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Research Article

Antioxidant Properties of *Sclerocarya birrea* (Anacardiaceae) on Monosodium Glutamate-Induced Memory Loss in the *Mus musculus* Swiss (Murideae)

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Abstract

Neurodegenerative diseases in the elderly have become a major health problem in Africa. Glutamate neurotoxicity has been implicated in numerous diseases such as Alzheimer's and Schizophrenia. Plants with antioxidant properties protect the brain against glutamate neurotoxicity. The aim of this study is to assess the therapeutic efficacy of *Sclerocarya birrea* (*S. birrea*) against monosodium glutamate-induced memory loss. To evaluate the pharmacological effects of *S. birrea* against monosodium glutamate (MSG)-induced memory loss in white Mus musculus Swiss mice. *S. birrea* decoctate was tested on the central nervous system of animals with MSG-induced cognitive deficits. Different doses (410; 205 and 102.5 mg/kg) of *S. birrea* decoctate were administered orally to the animals one hour before MSG administration (4 mg/kg *p.o.*) for 15 consecutive days of treatment. The pharmacological effects of *S. birrea* were evaluated for 3 days by behavioral tests consisting of T-maze and open-arena object recognition. After the behavioral tests, all animals were sacrificed by cervical decapitation and the brains were harvested for assessment of oxidative stress parameters. *S. birrea* decoctate reversed MSG-induced behavioral impairment by significantly increasing memory capacities in MSG-treated mice, significantly inhibited the reduction in locomotor and exploratory capacities of MSG-treated animals in T-maze and open arena behavioral tests. MSG-induced decreases in catalase activity (CAT), reduced glutathione (GSH) and increased malondialdehyde (MDA) levels were significantly reversed by *S. birrea* decoctate at doses of 102.5 and 205 mg/kg. So the *S. birrea* root bark decoctate possesses antioxidant and neuroprotective properties that facilitate memorization and correct MSG-induced cognitive deficits in white mice. All the results obtained in this work justify the use of *S. birrea* decoctate in traditional medicine.

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1. Introduction

Memory is one of the brain's cognitive functions, enabling us to perceive and adapt to the world around us [1]. It is one of the essential components of intelligence, with the ability to retain and retrieve information by situating it in time. Yet memory is not immune to aging, nor to degenerative diseases that lead to the deterioration of nerve cells [2, 3]. Brain degeneration during aging has become a major health problem. It refers to memory impairment during normal aging. The most common cause of neurodegenerative disease is neurotoxicity associated with loss of neurons in various areas of the brain [4].

MSG-induced neurotoxicity is implicated in numerous neurodegenerative diseases such as dementia, Alzheimer's disease and Parkinson's disease [5]. MSG, a neurotransmitter favored by pyramidal neurons in the neocortex and hippocampus, is strongly implicated in higher brain functions, including memory [6]. Despite its high consumption as a food additive, MSG can be toxic in rodents at high doses [7, 8]. According to Hassan *et al*. in 2014, MSG induces neurotoxicity in rodents similar to that observed in Alzheimer's disease. It causes abnormalities in the neuroendocrine system, neurodegeneration in the brain and oxidative stress damage in various organs of the body [8].

Neurotoxic substances such as monosodium glutamate and scopolamine have been shown to disrupt the memory process in various activities in animals and humans [9]. Nootropic agents such as piracetam and diclofenac are mainly used to improve memory, mood and behavior. These drugs are also thought to be used to alleviate age-related neurodegenerative diseases such as Alzheimer's and Parkinson's [9]. However, adverse effects associated with these agents have limited their use [10]. Despite the availability of various therapeutic molecules, natural plant products remain one of the best sources of new drugs [11]. Studies have shown that medicinal plants can boost memory and prevent age-related cognitive pathologies. Similarly, the World Health Organization estimates that in developing countries, medicinal plants make a significant contribution to primary health care [12]. It is therefore interesting to explore the usefulness of medicinal plants in the treatment of various cognitive disorders.

Sclerocarya birrea is a plant widely used as a vegetable by African populations and in traditional medicine for its nutritional and therapeutic properties [13]. Widespread in Saharan and sub-Saharan Africa, *S. birrea* is a liana with strong growth during the dry season and slower growth during the rainy season [14]. Various parts of *S. birrea*, especially the leaves, are used in the treatment of numerous illnesses such as sexual impotence, malaria, agalactia, pain, diarrhoea and trypanosomiasis [13]. *S. birrea* has demonstrated anti-inflammatory, analgesic, antioxidant and antipyretic activity [15]. Phytochemical analysis of *S. birrea* leaves reveals the presence of secondary metabolites such as tannins, flavonoids, alkaloids, saponosides, coumarins, steroids and terpenoids [16]. However, the protective effect of *S. birrea* on the central nervous system has not yet been the subject of extensive scientific study. The present study aims to test the hypothesis that the decoction of *S. birrea* leaves may exert neuroprotective and antioxidant properties due to its use in traditional medicine to treat and prevent neurodegenerative diseases.

2. Materials and Methods

2.1. Plant Material and Extract Preparation

Samples of *S. birrea*, harvested in May 2023 in southern Chad, were identified at the Yaoundé National Herbarium in Cameroon under reference 2748SFR. After harvesting, *S. birrea* root bark was washed with water and dried at room temperature in the shade, then crushed using a mortar and finally sieved using a 0.5-mm mesh sieve to obtain the powder needed to prepare the extract. The powder obtained is stored at room temperature in a closed jar.

