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Research Article

PROTECTIVE EFFECTS OF ALPINIA GALANGA ON BRAIN AGING INDUCED BY D-GALACTOSE

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ABSTRACT

Brain aging is a complex process characterized by cognitive decline and neuronal deterioration, often exacerbated by oxidative stress and inflammation. D-Galactose-induced brain aging is a widely used model to study these effects. This study investigates the protective effects of Alpinia galanga, a medicinal plant known for its antioxidant and anti-inflammatory properties, against D-Galactose-induced brain aging.

In this study, male Wistar rats were administered D-Galactose to induce brain aging, followed by treatment with Alpinia galanga extract. Behavioral assessments, including memory and cognitive function tests, were conducted to evaluate the impact of the treatment. Additionally, biochemical analyses were performed to measure oxidative stress markers, antioxidant enzyme activities, and inflammatory cytokine levels in the brain.

The results demonstrated that Alpinia galanga significantly improved cognitive function and reduced memory deficits in the D-Galactose-treated rats. Furthermore, the extract effectively decreased oxidative stress markers, enhanced antioxidant enzyme activities, and reduced inflammation in the brain tissue. These findings suggest that Alpinia galanga exerts neuroprotective effects, potentially through its antioxidant and anti-inflammatory properties, thereby mitigating D-Galactose-induced brain aging. This

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study highlights the therapeutic potential of Alpinia galanga as a natural intervention for combating age-related cognitive decline and offers insights into its mechanisms of action in neuroprotection.

KEYWORDS

Alpinia galanga, brain aging, D-Galactose, neuroprotection, oxidative stress, cognitive decline, antioxidant, inflammation, neurodegeneration, rat model.

INTRODUCTION

As the global population ages, understanding and mitigating the effects of brain aging has become increasingly critical. Brain aging is associated with a gradual decline in cognitive functions, such as memory and learning, largely driven by oxidative stress, inflammation, and neurodegeneration. One widely used experimental model to study brain aging is the D-Galactose-induced aging model, which simulates age-related cognitive impairments and neurobiological changes by elevating oxidative stress and inflammation levels in the brain. This model helps elucidate the underlying mechanisms of age-related cognitive decline and test potential therapeutic interventions.

In recent years, there has been growing interest in natural compounds with potential neuroprotective properties as alternatives or adjuncts to conventional treatments. Alpinia galanga, a plant traditionally used in various cultures for its medicinal properties, has garnered attention for its antioxidant and anti-inflammatory effects. Its rhizome contains bioactive compounds such as flavonoids and essential oils, which are believed to exert protective effects on the brain by combating oxidative stress and reducing inflammation.

The protective effects of Alpinia galanga against neurodegenerative conditions are of particular interest given its potential to address multiple facets of brain aging simultaneously. By evaluating its effects in the D-Galactose-induced aging model, this study aims to assess the efficacy of Alpinia galanga in preserving cognitive function and mitigating the biochemical and molecular markers of brain aging. This research

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seeks to provide valuable insights into the therapeutic potential of Alpinia galanga and contribute to the development of natural, effective strategies for combating age-related cognitive decline.

METHOD

To evaluate the protective effects of Alpinia galanga on brain aging induced by D-Galactose, a comprehensive experimental approach was employed. The study utilized male Wistar rats, which were randomly assigned to four groups: a control group, a D-Galactose-induced aging group, an Alpinia galanga extract-treated group, and a D-Galactose + Alpinia galanga extract-treated group. Brain aging was induced using D-Galactose, which was administered intraperitoneally at a dose of 150 mg/kg per day for 8 weeks. This regimen has been shown to elevate oxidative stress and mimic age-related cognitive decline in rodents.

Alpinia galanga extract was prepared from the dried rhizomes of the plant using a standardized extraction method involving solvent extraction. The extract was administered orally to the treatment groups at a dose of 200 mg/kg per day for the same duration as the D-Galactose administration. This dose was selected based on preliminary studies and literature suggesting its efficacy in reducing oxidative stress and inflammation.

Cognitive function was assessed using a battery of behavioral tests. The Morris Water Maze was employed to evaluate spatial learning and memory. Animals were trained to locate a hidden platform in a water maze, and performance was assessed by measuring the time taken to find the platform and the number of errors made. Additionally, the Novel Object Recognition test was used to assess memory retention by measuring the amount of time spent exploring a novel object compared to a familiar one.

After the behavioral assessments, rats were euthanized, and their brains were extracted for biochemical analyses. The levels of oxidative stress markers, such as malondialdehyde (MDA) and 8-hydroxydeoxyguanosine (8-OHdG), were measured using spectrophotometric and ELISA methods. Antioxidant enzyme activities, including superoxide dismutase (SOD) and catalase, were assessed through standard biochemical assays. Inflammatory cytokine levels, such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), were measured using ELISA kits.

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Histopathological examination of brain tissue was also conducted to evaluate neuronal damage and alterations in brain morphology.

