IJPSR (2022), Volume 13, Issue 12 (Research Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 14 September 2022; received in revised form, 11 November 2022; accepted, 15 November 2022; published 01 December 2022

MICHELIA CHAMPACA LEAF EXTRACTS EXHIBIT HYPOGLYCEMIC EFFECT AND HYPOLIPIDEMIC ACTIVITY IN STREPTOZOTOCIN-NICOTINAMIDE-INDUCED DIABETIC RATS

Jyoti Nanda [1, 2 *], Munesh Mani [1], Shanti Bhushan Mishra [3] and Neeraj Verma [4]

Pharmacy Academy [1], IFTM University, Moradabad - 244102, Uttar Pradesh, India.
School of Pharmaceutical Sciences [2], CSJM University, Kanpur - 208024, Uttar Pradesh, India.
United Institute of Pharmacy [3], Prayagraj - 211010, Uttar Pradesh, India.
Hygia Institute of Pharmaceutical Education and Research [4], Lucknow - 226020, Uttar Pradesh, India.

Keywords:

Michelia champaca, Biochemical, Streptozotocin-Nicotinamide, Insulin, Antidiabetic activity

Correspondence to Author:
Jyoti Nanda

Ph.D Research Scholar,
Pharmacy Academy,
IFTM University, Moradabad - 244102, Uttar Pradesh, India.

E-mail: jyotinanda954@gmail.com

ABSTRACT: A metabolic disease called diabetes mellitus in which blood glucose levels are abnormally high. It could be due to tissue glucose intolerance and impaired insulin production. In a Type II diabetes model generated by Streptozotocin and nicotinamide, the antidiabetic potential of ethanolic and aqueous leaf extracts of *Michelia champaca* (Magnoliaceae) was compared to a control group of diabetes. The anti-diabetic activity was tested on Wistar rats. The effective antihyperglycemic ethanolic and aqueous leaf extracts were tested at two doses of 250 mgkg-1 b.w. and 500 mgkg-1 b.w. for 21 days. Compared to the diabetic control group, the ethanolic extract at a dose of 500 mgkg-1 b.w. exhibits a highly significant ($p<0.001$) reduction in fasting blood glucose levels. After the trial, the blood sample was drawn from all animals for biochemical analysis. In extract-treated diabetic rats, the serum lipid profile was calculated. The biochemical investigation, serum cholesterol, serum triglyceride, high-density lipoprotein, and low-density lipoprotein support the ethanolic extract's anti-diabetic effectiveness.

INTRODUCTION: Hyperglycemia is a collection of illnesses marked by high blood sugar level, altered lipid, carbohydrate and protein metabolism, and an elevated risk of vascular consequences. Type II diabetes affects the vast majority of people. According to the WHO Global Report on Diabetes 2016, people with hyperglycemia have nearly doubled to 422 million [1]. There are diabetic patients that have insulin insufficiency or insulin resistance, as well as excessive glucagonemia.

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.13(12).5200-06

This article can be accessed online on www.ijpsr.com

DOI link: http://dx.doi.org/10.13040/IJPSR.0975-8232.13(12).5200-06

There is an increase in hepatic glucose synthesis, a decrease in peripheral glucose uptake and a reduction in glucose to glycogen conversion in the liver [2]. In Type 2 diabetes, beta-cells are remaining no longer to produce a sufficient amount of insulin. It arises due to sedentary lifestyle, alcohol consumption, cigarette smoking, physical inactivity and genetics which cause overweight and obesity leads to a reduction in insulin sensitization and glucose tolerance [3].

Patients with diabetic kidney disease (DKD) are at increased risk of end-stage kidney disease (ESKD) and cardiovascular disease, increased mortality, lower quality of life and higher health care costs [4]. Reactive oxygen species induce a complexing agent called advanced glycation end-product (AGE), which may convert normal glucose level

stage to hyper glucose level stage [5]. Flavonoids are widely distributed in plants, and many studies have shown that flavonoids possess antidiabetic properties and powerful antioxidant activity, which is an important factor in the treatment of diabetes and in preventing the development of diabetic angiopathies [6, 7]. Rutin decreases the formation of reactive oxygen species, advanced glycation end-product precursors and inflammatory cytokines. These effects are considered to be responsible for the protective effect of rutin against hyperglycemia and dyslipidemia-induced nephropathy, neuropathy, liver damage, and cardiovascular disorders [8].