Next, 2.5 grams of the *S. birrea* powder obtained earlier was transferred to a beaker containing 50 mL of distilled water. The mixture was boiled for 30 minutes on a hot plate set at 100 ℃. After cooling, the mixture was filtered through a Wattman n°1 filter paper, and the filtrate recovered constituted the stock solution.

In order to determine the mass yield of the extract, the filtrate obtained (stock solution), whose volume was 23 mL, was evaporated in an oven at 40 ℃. A mass of 0.9435 g of dry *S. birrea* extract was obtained in 37.74% yield, with a stock solution concentration of 41 mg/mL. Given an administration volume of 10 mL/kg, the initial dose of the extract is 410 mg/kg. Two other solutions with different doses (102.5 and 205 mg/kg) were prepared from the dry extract.

2.2. Tests de Caractérisation Phytochimique de l'extrait de Sclerocarya Birrea

Preliminary phytochemical characterization tests on *S.*

birrea were carried out using qualitative colorimetric methods [17], with a view to determining the main chemical groups.

2.2.1. Alkaloid Test

1 mL of the extract, prepared at 0.3 mg/mL, was taken into a test tube, then 1 mL of HCl, prepared at 5%, and 3 drops of Dragendorff's reagent were added. The formation of a white or orange precipitate indicates a positive test.

2.2.2. Tannin Test

1 mL of the extract, prepared at 0.3 mg/mL, was taken into a test tube and 3 drops of FeCl3, prepared at 1%, were added. The formation of a blue-blackish coloration confirmed the presence of tannins.

2.2.3. Flavonoid Test

1 mL of the extract, prepared at 0.3 mg/mL, was taken into a test tube, then 3 magnesium chips and 1 mL concentrated hydrochloric acid were added. The formation of an orange coloration indicates the presence of flavones, red that of flavonols and violet that of flavonones.

2.2.4. Test for Triterpenes or Steroids

1 mL of the extract, prepared at 0.3 mg/mL, was taken in a test tube. 1 mL chloroform, 1 mL concentrated H2SO4 and 1 mL acetic anhydride were added. The formation of a violet or blackish-green coloration confirms that the test is positive.

2.2.5. Anthraquinone Test

1 mL of the extract, prepared at 0.3 mg/mL, was taken into a test tube. 2 mL mixture (petroleum ether/chloroform) and 2 mL NaOH, prepared at 10%, were added to the extract. The formation of a red coloration indicates a positive test.

2.2.6. Phenolics Test

1 mL of *S. birrea* extract prepared at 0.3 mg/mL was taken into a test tube and 3 drops of FeCl3 prepared at 10% were added. The formation of a green or bluish coloration confirms the presence of phenolic compounds.

2.3. Evaluation of the Antioxidant Capacity of *Sclerocarya birrea* in Vitro

The Ferric reducing antioxidant power (FRAP) method is based on the ability of an extract to reduce ferric iron (Fe3+) to ferrous iron (Fe2+) [18]. A fresh solution of FRAP reagent was prepared by mixing 2.5 mL of TPTZ solution (10 mM in 40 mM HCl) with 2.5 mL of $FeCl_3.6H_2O$ (20 mM) and 25 mL of acetate buffer (300 mM sodium acetate, pH brought to 3.6 by acetic acid). 900 µL of FRAP reagent, previously incubated at 37 °C, was mixed with 70 µL of distilled water and 30 µL of plant decoctate at different concentrations (0.5 to 0.1 mg/mL). After 30 minutes of incubation, absorbance was read at a wavelength of 593 nm at 37 °C against the blank. The positive control was represented by a solution of a standard antioxidant, ascorbic acid, whose absorbance was measured under the same conditions as the samples.

The percentage reducing power of decoctate and vitamin C was calculated using the following formula:

$$PR\ (\%) = [(A_0 - A_1) / A_0] \times 100$$

where PR is the reducing power, A_0 the absorbance of the control and A_1 the absorbance of the sample.

2.4. Behavioral Tests

2.4.1. Animal Model

Naïve white mice, Mus musculus Swiss (Murideae), weighing between 25 and 30 g were used in this study [19]. These mice were supplied by the Laboratoire National Vétérinaire (LANAVET) du Cameroun (Garoua, Cameroon). They were acclimatized for one week at the Laboratoire des Plantes Médicinales, Santé et Formulation Galénique of the University of Ngaoundéré before the start of the experiments [19]. These animals were housed in standard cages, at room temperature, on a 12/12-hour light-dark cycle, consuming tap water and granules ad libitum. Experiments were conducted in accordance with the International Guidelines for the Care and Use of Laboratory Animals published by the National Institutes of Health, USA (NIH Publication No. 85 - 23, revised 1996) and with the guidelines of the Cameroon National Ethics Committee (No. FWA-IRB00001954, October 22, 1987).

For each test, mice were divided into 6 homogeneous batches of 5 mice and treated for 15 days as follows: a first batch received distilled water (10 mL/kg p.o.) [28] and served as a negative control batch; a second batch received vitamin C (100 mg/kg i.p.) [29] and served as a positive control batch. The other three batches received different doses (102.5; 205 and 410 mg/kg, p.o.) of the plant and served as test batches. All these batches received monosodium glutamate (4 mg/kg p.o.) 1 hour after the first treatment, to induce memory loss [20]. A sixth batch was added and this received distilled water (10 ml/kg b.w.) only, serving as a normal control batch. On test day, 30 minutes after the last treatment, the animals were subjected to the various behavioral tests.

