**Evaluation of Antiparkinsonian Activity of Methanol Leaves Extract of *Mucuna pruriens* in Haloperidol-induced Parkinson’s disease**

**ABSTRACT**

**Background:** This research aims to analyse the antiparkinsonian activity of the methanolic leaf extract of  *Mucuna pruriens* (MLEMP). Parkinson's disease is the second most common neurodegenerative condition. It is characterised by the destruction of dopaminergic neurons in the substantia nigra of the striatum, resulting in a decrease in dopamine (DA) levels. *Mucuna pruriens* is a plant used for its anti-inflammatory, anxiety-relieving, and insomnia-relieving properties, as well as for other traditional medicinal purposes, including relief from respiratory issues, skin conditions, digestive issues, and more.

**Materials and Method:** Catalepsy test, rotarod test, exploratory behaviour test (rearing) and locomotor activity tests were conducted to observe antiparkinsonian activity of the MLEMP (200, 400, 800 mg/kg) in haloperidol-induced Parkinson’s disease using rats.  The levels of malondialdehyde (MDA) and reduced glutathione (GSH) in the brain's striatum were measured to assess oxidative stress.

**Results:** MLEMP pretreated groups showed a significant decrease in the latency period in the catalepsy test (p < 0.05) and a significant increase in retention time in the rotarod test (p < 0.05) compared to the haloperidol-treated group alone. The MLEMP-pretreated groups demonstrated a significant antioxidative effect, shown by a marked increase in GSH levels (p < 0.05) and a reduction in brain MDA levels (p < 0.05).

**Conclusions:** In the pathophysiology of Parkinson's disease (PD), oxidative stress plays a crucial role. The results of this study demonstrate that MLEMP exhibits antioxidant activity and provides neuroprotective effects in the haloperidol experimental model of PD.

*Keywords: Mucuna pruriens, Haloperidol, Anti-oxidant, Glutathione, Malondialdehyde.*

1. **INTRODUCTION**

Parkinson's disease is a progressive neurodegenerative disorder characterized by both motor and non-motor symptoms (Hayes, 2019; Malaiwong et al., 2019). The prevalence of Parkinson's disease increases with age, affecting approximately 1–3% of individuals over 60 years old globally (Ball et al., 2019). One of the causes of Parkinson's disease is the use of antipsychotic drugs, leading to a condition known as Drug-Induced Parkinsonism. This occurs due to extrapyramidal side effects caused by the blockade of dopamine receptors (Grubor et al., 2020). Clinically, this condition is characterized by symptoms such as akinesia, tremors, bradykinesia, muscle rigidity, and postural instability, which can appear within days or weeks after starting antipsychotic medication (Erjavec et al., 2022). Drug-induced Parkinsonism is the second most common cause of Parkinson's disease in the elderly (Kabra et al., 2020). It is also the most prevalent type of Parkinsonism in the working-age population, with cases identified in individuals as young as 39 years old. DIP accounts for 11 out of 15 cases of parkinsonism (Jeong et al., 2021). Haloperidol is a typical antipsychotic that has stronger extrapyramidal effects compared to atypical antipsychotics. The increase in Parkinsonism driven by these extrapyramidal effects may elevate the prevalence of Parkinson's disease among the working-age population in Africa. In psychiatric treatment, antimuscarinic antiparkinsonian medications are commonly used to alleviate extrapyramidal motor symptoms caused by neuroleptic antipsychotic drugs. When used alongside antipsychotics, antimuscarinic antiparkinsonian agents have been reported to counteract the therapeutic effects of neuroleptics. Additionally, several reports indicate that these agents can induce various psychotic syndromes, elevate mood, create stimulant effects, and lead to stereotypy, dyskinesia, and behavioural agitation. Extensive data has shown that antimuscarinic antiparkinsonian medications also act as strong indirect dopamine agonists (Vaiman et al., 2022). There is a need for safe alternatives to antiparkinsonian medications to be used as adjunct therapy for patients with psychotic disorders. Currently, many naturally derived medicines are being researched for their potential benefits in treating Parkinsonism.

