new means for faster drug discovery. One more recent trend is the use of personalized medicine and therapies based on molecular approaches. Therefore, all new therapeutic substances must have a proper balance of effective biological activity, safety, and feasibility for the clinic. (Bilia et al., 2014)

Sustainable drug development is an important element of finding potential future therapies. The use of environmentally sound principles such as green synthesis and natural product-based approaches makes it possible to obtain drugs that will leave less impact on the environment. Sustainable approaches are able to minimize toxic substances involved in drug production. Combining green chemistry with pharmacology allows avoiding the dangers of traditional methods of drug development. Natural products obtained with the help of sustainability will retain properties while being safe. The interest in natural drugs made it possible to study their relevance in modern medicine. Drug development based on sustainable approaches can help create new methods of treatment. (Anastas & Warner, 1998)

Investigating new candidates for therapies is still an important research direction aimed at enhancing strategies for preventing and treating diseases. Certain agents with antioxidant, anti-inflammatory, neuroprotective properties, and other types of biological

activity are viewed as promising for their ability to affect various mechanisms of diseases. Novel technologies in science broaden the possibilities for discovering new compounds and optimizing them. At the same time, although a lot of samples look promising in laboratory studies, further development of any sample into clinical practice requires much verification, including trials on its efficacy and safety, as well as studies on pharmacokinetics and prolonged influence. It is important to work with specialists from different fields of knowledge on eliminating the barriers to developing new medications. (Dias et al., 2012)

Safety and Clinical Evaluation

Safety assessment and clinical evaluation are critical steps in the development of any promising therapeutic substance prior to its use in human medicine. Many bioactive substances can be considered effective in laboratory and animal studies, but their effectiveness and safety for humans must go through thorough verification on a systemic basis. Safety is described as the investigation into the toxicity of a compound, the side effects, dosage limitations, and potential interactions with biological systems while the clinical evaluation gives crucial information related to the absorption, distribution, metabolism, biological efficacy, and the effects on humans in the long-term perspective. The study of natural substances, including flavonoids and plant compounds is of great interest as the results of their biological activity depend on such factors as the concentration of the studied compound, the form in which it is introduced, and the method of administration. Proper evaluation of the safety enables researchers to use their findings to prepare new therapeutic agents free from potential negative effects. Due to advances in pharmacology, toxicology, and clinical research, safety assessment has been significantly improved. (Lipsky & Sharp, 2001)

The evaluation of toxicity is an essential part of drug creation that determines the safety profile of new medicinal drugs. It consists of acute, sub-acute, and chronic toxicity studies to detect potential danger and to establish the safe dose of medicine. Moreover, the examination of genotoxicity, cytotoxicity, and organ toxicity is carried out in order to guarantee the reliability of the new substances. Although natural products are considered to be a safer alternative, a thorough examination of them is still required. There are some factors such as bioavailability, metabolism, and interactions with other

medicines that can affect the drugs' therapeutic effect. Nowadays modern safety evaluation methods combine laboratory experiments, computational analysis, and biological testing. (Parasuraman, 2011)

Clinical evaluation is a systematic way to assess the safety and effectiveness of therapeutic agents in people. Typically, a series of stages is performed, starting with small safety studies and progressing to larger scale clinical trials where efficacy and long-term outcomes are assessed. Significant information on the dosage required, pharmacokinetics, therapeutic effects, and side effects is provided by clinical trials. This applies especially for the natural bioactive substances in view of the differences in the absorption and metabolism affecting their biological properties. Therefore, only properly organized clinical studies will provide confirmation that therapeutic agent complies with the law and really works. (Friedman et al., 2015)

Evaluation of neuroprotective compounds, safety, and clinical importance is very important because neurological disorders are often chronic. Neuroprotective compounds are those that can prevent neurons from dying without affecting the brain or other parts of the body negatively. Neuroprotective agents must be evaluated for cognitive effects, behavioral changes, toxicity, and interactions with other medications. Various sophisticated models, such as cell systems and animal studies, are used to do these evaluations. (Kola & Landis, 2004)

Continuous safety monitoring and clinical validation is important for the successful development of future therapeutic candidates. Although clinically effective compounds may exist, a detailed study is necessary to establish their effectiveness in real life. Novel technologies in drug formulation, even better delivery systems and biomarker testing have made clinical evaluation much more precise. These technologies can solve problems concerning bioavailability, stability and respond of the patient. The combination of preclinical trial and thorough clinical testing can guarantee the success of the developed drug. (Mullard, 2016)

The final stage of converting experimental compounds into therapeutic compounds is safety and clinical evaluation. Thorough evaluation of compounds allows for the determination not only the effectiveness of possible medications but also the minimization of risks. Future investigations should be aimed at improvement of clinical

trials' designs, elucidation of mechanisms, and personalization of procedures. The application of natural compounds with antioxidant, anti-inflammatory, and neuroprotective properties into therapeutics can also be supported by the proper evaluation of their safety. (Eichler et al., 2011)