2.4.2. T-maze Test

The effects of *S. birrea* on the level of exploration and memory in naïve mice (unmanipulated mice) placed in the T-maze were evaluated [21]. Two days before the start of the experiments, the animals were progressively deprived of food to maintain them at 80-85% of their body weight. The mice were placed one after the other in the starting arm of the T-maze one hour after administration of the various substances. This task was carried out in three phases: habituation, acquisition and retention.

In the first or habituation phase, the mice were familiarized with the device for a period of 5 minutes. Food is placed in each corridor to encourage exploration. The experimenter places the mice in the starting compartment. After 15 seconds, he opens all the guillotine doors. The animal can then choose one or other of the lanes on the arms of the device, indicating its preference.

The second or acquisition phase begins 24 hours after the habituation phase. The corridor of the arm discriminated by the animal is closed, then a reinforcer (food) is placed in the arm chosen by the animal. The experimenter places the mouse in the starting compartment and lets it move towards the open corridor (preferred corridor during habituation). This phase takes 5 minutes for each animal.

Finally comes the retention phase, 24 hours after the acquisition phase. Each animal is placed in the device for 5 minutes, this time with all arms open. The experimenter places the food in both arms of the maze. The parameters recorded are: latency time to find the preferred arm, number of returns to the starting arm and time spent in the preferred arm.

2.4.3. Object Recognition Task in Open Field

The object recognition test was performed using the method described by Ennaceur and Delacour [22]. This test was conducted in an open field box (50 × 50 × 40 cm) and is comprised of three phases. At the end of the treatment, the mice were allowed to explore the open field for 5 min during the habituation phase. During the acquisition phase (T1), two identical objects (red cubes 4 × 4 × 4 cm) were placed in two corners of the open field at 10 cm from the sidewall. The mice were placed in the middle of the open field and allowed to explore these two identical objects for 5 minutes. After, they were put back in their cages. Subsequently, 24 hours after T1, the test “choice” (T2) was made. During T2, a new object (blue cone) has been introduced and mice were reexposed to the two objects: the familiar (F) and the new (N). The time spent by the mice in the exploration of each object during T1 and T2 was manually recorded using a stopwatch. A discrimination index (DI) was then calculated as follows:

$$DI = (TN - TF / TN + TF) \times 100$$

We used the discrimination index (DI) to evaluate the curiosity of mice towards new objects. The DI was defined as the percentage of time spent on a novel object to the total time spent on familiar and novel objects, where TN is time spent with the novel object and TF is time spent with the familiar object.

2.5. Assessing the Antioxidant Capacity of *Sclerocarya birrea* in Vivo

2.5.1. Brain Sampling and Preparation of Homogenates

Homogenates were prepared on day 15. Immediately after behavioral testing, previously established animal models of neuroinflammation were sacrificed individually by cervical decapitation. Brains were harvested, rinsed in NaCl (9‰) solution, wrung out and weighed. These brains were placed in a ceramic mortar. A total of 500 µL of PBS solution was added to each brain in the mortar, and the mixture was ground. The prepared homogenate was then centrifuged at 10,000 rpm for 15 minutes at 4 °C. A 20 mg volume of the supernatant was pipetted into a new tube and labeled for markers of oxidative stress.

2.5.2. Determination of Oxidative Stress Markers in the Brain

(i). Determination of Malondialdehyde Levels

The concentration of malondialdehyde (MDA) in the brain was determined in the homogenate using the thiobarbituric assay (TBA). To 1 mL homogenate, 0.5 mL thiobarbituric acid (20%) and 1 mL thiobarbituric acid (0.67%) were added. The mixture was heated in a water bath at 100 °C for one hour. After cooling, the mixture was centrifuged at 3000 rpm for 15 minutes and the absorbance of the homogenate was read spectrometrically at 530 nm. The amount of MDA was calculated using Beer Lambert's formula and an extinction coefficient of 1.56 x 105 M/cm [23].

(ii). Determination of Catalase Activity

Catalase activity (CAT) was determined by the method of Sinha [24]. 50 µL of brain homogenate sample was mixed with 750 µL of 0.1 M phosphate buffer (pH 7.5) and 200 µL of H2O2. The reaction was stopped by adding 200 µL of acid reagent (dichromate/acetate). All tubes were heated for 10 minutes and absorbance read by spectrometry at 620 nm. CAT concentration was expressed in terms of mmol H2O2/mg protein.

(iii). Détermination du Taux de Glutathion réDuit

The level of reduced glutathione (GSH) in the brain was determined in the homogenate following the protocol described by Ellman [25]. 20 µL of brain homogenate was mixed with 3 mL of Ellman's reagent at room temperature. After one hour, the absorbance of the yellow compound was read by spectrometry at 412 nm. The amount of glutathione was calculated using the Beer Lambert formula.

(iv). Determination of Superoxide Dismutase Levels

The determination of SOD was carried out according to the method described by Beyssiri *et al* [23]. In the control tube, 1666 µL of carbonate buffer (0.05 M, pH 10.2), 0.2 mL of adrenaline solution (0.3 mM) and 134 µL of distilled water were introduced to calibrate the spectrophotometer. Next, 134 µL of homogenate and 1,666 µL of carbonate buffer are added to the spectrophotometer. Once the spectrometer has been calibrated, the reaction is started by adding 0.2 mL of adren-

aline solution to the reaction mixture, followed by homogenization. The optical density (OD) is read after 20 s and at 80 s at 480 nm.

$$\text{SOD Activity} = \left(\frac{\text{U}}{\text{mg}} \text{ of protein}\right) = \left(\frac{\text{Number of units } \frac{\text{SOD}}{\text{mL}}}{\text{mg of protein}} * \text{ Dilution factor}\right)$$

SOD unit = (100 - ((Δ DOessay x 100)) / ΔDOwhite =% inhibition; 50% inhibition corresponds to 1 SOD unit; OD variation: ΔDOmin = DO20s - DO80s.