Mucuna pruriens is a common weed found in fields, bushes, and fallow farmland. It is native to southern China and eastern India but is also widely distributed in tropical regions, including Nigeria. Mucuna pruriens is a vigorous annual climbing legume. Young plants are covered with fine hairs, which disappear as they mature. The leaves are trifoliate, and the flowers are purple. The pods are curved and have longitudinal ribs, while the seeds are black and oval-shaped. Contact with the seeds can cause severe itching on the skin. The plant is used in agriculture to enhance soil fertility (Gamaniel, 2000). In ethnomedicine, it is employed to treat various ailments, including enhancing libido and sexual performance, reversing osteoporosis, improving cholesterol levels, and strengthening the immune system (Prakkash et al., 2001; Malluruwar et al., 2006). The effects observed have been linked to the presence of bioactive compounds, including mucinine, mucunadine, mucunadenine, and pruriendine. Additionally, other chemical substances such as lecithin, glutathione, nicotine, L-dopa, and gallic acid, which have been isolated from the plant, may also contribute to these effects (Guerranti et al., 2001; Raina and Khatri, 2011).

**2. MATERIALS AND METHODS**

**2.1 Identification and Preparation of Plant Material**

The plant material used for this study was collected from Iwo in Osun State, Nigeria. It was identified at the University of Ilorin Herbarium unit where the voucher specimen was deposited and the voucher number was give as UILH/001/1563/2025. The leaf was washed, dried, and ground into a fine powder. The powdered sample was then stored in an airtight container at 4°C for future experimental use.

**2.2 Preparation of Extract**

A 1000 g powdered sample was extracted using 2.5 L of absolute methanol for 36 hours through the cold maceration method, with occasional stirring. The liquid extract was then filtered using Whatman filter paper No. 1, and the filtrate was concentrated with a rotary evaporator. The concentrated extract was stored at 4°C for future experimental use.

**2.3 Animal Material**

Healthy male Wistar rats (weighing 180-220 g) were obtained from the Animal House of Ladoke Akintola University of Technology in Ogbomosho, Oyo State, Nigeria, for this study. The rats were housed in standard cages, with six animals per cage. They were kept in a temperature-controlled environment (22.5°C ± 2.5°C) and were on a light cycle with the lights on/off routine set for 7 o’clock. The rats had free access to food and water except during behavioral tests. Throughout the experiment, all animals were fed a commercial standard rodent chow that contained 29% protein, 13% fat, and 58% carbohydrate. All regulations regarding animal safety and care were strictly followed.

**2.4 Behavioral Assessment**

Behavioral analyses were conducted on the 7th, 14th, and 28th days of the study, with observations recorded on the 28th day. All groups of rats underwent the following behavioral tests:

**2.4.1 Catalepsy test**

Catalepsy is a behavioral state observed in rodents where the animals are unable to adjust to externally imposed postures. In this study, haloperidol (1 mg/kg, administered intraperitoneally) was used to induce catalepsy in rats. The duration of catalepsy was measured in seconds using a standard bar test. The bar used for the test was elevated 9 cm above the base. The rat's front paws were placed on this wooden bar, and the time it took for the paws to remain on the elevated bar until they touched the floor was recorded as the cataleptic score. A cutoff time of 180 seconds was applied. The test was conducted on the 28th days of the study (Aubin et al., 1987).

 2.4.2 **Exploratory behavior (rearing)**

Rodents exhibit exploratory behavior, such as rearing, when placed in a new environment. During rearing behavior, their forelimbs make contact with the walls of the container. In this study, small individual plexiglass cages measuring 30 × 20 × 30 cm were used for each animal. The rats were allowed a 5-minute habituation period before the test began. After the habituation period, the number of rearing instances was recorded over the next 5 minutes (Cannon et al., 2009; Aslam et al., 2021).