Modern pharmacotherapeutics, such as insulin, biguanides, sulfonylureas and thiazolidinediones, have emerged as a result of the advancement of modern medicine [9]. The widely used allopathic oral hypoglycemic drugs for treating diabetes have been demonstrated to have a number of undesirable side effects. As a result, research is still concentrated on traditional medicinal plants that have been shown to have hypoglycemic effect; herbal therapy for diabetes is now a well-liked treatment option globally. Aims to formulate new pharmaceuticals with maximal performance and minimum adverse effects by extracting newer orally therapeutic hypoglycemic phytoconstituents. Diabetes therapy with herbs has been a focus of study on currently used traditional medicinal plants with established scientific evidence for hypoglycemic action.

Streptozotocin (STZ), a diabetogenic drug, is routinely administered to animals to cause diabetes. Diabetes mellitus can be triggered by 3 different strategies, including feeding rats a high-fat diet (HFD) and administering STZ injections after the administration of nicotinamide (STZ-NA) [10, 11]. In order to evaluate the anti-diabetic effectiveness of *Michelia champaca* leaves, one of the 3 method was the STZ-NA model [12]. The Magnoliaceae family includes *Michelia champaca* Linn, also known as Svarna Champa. The tree's unusual appearance, which includes a smooth trunk and large ovate, glossy leaves, is used in many conventional herbal remedies. It is well renowned for its gigantic, fragrant yellow blossoms. It flourishes from hot, humid weather and acidic soil [13]. The leaves, stems, roots of *Michelia champaca* comprise a variety of phytoconstituents, including alkaloids, sugars, glycosides, tannins, proteins, amino acids and flavonoids [14].

MATERIALS AND METHODS:

Plant Material and Extract Preparation: The leaves of *M. champaca* L. were collected in and around Lucknow. Principal Scientist Dr. Lal Babu Chaudhary, certified and authenticated *Michelia champaca* Linn. leaves at Department of Plant Diversity, Systematics, and Herbarium Division, National Botanical Research Institute, Lucknow, Uttar Pradesh, India. The plant's herbarium with accession number LWG 109567 has been deposited for future reference. Before being processed with a mechanical grinder, fresh leaves were dried in the shade. One kilogram of dried *Michelia champaca* leaf powder was extracted using petroleum ether, chloroform, ethyl acetate, ethanol, and distilled water in a Soxhlet apparatus. Collected extracts were heated to 40 °C in a hot air oven after being concentrated in a vacuum rotary evaporator at the Hygia Institute of Pharmaceutical Education and Research in Lucknow, Uttar Pradesh, India. The percentage yields of the ethanolic extract (12.5%)) and the aqueous extract (16.2%) of *Michelia champaca* leaves were calculated on the basis of the overall volume of powder used for the extraction.

Preliminary Phytochemical Screening: The extract was subjected to preliminary phytochemical screening for the identification of various active constituents by using standard procedure.

Drugs and Chemicals: Streptozotocin (Calbiochem, Mumbai, India), Nicotinamide (HiMedia, Mumbai, India), Glibenclamide pure powder (API as a gift sample from Sigma-Aldrich Ltd., Mumbai, India), and the Accu-chek Blood Glucose Test Strips and a functioning meter (Roche, India) were all acquired as chemicals and medications. All of the chemicals and reagents utilized were of the analytical sort.