2.6. Assessment of the Cholinergic System (Determination of Acetylcholinesterase Activity)

Each activity was determined using the method of Ellman [23]. To do this, 0.05 mL of aliquot of the homogenate (supernatant) was added to a cuvette containing 3 mL of phosphate buffer (0.1 M, pH 8), 0.1 mL of 5,5'dithio-bis (2-nitrobenzoic acid) (Ellman's reagent) and 0.1 mL of acetylthiocholine iodide. The contents of the cuvette were mixed thoroughly by bubbling in air. The absorbance was read by spectrophotometer at 412 nm for 2 minutes at 30 sec intervals. Enzyme activity was calculated using the following formula:

$$\text{Acetylcholinesterase activity} = ((\text{A/min}) \times \text{Vt}) / \mathcal{E} \times \text{b} \times \text{Vs}$$

A/min is the variation in absorbance per min; ε is 1.361 X 104 M-1; cm-1; b is the length of the cell (1 cm); Vt is the total volume (3.2 mL); Vs is the volume of the sample (0.4 mL). Enzyme activity is expressed as U/min/mg protein in brain tissue (1 U/min/mg AchE was defined as the amount of enzyme that hydrolysed 1 µmol acetylthiocholine iodide).

2.7. Statistical Analysis of Data

Data were analyzed by descriptive statistics: using Microsoft Excel 2016 software to determine the mean ± Standard Error on the Mean (SEM), analysis of variance (ANOVA) followed by Tukey's multiple comparison test were performed using Graph Pad Prisme software version 8.3.1. Values are considered significant at $p \leq 0.05$.

3. Results

3.1. Phytochemical Screening of *Sclerocarya birrea* Extract

The results of phytochemical characterization tests on *S. birrea* decoctate are given in Table 1 below.

Table 1. *Major chemical families of Sclerocarya birrea.*

Chemical compound families	Existence
Alkaloids	++
Flavonoids	+
Saponins	+
Tannins	+++
Triterpenes	+++
Anthraquinones	++
Steroids	++
Polyphenols	+++

Legend: + = Present; ++ = Abundant; +++ = Very abundant

3.2. Anti-free Radical Activity of *Sclerocarya birrea* Decoctate (Iron Reducing Power)

The reducing power of extracts increases proportionally with concentration. It is expressed in milligrams of ascorbic acid equivalent per gram of dry extract (mg AAE/g dry extract). The results obtained are shown in Table 2 below.

Table 2. *Reducing power of extracts.*

Extract concentrations	0,5 mg/mL	0,4 mg/mL	0,3 mg/mL	0,2 mg/mL	0,1 mg/mL
Reducing power of Vit C (mg EAA/g dry extract)	85,63 ±0,07	81,81 ±0,10	66,27 ±0,18	56,90 ±0,23	47,90 ±0,28
Reducing power of decoctate (mg AAE/g dry extract)	69,09 ±0,17	54,54 ±0,25	44,54 ±0,30	40,54 ±0,32	34,54 ±0,36

Each value represents the mean ± MSE, n=5. AAE: Ascorbic acid equivalent.

3.3. Effects of *Sclerocarya birrea* on Monosodium Glutamate-Induced Memory Loss in the T-maze Test

3.3.1. Effects on Latency of Preferred Arm Choice

After 15 days of treatment, Figure 1 shows that mosodic monosodium glutamate increases ($P < 0.001$) the latency of preferred arm choice, which varies from 3.6 ± 0.54 sec in normal control mice to 24.8 ± 0.83 sec in negative control mice. *S. birrea* decoctate antagonized the effects of monosodium glutamate, reducing ($P < 0.001$) this time to minimum values of 6.4 ± 0.89 s and 4.6 ± 0.89 sec in nimals treated with 102.5 mg/kg and vitamin C ($P < 0.001$) compared with negative control.

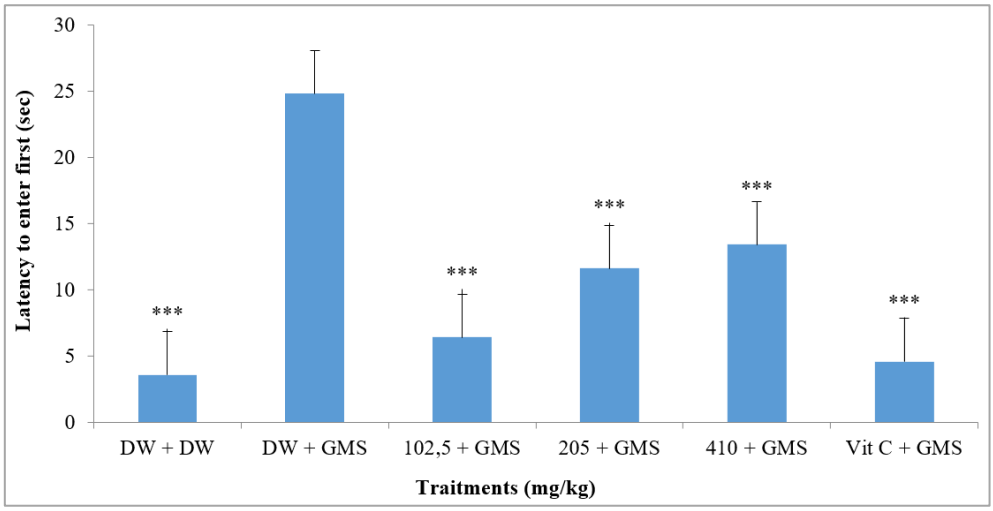

Figure 1. *Effects of Sclerocarya birrea decoctate on latency of preferred arm choice in the T maze.*