**2.4.3 Rotarod motor coordination test**

The Rotarod test was utilized to assess the grip strength and muscle rigidity of all animals involved in the study. This test is a commonly used model for evaluating muscle coordination and motor function. Prior to starting the therapy, each rat underwent training to acclimate them to the Rotarod apparatus. During the test, each rat was placed on a rotating rod set to a speed of 25 revolutions per minute (rpm). A cutoff time of 180 seconds was established for the experiment, and the time until each animal fell was recorded in seconds. The test was conducted on the 7th, 14th, and 28th days of the study (Aubin et al., 1987).

**2.4.4 Locomotor activity**

In this study, the locomotor activity of animals was assessed on the 28th days using a digital actophotometer equipped with infrared photocells. The animals' locomotor activity was recorded over a period of 5 minutes, and the results were expressed as counts per 5 minutes (Sing et al., 2010; Shaheen Khan and Imtiyaz Ansari, 2021).

**2.5 Assessment of oxidative stress**

Oxidative stress was assessed in the striatal region of the brain by estimating malondialdehyde (MDA) and reduced glutathione (GSH).

**2.5.1 Estimation of MDA**

MDA (a marker of lipid peroxidation) was measured as described by Ohkawa et al. Thiobarbituric acid was mixed with the brain homogenate under acidic conditions, and the absorbance of the resulting colour, developed after heating, was measured spectrophotometrically at 535 nm.

**2.5.2 Estimation of reduced glutathione assay (GSH)**

An assay for reduced glutathione was performed by precipitating 1 ml of tissue homogenates with 10% trichloroacetic acid (TCA). Additionally, 0.5 ml of 5,5'-dithio-bis-(2-nitrobenzoic acid) (DTNB) reagent and 4 ml of phosphate buffer solution were added to the homogenized supernatant. The absorbance was measured at 412 nm Aslam and Sial, 2014; Aslam et al, 2021).

**3.0 RESULTS**

**3.1 The Effect of Methanol leaves extract of *Mucuna pruriens* on Exploratory Behavior (rearing) in Rats**

Table 1 revealed that the rearing activity of animals was significantly increased in the groups treated with MLEMP in a dose dependent manner when compared with the haloperidol group.

|  |
| --- |
| Treatments Doses (mg/kg) Rearing Counts/5 min\*\* |
| Control 0 35.3±0.05Haloperidol 1 15±0.01MLEMP 200 20.47±0.09\*MLEMP 400 27.58±1.17\*MLEMP 800 38.32±2.12\*Bromocriptine 2.5 39.54±3.21\* |

\*\*Values are recorded as means±SEM (n=5).

\*Values are statistically significant (p<0.05) in relation to control. One way ANOVA followed by Dunnett’post-hoc Multiple Comparison tests

**3.2 Motor Co-ordination Test**

The results indicated a significant reduction in the fall off time in rotarod test in haloperidol-treated group compared to the vehicle control group. However, this performance improved significantly with the administration of Bromocriptine at a dosage of 2.5 mg/kg, as well as MLEMP at doses of 200, 400 and 800 mg/kg. Table 2

TABLE 2: Effect MLEMP on motor coordination test using rotarod

|  |
| --- |
| Treatments Doses (mg/kg) Fall of Time (Sec)\*\* |
| Control 0 49.74±1.21Haloperidol 1 14.32±1.17MLEMP 200 50.17±2.05\*MLEMP 400 59.12±0.51\*MLEMP 800 67.45±0.19\*Bromocriptine 2.5 61.43±1.81\* |

\*\*Values are recorded as means±SEM (n=5).

\*Values are statistically significant (p<0.05) in relation to control. One way ANOVA followed by Dunnett’post-hoc Multiple Comparison tests

**3.3 Effect of MLEMP on Locomotor Activity using actophotometer**

Table 3 showed a significant decrease in spontaneous motor activity in the group treated with haloperidol compared to the vehicle control group. However, the methanol extract of MLEMP significantly increased locomotor activity in a dose-dependent manner when compared to the animals treated with haloperidol.