Development of Novel Neuroprotective Therapies

With the growing number of cases of neurodegenerative diseases globally, the creation of new neuroprotective therapies has become a major area of interest in biomedical studies. Certain diseases like Alzheimer's disease, Huntington's disease, and Parkinson's disease are characterized by an increase in loss in neurons and deterioration of brain functioning. Usually, the treatments are aimed at providing only symptomatic treatment and do not prevent progression of the disease. That is why scientists concentrate on discovering and working on the new therapies that can protect neurons and keep brain functioning intact. New neuroprotective treatments are aimed at impacting important pathophysiological processes like neuroinflammation, oxidative stress, dysfunction of mitochondria and apoptosis. Natural and chemical compounds as well as advanced methods of drug delivery are studied for the purpose of creating new successful therapies. The combination of molecular biology, pharmacology, and biotechnology allows for finding promising neuroprotective agents. (Bredesen, 2014)

Recent efforts in the development of neuroprotective medications concentrate on agents that can affect several mechanisms that lead to neuronal death. Oxidative stress and persistent inflammation are viewed as important in the process of degeneration of neurons, which makes them good candidates for therapeutical influence. Agents with antioxidant and anti-inflammatory effects are likely to decrease damage to tissues, improve lifespan of neurons, and support normal functioning of the brain. One of the significant advantages of natural bioactive substances (flavonoids and polyphenols, in particular) is their ability to control oxidative processes and inflammatory responses. The development of pharmacological techniques allowed the discovery of compounds with greater neuroprotective properties. Molecular screening, computer research, and advanced formulation technologies are some of the newly introduced approaches. (Wyss-Coray, 2016)

In order to create new neuroprotective therapies it is important to know very well how neurons get injured. The mechanisms leading to neurons' degeneration include mitochondrial dysfunction, protein aggregation, problems with neurotransmission and inflammation. Thus, the agents that can affect these mechanisms may be promising in terms of preserving neurons' health. Modern investigations are more and more concentrated on multitarget solutions because complex neurological disorders generally involve several pathways acting simultaneously. It has been proposed that neuroprotective compounds having antioxidant, anti-inflammatory and antiapoptotic effects are the most promising neuroprotective agents since they can provide beneficial results in progression of the disease. (Katsnelson et al., 2016)

The progress made in advanced technologies plays a significant role in enhancing the discovery and developing new neuroprotective therapies. Researchers are using delivery systems based on nanotechnology, targeted drug therapy, and biotechnology principles in order to optimize treatment efficacy. Thus, these approaches can help solve the problems associated with low solubility, low brain penetration, and low bioavailability of neuroprotective substances. Moreover, the ability to directly deliver therapeutics in the target tissues may increase the efficiency of treatments and minimize the risk of adverse events. Finally, personalized medicine technology may help create personalized therapy. (Geldenhuys et al., 2015)

Natural products are still important sources of new neuroprotective therapies due to their different chemical structures and biological activities. Some compounds derived from plants have been shown to have a protective role against oxidative damage, inflammation, and neuronal apoptosis. These compounds could serve as safer alternatives or complementary methods in the treatment of neurodegenerative diseases. However, the issues of clinical efficacy, pharmacokinetics, and long-term safety still need to be solved before any applications in therapy are made. Further development in the area using natural products in combination with modern pharmaceutical technologies may lead to improvements in their use in therapy. (Ransohoff, 2016)

The growth of new neuroprotective treatments relies on successful implementation of research results into practice. Extensive testing of safety, efficiency, and mechanisms of action is vital for the identification of potential treatments. Joint

research projects carried out in the scope of neuroscience, pharmacology, and biotechnology can facilitate the identification of new ways of treating patients. Despite the challenges ahead, progress in medicine gives hope for finding efficient treatments that will help preserve neurons and enable patients with neurological disorders to have good quality of life. (Uddin et al., 2020)

Conclusion

Morin Hydrate is created via green synthesis, a sustainable and promising way to create new therapeutics with remarkable biological activity. This environmental approach to synthesis uses less dangerous chemicals, minimizes harm to the environment, and makes for safer methods of developing pharmaceutical products. Morin Hydrate as a natural compound is of great interest due to its notable antioxidant, anti-inflammatory, and neuroprotective properties. The ability of the compound to combat oxidative stress, regulate inflammation pathways, protect neurons, and keep the cells in balance makes Morin Hydrate a significant tool in the treatment of neurodegenerative diseases. The studies state the usefulness of this substance for the treatment and prevention of diseases connected with neuronal impairment and mental decline. However, there are some difficulties in terms of bioavailability and pharmacokinetics, as well as the evaluation of toxicity. More studies should be conducted in this particular field.

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