Each bar represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

3.3.2. Effects on the Number of Returns to the Start Arm

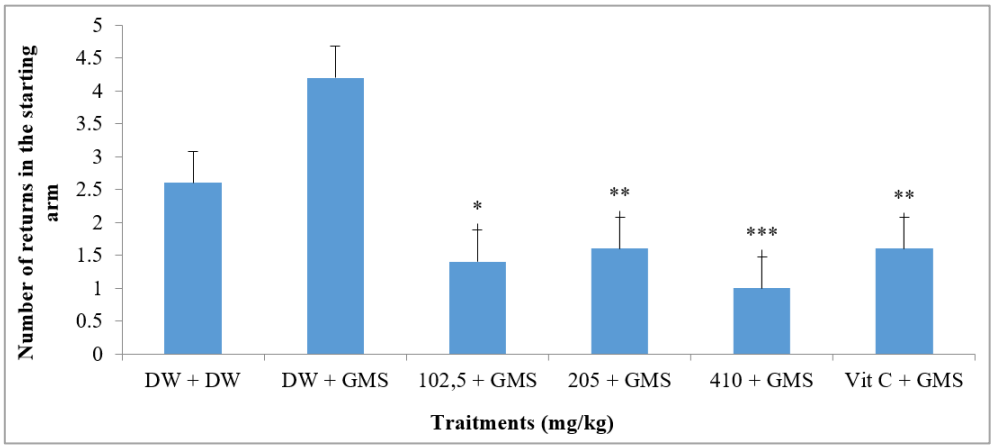

Figure 2. *Effects of Sclerocarya birrea decoctate on the number of returns in the T maze.*

Figure 2 shows the effect of decoctate on the number of returns to the starting arm of the T-maze. Monosodium glutamate induces an increase ($P < 0.001$) in this number, from 2.6 ± 0.54 in normal control mice to 4.2 ± 0.44 in negative

control mice. *S. birrea* decoctate inhibits the effects of monosodium glutamate by lowering ($P < 0.001$) this number at all doses, with minimum values of 1.00 ± 0.00 and 1.6 ± 0.54 in mice treated with 410 mg/kg and vitamin C ($P < 0.001$) compared with negative control.

Each bar represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

3.3.3. Effects on Time Spent in the Preferred Arm

Figure 3 shows that monosodium glutamate induces a decrease ($P < 0.001$) in the time spent in the preferred arm, ranging from 78 ± 0.70 s in normal control animals to 55 ± 0.70 s in negative control animals. *S. birrea* decoctate inhibits the effects of monosodium glutamate by increasing ($P < 0.001$) this time to 136.2 ± 0.83 s and 127 ± 0.70 s in mice treated with 205 mg/kg and vitamin C ($P < 0.001$) compared with negative control.

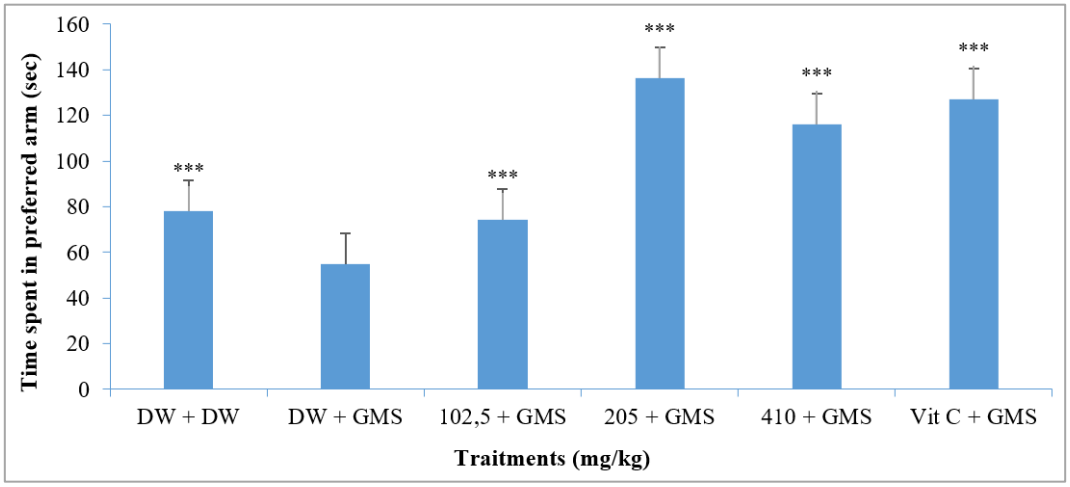

Figure 3. *Effects of Sclerocarya birrea decoctate on time spent in the preferred arm in the T maze.*