*Table 3: Effect of MLEMP on Locomotor Activity using actophotometer*

|  |
| --- |
| Treatments Doses (mg/kg) Ambulations Counts/10 min\*\* |
| Control 0 161.3±6.15Haloperidol 1 2.71±0.71MLEMP 200 10.43±0.31\*MLEMP 400 13.18±1.02\*MLEMP 800 15.56±1.92\*Bromocriptine 2.5 19.13±1.41\* |

\*\*Values are recorded as means±SEM (n=5).

\*Values are statistically significant (p<0.05) in relation to control. One way ANOVA followed by Dunnett’post-hoc Multiple Comparison tests

**3.4 Effect of MLEMP on haloperidol-induced Catalepsy in Mice**

Table 4 revealed that the haloperidol control group shows a significantly increased cataleptic score compared to the vehicle control group. MLEMP showed significant inhibition of catalepsy, decreasing the cataleptic score in a dose-dependent manner. Similarly, Bromocriptine also revealed a decrease in cataleptic score.

Table 4- Cataleptic scores

|  |
| --- |
| Treatments Doses (mg/kg) Cataleptic scores\*\* |
| Control 0 0Haloperidol 1 2.78±0.12MLEMP 200 1.98±0.17\*MLEMP 400 1.21±0.05\*MLEMP 800 0.75±0.07\*Bromocriptine 2.5 0.73±0.01\* |

\*\*Values are recorded as means±SEM (n=5).

\*Values are statistically significant (p<0.05) in relation to control. One way ANOVA followed by Dunnett’post-hoc Multiple Comparison tests

**3.5 Effect of MLEMP MDA Levels**

**The brain MDA levels increases significantly (p<0.05) in the group treated with haloperidol compared to the control group. Conversely, the groups pretreated with MLEMP at 800 mg/kg and levodopa exhibited a significant decrease (p < 0.05) in brain MDA levels compared to the haloperidol-treated group, as shown in Table 5. Additionally, there was no significant difference in brain MDA levels between the groups treated with MLEMP at 800 mg/kg and those treated with levodopa.**

*Table 5: Effect of MLEMP on brain levels of MDA in haloperidol-treated mice.*

|  |
| --- |
| Treatments Doses (mg/kg) MDA(nmol/g tissue)\*\* |
| Control 0 194.1±5.23HAL 1 602.6±9.21MLEMP 200 597.3±7.30MLEMP 400 591.7±7.45MLEMP 800 235.5±6.33\*Levodopa 30 230.3±6.17\* |

\*\*Values are recorded as means±SEM (n=5).

\*Values are statistically significant (p<0.05) in relation to control. One way ANOVA followed by Dunnett’post-hoc Multiple Comparison tests

**3.6 Effect of MLEMP GSH Levels**

**In the group treated with haloperidol, there was a significant decrease in brain glutathione (GSH) levels (p < 0.001) compared to the control group. However, the groups that received MLEMP at doses of 200, 400, and 800 mg/kg, as well as the levodopa-pretreated groups, showed a significant increase (p < 0.05) in brain GSH levels when compared to the haloperidol-treated group, as illustrated in Table 6. The group treated with levodopa showed a significantly greater effect compared to the group that received the extract.**

*Table 6: Effect of MLEMP on brain levels of GSH in haloperidol treated mice.*

|  |
| --- |
| Treatments Doses (mg/kg) GSH (μg/g tissue)\*\* |
| Control 0 547.8±9.03HAL1 1 45.2±7.12MLEMP 200 301.3±8.33\*MLEMP 400 346.5±7.38\*MLEMP 800 445.6±5.43\*Levodopa 30 601.1±8.40\* |

\*\*Values are recorded as means±SEM (n=5).