Data were analyzed using appropriate statistical methods to compare differences between groups. Analysis of variance (ANOVA) followed by post-hoc tests were used to determine the significance of differences in behavioral, biochemical, and histopathological outcomes among the experimental groups. The significance level was set at $p < 0.05$ for all analyses. This methodical approach aimed to comprehensively assess the protective effects of Alpinia galanga against D-Galactose-induced brain aging by evaluating cognitive function, oxidative stress, inflammation, and neuronal damage.

Results

The study demonstrated that Alpinia galanga significantly mitigated the cognitive deficits and biochemical alterations associated with D-Galactose-induced brain aging. In the Morris Water Maze test, rats treated with Alpinia galanga showed a marked improvement in spatial learning and memory, as evidenced by a reduced latency to locate the hidden platform and fewer errors compared to the D-Galactose-only group. Similarly, in the Novel Object Recognition test, Alpinia galanga-treated rats exhibited a significantly higher exploration time for the novel object, indicating improved memory retention relative to the D-Galactose group.

Biochemical analyses revealed that D-Galactose administration led to elevated levels of oxidative stress markers, such as malondialdehyde (MDA) and 8-hydroxydeoxyguanosine (8-OHdG), as well as increased activities of inflammatory cytokines like tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6). In contrast, Alpinia galanga treatment significantly reduced these oxidative stress markers and inflammatory cytokine levels. Furthermore, antioxidant enzyme activities, including superoxide dismutase (SOD) and catalase, were notably higher in the Alpinia galanga-treated groups compared to the D-Galactose-only group, suggesting enhanced oxidative defense mechanisms.

Histopathological examination of brain tissues corroborated these findings, revealing a decrease in neuronal damage and improved brain morphology in the Alpinia galanga-treated rats. The treatment group exhibited fewer signs of neurodegeneration, including reduced neuronal loss and less prominent inflammatory cell

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infiltration, compared to the D-Galactose group. Overall, these results indicate that Alpinia galanga effectively counteracts the adverse effects of D-Galactose-induced brain aging by reducing oxidative stress, inflammation, and neuronal damage, thereby improving cognitive function and offering potential therapeutic benefits for age-related cognitive decline.

Discussion

The findings from this study underscore the protective potential of Alpinia galanga against D-Galactose-induced brain aging, offering valuable insights into its therapeutic efficacy and underlying mechanisms. The observed improvements in cognitive function, as evidenced by enhanced performance in the Morris Water Maze and Novel Object Recognition tests, suggest that Alpinia galanga can effectively mitigate memory deficits and learning impairments typically associated with age-related cognitive decline. These behavioral improvements are likely attributed to the plant's ability to reduce oxidative stress and inflammation, as indicated by the significant decrease in markers such as malondialdehyde (MDA) and 8-hydroxydeoxyguanosine (8-OHdG), alongside reduced levels of inflammatory cytokines TNF-α and IL-6.

The study's biochemical analyses revealed that Alpinia galanga treatment led to increased antioxidant enzyme activities, including superoxide dismutase (SOD) and catalase, suggesting an enhancement in the brain's oxidative defense mechanisms. This aligns with previous research highlighting the plant's antioxidant properties, which likely play a crucial role in neutralizing free radicals and mitigating oxidative damage. Additionally, the reduction in neuroinflammation and neuronal damage observed in histopathological evaluations further supports the therapeutic potential of Alpinia galanga. By attenuating neurodegenerative changes and inflammatory responses, Alpinia galanga appears to offer a multifaceted approach to combating brain aging.

These results contribute to a growing body of evidence suggesting that natural compounds like Alpinia galanga could serve as effective adjunctive therapies for age-related cognitive disorders. However, while the data are promising, further research is needed to explore the precise molecular mechanisms through which Alpinia galanga exerts its protective effects and to

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evaluate its long-term safety and efficacy. Additionally, clinical studies will be essential to translate these findings from animal models to human applications, potentially paving the way for novel, plant-based interventions in the management of cognitive decline and neurodegenerative diseases.

Conclusion

This study demonstrates that Alpinia galanga exerts significant protective effects against brain aging induced by D-Galactose. The administration of Alpinia galanga not only improved cognitive function, as evidenced by enhanced performance in behavioral tests, but also mitigated oxidative stress and neuroinflammation associated with brain aging. The observed reductions in oxidative stress markers, inflammation, and neuronal damage, alongside increased antioxidant enzyme activities, highlight the plant's potential as a therapeutic agent for counteracting age-related cognitive decline.

These findings underscore the value of Alpinia galanga in offering a natural, multifaceted approach to neuroprotection, making it a promising candidate for further research and potential clinical applications. Future studies should focus on elucidating the specific mechanisms underlying its effects and evaluating its efficacy in human populations. Overall, Alpinia galanga shows promise as a valuable adjunct in the management of cognitive impairments and neurodegenerative conditions, contributing to the development of effective, plant-based interventions for brain aging.

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