Each bar represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

3.4. Effects of *Sclerocarya birrea* on the Open Arena Object Recognition Test

3.4.1. Effects on Object Exploration Time

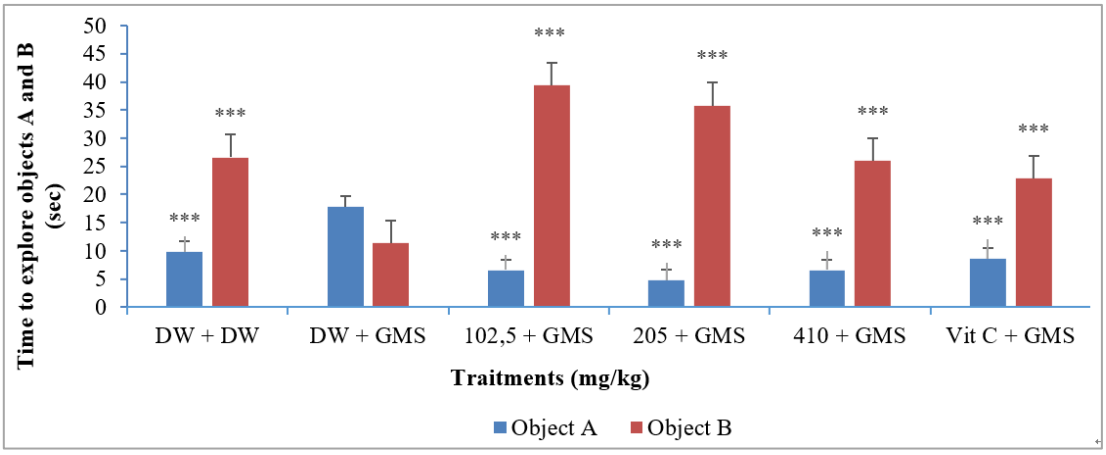

Figure 4. *Effects of Sclerocarya birrea decoctate on the exploration time of objects A and B in the open arena.*

Following 4 days of treatment, Figure 4 shows that monosodium glutamate increased (P < 0.001) the exploration time of the familiar object (A) from 9.8 ± 0.32 sec in normal control mice to 17.8 ± 0.64 s in negative control mice. *S. birrea* decoctate inhibits the effects of monosodium glutamate by decreasing (P < 0.001) this time at all doses, with minimum values of 4.8 ± 0.96 sec and 8.6 ± 0.48 sec in animals treated with 205 mg/kg and vitamin C (P < 0.001) compared with the negative control.

Similarly, the figure shows that monosodium glutamate reduces (P < 0.001) the time taken to explore the novel object (B) from 26.6 ± 0.72 s in normal control mice to 11.4 ± 0.88 s in negative control mice. *S. birrea* decoctate inhibits the effects of monosodium glutamate, increasing (P < 0.001) this time by 39.4 ± 0.48 s and 22.8 ± 0.64 s in mice treated with 102.5 mg/kg and vitamin C (P < 0.001) compared with negative control.

Each bar represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

3.4.2. Effects on the Percentage of Object Discrimination Index

Figure 5 shows that monosodium glutamate decreases (P < 0.001) the percentage of new object recognition index from 60.6 ± 0.72% in normal control mice to 9.8 ± 0.32% in negative control mice. *S. birrea* decoctate inhibits the effects of monosodium glutamate, increasing (P < 0.001) this percentage at all doses, with optimal values of 78.2 ± 0.32% and 70 ± 0.80% in animals treated with 102.5 mg/kg and vitamin C (P < 0.001) compared with negative control.

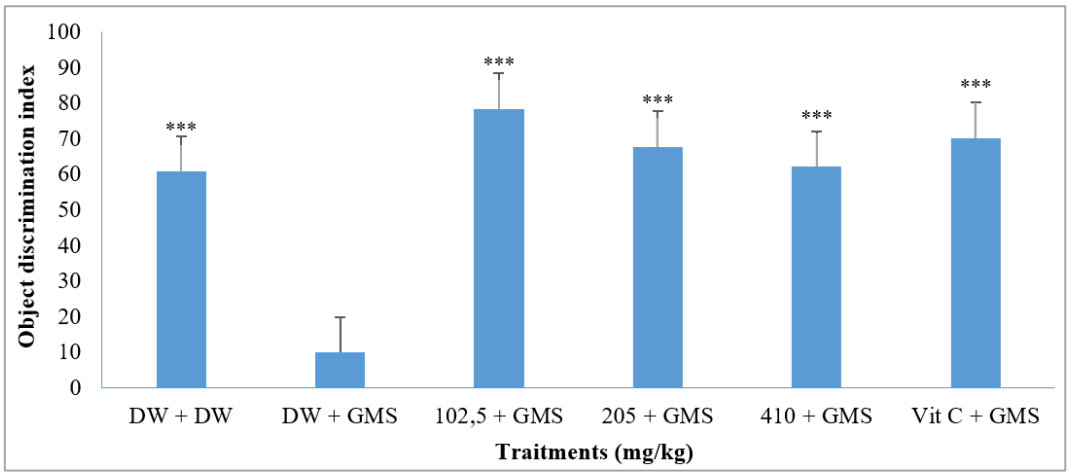

Figure 5. *Effects of Sclerocarya birrea decoctate on the percentage of new object recognition index in the open arena.*

Each bar represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

3.5. Effects of *Sclerocarya birrea* on Monosodium Glutamate-induced Oxidative Stress Parameters

3.5.1. Effects on Malondialdehyde Concentration

Table 3 illustrates the influence of monosodium glutamate on MDA concentration. Monosodium glutamate increases (P < 0.001) MDA concentration from 4.95 ± 0.04 mol/g tissue in normal control animals to 10.62 ± 0.23 mol/g tissue in negative control animals. *S. birrea* decoctate inhibits the increase in MDA concentration induced by monosodium glutamate, reducing (P < 0.001) this concentration to minimum values of 8.56 ± 0.13 and 5.12 ± 0.29 mol/g tissue in mice treated with 102.5 mg/kg and vitamin C (P < 0.001) compared with negative control.