\*Values are statistically significant (p<0.05) in relation to control. One way ANOVA followed by Dunnett’post-hoc Multiple Comparison tests

**4.0 DISCUSSION**

Parkinson’s disease is a chronic neurodegenerative disorder which may be due to the reduction in dopaminergic neurons present in the region of substantia nigra pars compacta. Several pathologies, including mitochondrial dysfunction, oxidative stress, protein accumulation such as alpha-synuclein, and apoptosis, are involved in this disease. However, the most important pathology of PD has been oxidative stress (Friedlich et al., 2009). Haloperidol-induced catalepsy, exploratory behaviour, the rotarod test, and locomotor activity are the most frequently used models for evaluating neurodegenerative disorders in animals. A specific complex I inhibitor (haloperidol) reproduces Parkinsonian signs and symptoms in rodents (Chen et al., 2015). Many research studies have shown that systemic administration of haloperidol can lead to the degradation of dopaminergic neurons in the nigrostriatal pathway, which progresses the development of behavioural, neurochemical, and pathological events of (Chen et al., 2015). The results of haloperidol-induced catalepsy showed that *Mucuna pruriens* provides a significant ameliorative effect on Parkinson’s disease in rats. The effect of *Mucuna pruriens* extract on rearing, muscle rigidity, and locomotor activity of rats was also evaluated, as earlier studies have shown that patients suffering from PD exhibit loss of brain motor coordination and are unable to maintain normal limb posture (Bais et al., 2015). Efficient locomotor activity was observed among the animals treated with *Mucuna pruriens* extract compared to the control group, providing further evidence of the ameliorative effect of *Mucuna pruriens* on PD. The assessment of oxidative stress biochemical parameters involved measuring brain MDA and reduced GSH levels. The group treated with Haloperidol showed a significant increase in brain MDA and a decrease in GSH levels. *Mucuna pruriens* and levodopa significantly decreased brain MDA levels and increased GSH levels. The biochemical test results of our study align with previous studies (Polydoro et al., 2004). The oxidative stress parameters, such as MDA and GSH, are positively influenced by *Mucuna pruriens*, which helps reduce oxidative damage to neurons. *Mucuna pruriens* is a medicinal plant of significant importance, playing a crucial role in protecting against oxidative stress. It has been suggested that antioxidants may protect neurons in Parkinson's disease by preventing degeneration caused by intracellular free radicals (Slivka and Cohen, 1985).

Inflammation and oxidative stress are widely recognized as interconnected. Oxidative stress can exacerbate inflammation, while inflammation can also lead to an increase in oxidative stress (Teismann et al., 2003). The role of neuroinflammation in Parkinson's disease (PD) has coincided with increasing interest in determining whether anti-inflammatory medications might help prevent PD. Recent studies have reported the role of inflammatory processes in the pathogenesis of Parkinson's disease (PD) (Yuan et al., 2007).

Experimental evidence from animal models supports a preventative role for non-steroidal anti-inflammatory drugs in Parkinson's disease (Aubin et al., 1998).

**5.0 CONCLUSSION**

The results of the present study conclusively showed that *Mucuna pruriens* has antioxidant activity and a neuroprotective role in the haloperidol experimental model of PD. *Mucuna pruriens* has been shown to improve rota rod performance and reduce catatonic responses. Therefore, the neuromodulatory effects of *Mucuna pruriens* on behaviour and oxidative stress may be attributed to its neuroprotective and antioxidant properties.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

**CONSENT**

It’s not applicable.

**ETHICAL APPROVAL**

Animal Ethic committee approval has been collected and preserved by the author(s)

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**REFERENCES**

Aslam, M., Hammad, A., Tayyaba, M., and Gahzal H., (2021). Antiparkinsonian Activity of Aqueous Extract of Agaricus Blazei Murill in Rotenone-induced Parkinson’s Disease. Journal of Pharmaceutical Research International 33(33B): 121-131, Article no.JPRI.69598 ISSN: 2456-9119

Aslam, M., Sial AA., (2014). Neuroprotective effect of ethanol extract of leaves of Malva parviflora against amyloid-β-(Aβ-) mediated Alzheimer’s disease. Int Sch Res Notices; 2014

Aubin, N., Curet, O., Deffois, A., Carter, C. (1998). Aspirin and salicylate protect against MPTP-induced dopamine depletion in mice. J Neurochem. 71(4):1635-42.

Ball, N., Teo, W. P., Chandra, S., & Chapman, J. (2019). Parkinson's disease and the environment.Frontiers in neurology,10, 218.https://doi.org/10.3389/fneur.2019.00218

Bais, S., Gill, N.S., Kumar, N. (2015). Neuroprotective effect of Juniperus communis on chlorpromazine induced Parkinson disease in animal model. Chinese J Biol. 8(2) 235-248

Cannon, J.R., Tapias, V., Na, H.M., Honick, A.S., Drolet, R.E., Greenamyre, J.T (2009). A highly reproducible rotenone model of Parkinson's disease Neurobiol Dis. 34(2):279-90

Chen, Y., Zhang, D.Q., Liao, Z., Wang, B., Gong, S., Wang, C., Zhang, M.Z., Wang, G.H., Cai, H., Liao, F.F., Xu, J.P (2015). Anti-oxidant polydatin (piceid) protects against substantia nigral motor degeneration in multiple rodent models of Parkinson’s disease. Mol Neurodegener. 10(1):1-4.

Ellman, G.L. (1959). Tissue sulfhydryl groups. Arch Biochem Biophys. 82(1):70-7.

Erjavec, G. N., Grubor, M., Zivkovic,M., Bozina, M., Sagud, M., Perkovic, M.N.,et al. (2022).SLC6A3, HTR2C and HTR6 gene polymorphisms and the risk of haloperidol-induced parkinsonism, Biomedicines, 10(3237), 1-16 <https://doi.org/10.3390/biomedicines10123237>

Friedlich, A.L., Smith, M.A., Zhu, X., Takeda, A., Nunomura, A., Moreira, P.I., Perry, G. (2009). Oxidative stress in Parkinson’s disease. Open Pathol J. 3(1):38-42

Gamaniel, K.S. (2000). Toxicity from Medicinal Plants and their Products. Nig. J. Nat Proc and Med 4:4-9.

Guerranti, R., Aguiyi, J.C., Errico, E and Pagani, R., (2001). Effect of Mucuna pruriens extract on activation of prothrombin by Echis carinatus venom. Journal of Ethnopharmacy 75 175 – 180.

Grubor, M., Zivkovic, M., Sagud, M., Nikolac Perkovic, M., Mihaljevic-Peles, A., Pivac, N., Muck-Seler, D., & Svob Strac, D. (2020). HTR1A, HTR1B, HTR2A, HTR2CandHTR6gene polymorphisms and extrapyramidal side effects in haloperidol-treated patients with Schizophrenia. International journal of molecular sciences, 21(7), 2345. <https://doi.org/10.3390/ijms21072345>

Hauser, D.N., Hastings, T.G (2013). Mitochondrial dysfunction and oxidative stress in Parkinson's disease and monogenic parkinsonism. Neurobiol Dis. 51:35-42.

Hayes, M. T., (2019). Parkinson's Disease and Parkinsonism. The American journal of medicine,132(7), 802–807. <https://doi.org/10.1016/j.amjmed.2019.03.001>

Jeong, S., Cho, H., Kim, Y. J., Ma, H. I., & Jang, S. (2021). Drug-induced Parkinsonism: A strong predictor of idiopathic Parkinson's disease.PloS one,16(3), e0247354. [https://doi.org/10. 1371/journal.pone.0247354](https://doi.org/10.%201371/journal.pone.0247354)

Kabra, A., Baghel, U. S., Hano, C., Martins, N., Khalid, M., & Sharma, R. (2020). Neuroprotective potential of Myrica esulenta in Haloperidol induced Parkinson's disease. Journal of Ayurveda and integrative medicine,11(4), 448–454. <https://doi.org/10.1016/j.jaim.2020.06.007>