3.5.2. Effects on Catalase Concentration

Similarly, this Table reveals that daily administration of monosodium glutamate induced a decrease (P < 0.001) in catalase concentration, from 13.55 ± 0.70 mol/g tissue in normal control mice to 10.74 ± 0.56 mol/g tissue in negative control mice *S. birrea* decoctate inhibits the effects of monosodium glutamate, increasing (P < 0.001) this concentration at all doses. *S. birrea* inhibits the effects of monosodium glutamate by increasing (P < 0.001) this concentration at all

doses, with optimum values of 13.80 ± 0.63 and 13.92 ± 2.23 mol/g tissue in animals treated with 102.5 mg/kg and vitamin C ($P < 0.001$) compared with the negative control.

3.5.3. Effects on Reduced Glutathione Concentration

The same table shows that monosodium glutamate induced a decrease ($P < 0.001$) in GSH concentration from 0.06 ± 0.00 mol/g tissue in normal control mice to 0.03 ± 0.00 mol/g tissue in negative control mice. *S. birrea* decoctate antagonizes the effects of monosodium glutamate, increasing ($P < 0.001$) this concentration to 0.06 ± 0.00 and 0.07 ± 0.00 mol/g tissue in animals treated with 205 mg/kg and vitamin C increases ($P < 0.001$) compared to negative control.

3.5.4. Effects on Superoxide Dismutase Concentration

Finally, the same table shows that monosodium glutamate induced a decrease ($P < 0.001$) in SOD concentration, ranging from 4.48 ± 0.23 SOD/mg in normal control mice to 4.07 ± 0.61 SOD/mg in negative control mice. *S. birrea* decoctate antagonizes the effects of monosodium glutamate, increasing ($P < 0.001$) this concentration at all doses, with optimum values of 5.15 ± 0.53 and 5.16 ± 0.10 SOD/mg in animals treated with 102.5 mg/kg and vitamin C ($P < 0.001$) compared with the negative control.

Table 3. *Effects of Sclerocarya birrea on oxidative stress.*

Traitments (mg/kg)	ED	ED + GMNS	102,5 + GMNS	205 + GMNS	410 + GMNS	Vit C+GMNS
MDA (mol/g)	4,95 ±0,04***	10,62 ±0,23	8,56 ±0,13***	9,81 ±0,23***	10,75 ±0,25	5,12 ±0,29***
CAT (mol/g)	13,55 ±0,70**	10,74 ±0,56	13,80 ±0,63**	11,83 ±0,88	11,39 ±0,53	13,92 ±2,23**
GSH (mol/g)	0,06 ±0,00***	0,03 ±0,00	0,05 ±0,00***	0,06 ±0,00***	0,03 ±0,00	0,07 ±0,00***
SOD (SOD/mg)	4,48 ±0,23	4,07 ±0,61	5,15 ±0,53**	4,76 ±0,54	4,86 ±0,32	5,16 ±0,10**

Each value represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

3.6. Effects of *Sclerocarya birrea* on Parameters of the Cholinergic System Induced by Monosodium Glutamate

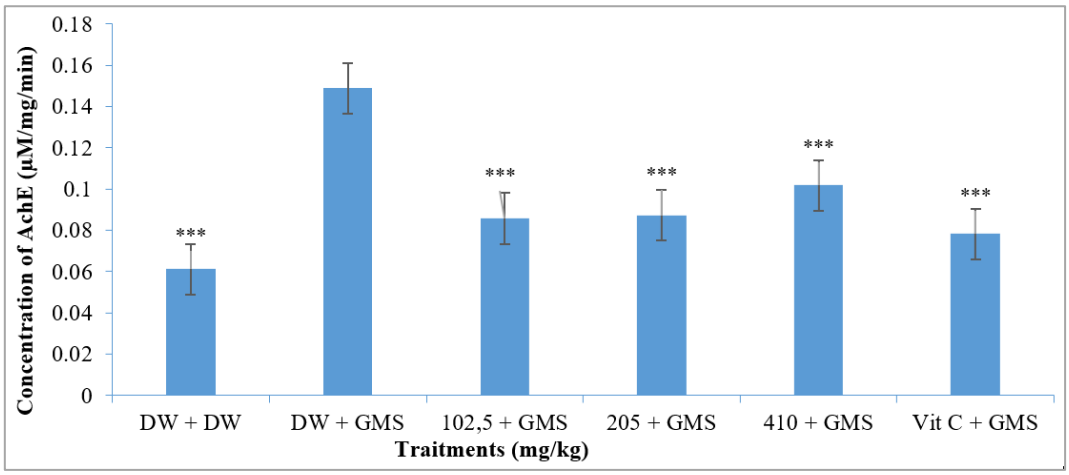

Figure 6. *Effects of Sclerocarya birrea decoctate on acetylcholinesterase concentration in the brain of white mice.*

Figure 6 shows that monosodium glutamate induced a significant ($P < 0.001$) increase in AchE concentration from 0.06 ± 0.46 µM/mg/min in normal control mice to 0.14 ± 0.07 µM/mg/min in negative control mice. *S. birrea* decoctate inhibits the effects of monosodium glutamate by significantly ($P < 0.001$) lowering this concentration to minimum values of 0.10 ±0.52 and 0.07 ±0.38 µM/mg/min in animals treated with 410 mg/kg and vitamin C compared with the negative control.