Malaiwong, N., Chalorak, P., Jattujan, P., Manohong, P., Niamnont, N., Suphamungmee, W., Sobhon, P., & Meemon, K. (2019). Anti-parkinson activity of bioactive substances extracted from Holothuria leucospilota.Biomedicine & pharmacotherapy = Biomedecine & pharmacotherapie,109, 1967–1977.https://doi.org/10.1016/j.biopha.2018.11.063

Malluruwar, V.R., Joharapurkar, A .J and Duragkar N.J (2006). Studies on immunomodulatory activity of Mucuna pruriens. Indian J. Pharm. Educ. Res. 40(3) 205-207

Muhammad Aslam, Hammad Ahmed, Tayyaba Mumtaz, and Gahzal Hakani. (2021). Antiparkinsonian Activity of Aqueous Extract of Agaricus Blazei Murill in Rotenone-induced Parkinson’s Disease Journal of Pharmaceutical Research International. 33(33B): 121-131; Article no.JPRI.69598 ISSN: 2456-9119

Ohkawa, H., Ohishi, N., Yagi, K., (1979) Assay for lipid peroxide in animal tissues by thiobarbituric acid reaction. Anal Biochem. 95(2):351-8.11.

Polydoro, M., Schröder, N., Lima, M.N., Caldana, F., Laranja, D.C., Bromberg, E., (2004) Haloperidol- and clozapine-induced oxidative stress in the rat brain. Pharmacol Biochem Behav. 78(4):751-6.

Prakash, D., Niranjan, A and Tewari, S.K (2001). Some nutritional properties of the seeds of three Mucuna species. Int. J. Food Sci. Nutr. 52(1):79-82.

Radenović, L., Selaković, V., Janać, B., Todorović, D (2007). Effect of glutamate antagonists on nitric oxide production in rat brain following intrahippocampal injection. Arch Biol Sci. 59(1):29-36.

Raina, A.P., and Khatrir R (2011). Quantitative determination of L-Dopa in seeds of Mucuna pruriens Germplasm by high performance liquid chromatography. Indian J. Pharm. Sci. 73(4):459-62.

Shaheen Khan and Imtiyaz Ansari (2021). Antiparkinsonian activity of hydroalcoholic extract of the stem of Capparis decidua (FORSSK). IJPSR, 12(10): 5388-5395.

Sharma, N., Nehru, B (2013). Beneficial effect of vitamin E in rotenone induced model of PD: behavioural, neurochemical and biochemical study. Exp Neurobiol. 22(3):214.

Singh, B., Chopra, A., Ishar, M.P., Sharma, A., Raj, T (2010). Pharmacognostic and antifungal investigations of Elaeocarpus ganitrus (Rudrakasha). Indian J Pharm Sci. 72(2):261-5

Slivka, A., Cohen, G. (1985). Hydroxyl radical attack on dopamine. J Biol Chem. 260(29):15466-72.

Teismann, P., Vila, M., Choi, D.K., Tieu, K., Wu, D.C., Jackson-Lewis, V, et al. (2003). COX-2 and neurodegeneration in Parkinson’s disease. Ann N Y Acad Sci. 991:272-7.

Vaiman, E. E., Shnayder, N. A., Khasanova, A. K., Strelnik, A. I., Gayduk, A. J., Al-Zamil, M., Sapronova, M. R., Zhukova, N. G., Smirnova, D. A., & Nasyrova, R. F. (2022). Pathophysiological Mechanisms of Antipsychotic-Induced Parkinsonism.Biomedicines, 10(8), 2010. https://doi.org/10.3390/biomedicines10082010

Yuan, H., Zheng, J.C., Liu, P., Zhang, S.F., Xu, J.Y., Bai, L.M(2007). Pathogenesis of Parkinson’s disease: oxidative stress, environmental impact factors and inflammatory processes. Neurosci Bull. 23(2):125-30.