Each bar represents the mean ± SEM of five animals. The data analysis was performed using one way ANOVA followed by Turkey multiple comparisons test. ***p < 0,001 vs. Negative control (DW + MSG). DW: Distilled water (normal control). MSG: monosodium glutamate (4 mg/kg). 102,5; 205 and 410: *S. birrea* doses in mg/kg. Vit C: Vitamin C 100 mg/kg (positive control).

4. Discussion

Monosodium glutamate, a neurotransmitter favored by pyramidal neurons in the neocortex and hippocampus, is strongly implicated in higher brain functions, particularly memory. Despite its widespread consumption as a food additive, at high doses monosodium glutamate induces neurotoxicity in rodents such as that observed in Alzheimer's disease [8]. It causes neurodegeneration in the brain, as well as oxidative stress damage in various organs of the body [9]. The present study demonstrated that prolonged administration of monosodium glutamate results in the loss of spatial memory and object recognition memory assessed in the T-maze and open arena respectively.

Numerous reports suggest that repeated administration of *S. birrea* decoctate has shown its ability to reverse cognitive dysfunction, suggesting its neuroprotective effect against monosidic glutamate-induced neurotoxicity [26]. *S. birrea* decoctate has been found to contain phenolic compounds such as polyphenols, tannins and triterpenes. These secondary metabolites present in plants have a wide range of therapeutic effects. They may be responsible for the antioxidant and antiradical capacity of the extract According to Koto-te-Nyiwa et al (2016). Evaluation of the extract's reducing power reveals its reducing power in the FRAP test, expressing its ability to reduce free radicals and transfer them to Fe3+ ions, as well as its capacity to potentiate the body's enzymatic antioxidant system [27].

In the T maze, *S. birrea* decoctate significantly decreases latency and increases time spent in the preferred arm. The decrease in latency time indicates an improvement in memory [28]. The increase in time spent in the preferred arm and the decrease in the number of returns to the starting arm suggest an increase in exploration linked to reduced stress and anxiety, and a good improvement in memory. These results are similar to those described by Ahmad et al [28] in their studies of fesitin against lipopolysaccharide-induced neurodegeneration and memory impairment.

At the end of the novel object recognition test, there was a significant increase in the time taken to explore the novel object and in the discrimination index in mice treated with *S. birrea* decoctate. However, the increase in time to explore the novel object and the discrimination index show the curiosity of rodents to develop a performance towards the novel object [29]. This analysis suggests an improvement in episodic memory. Indeed, according to Koutseff (2011), *S. birrea* decoctate has memetic effects that can improve learning capacity and memory recall.

Similarly, assays for markers of oxidative stress induced by monosodium glutamate revealed that S. birea decoctate significantly increased the concentration of GSH, SOD and CAT, as well as significantly decreasing the concentration of MDA, compared to mice from the respective negative control batches. These results are similar to those observed by Lobo et al, (2010) in their studies on the impact of free radicals and antioxidants on human health. The excessive accumulation of reactive oxygen species in cells as a result of their insufficient or incomplete degradation has been directly implicated in the mechanism of oxidative stress [30].

At the same time, monosodium glutamate increases the concentration of acetylcholinesterase, involved in the loss of cholinergic neurons [31, 32]. The increase in this cholinergic enzyme is coupled with an increase in reactive oxygen species and intracellular calcium concentrations [33]. However, treatment of the animals with *S. birrea* decoctate suppressed the increase in MDA concentration and cholinergic enzymes to restore the antioxidant defense system and proper cholinergic transmission in the mice.

5. Conclusion

At the end of this study, we can conclude that *S. birrea* extract counteracts the neurotoxic effects induced by monosodium glutamate. S. birrea decoctate was tested on the central nervous system of animals with MSG-induced cognitive deficits.

Different doses (410, 205, and 102.5 mg/kg) of S. birrea decoctate were orally administered to the animals one hour before MSG administration (4 mg/kg p.o.) for 15 consecutive days of treatment.

The pharmacological effects of S. birrea decoctate reversed MSG-induced behavioral impairments by significantly increasing memory abilities in MSG-treated mice, significantly inhibited the reduction in locomotor and exploratory abilities of MSG-treated animals in the T-maze and open arena behavioral tests.

MSG-induced decreases in catalase (CAT) activity, reduced glutathione (GSH) and increased malondialdehyde (MDA) levels were significantly reversed by S. birrea decoctate at doses of 102.5 and 205 mg/kg. Thus, S. birrea root bark decoctate has antioxidant and neuroprotective properties that facilitate memory and correct MSG-induced cognitive

deficits in white mice.

Our results obtained justify the use of S. birrea decoctate in traditional medicine. In order to contribute to the reduction of the effects of neurodegenerative diseases in the elderly in Africa such as Alzheimer's and schizophrenia. Or its therapeutic efficacies against memory loss.

Abbreviations

MSG	Monosodium Glutamate
CAT	Catalase
GSH	Reduced Glutathione
HCL	hydrochloric Acid
MDA	Malondialdehyde
FRAP	Ferric Reducing Antioxidant Power
Vit C	Vitamin C
S. birrea	*Sclerocarya birrea*

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Data Availability Statement

All data and materials are reported in the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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