Experimental Animals: Wistar rats of both sexes were provided by the Animal House at the United Institute of Pharmacy in Prayagraj, U. P., India. Standard husbandry practices were employed to house the animals, including a diurnal cycle at room temperature for 7-day acclimatization phase. The experimental investigation followed the

standards for laboratory animal experimentation established by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA), and the research protocol (UIP/IAEC/Nov.-2020/06) was approved by the United Institute of Pharmacy's Institutional Animal Ethics Committee (Reg. No. 1451/PO/Re/S/11/CPCSEA). For the experiment, animals of both sexes weighing 150–167 grams were employed.

Acute Toxicity Study of Extracts: According to the recommendations of the Organization for Environmental Control Development (OECD)-423, acute toxicity tests are carried out in experimental animals to obtain the LD_{50} value, which is used to estimate the therapeutic dose.

Different groups of rats received a single dosage of EEMC and AEMC extracts by oral gavage at doses of 5 $mgkg^{-1}$, 50 $mgkg^{-1}$, 300 $mgkg^{-1}$, 2000 $mgkg^{-1}$ and 5000 $mgkg^{-1}$ in appropriate water (three each). Based on the LD_{50} calculation, dosages of 250 $mgkg^{-1}$ and 500 $mgkg^{-1}$ were selected for their ability to have an anti-diabetic effect.

Experimental Induction of Diabetes: Animals developed diabetes after exposure to the STZ-NA model. The trial involves repeated oral dosing over the course of 21 days. The overnight-fasting rats from Groups II to VII were given intraperitoneally single injected dose of NA (120 mg/kg body weight) and after 15 minutes, STZ (60 mg/kg body weight) intraperitoneally injected to induce Non-insulin-dependent diabetes mellitus.

Using a glucometer to measure the rats' blood sugar levels (BSL), was determined after 72 hours receiving STZ-NA injections. The animals were randomly assigned to seven different groups i.e. Group I to VII. Group I served as normal control (NC) containing 6 normal rats.

Experimental Approach for Anti-diabetic Activity: Six groups (6 animals in each group) of STZNAD rats of either sex were randomly created, and one group had six ND rats.

Throughout the trial, they had unrestricted access to water and animal food. For 21 days, oral doses of AEMC 250 mg/kg, AEMC 500 mg/kg, EEMC 250 mg/kg, and EEMC 500 mg/kg were administered.

Group I-NC: ND animals are given Distill water and served as Normal Control

Group II-DC: STZNAD animals used as Diabetic Control got Distill water.

Group III-STD: Glibenclamide 600 µg/kg/day given to STZNAD rats.

Group IV- AEMC 250mg/kg: STZNAD animals givenAEMC 250 $mgkg^{-1}day^{-1}$.

Group V- AEMC 500mg/kg: STZNAD animals given AEMC 500 $mgkg^{-1}$ day^{-1}.

Group VI- EEMC 250mg/kg: STZNAD rats received EEMC 250mg/kg /day.

Group VII- EEMC 500mg/kg: STZNAD rats received EEMC 500mg/kg /day.

Monitoring of Blood Sugar Level During Treatment: Animal's blood was drawn by clipping the tips of their tails, and blood sugar levels (BSL) were measured using an Accu-Check glucometer. Throughout the study period, BSL readings were taken every week at intervals (0th, 7th, 14th, and 21st days). The values of sample treated were compared with that of the standard group which was treated with Glibenclamide. Then, all animals were sacrificed by a sodium pentobarbitone overdose (150 mg/kg). The collected blood samples were immediately centrifuged at 2500 rpm for 15 min. The serum separated was collected in fresh serum tubes and stored tightly capped in refrigerator (2-4 degree centigrade). Effect of test extracts on antioxidant enzymes and lipid profile were assessed.

***In-vivo* Antioxidant Activity in Diabetic Rats:** Measurement of Glutathione-S-transferase (GST), Reduced glutathione (GSH) and Glutathione peroxidase (GPx), Catalase (CAT), and Superoxide dismutase (SOD) were determined to ascertain its antioxidant activity by standard procedure [17].

Estimation of Biochemical Parameters: Measurement of lipid level, triglyceride and total cholesterol in blood serum were determined after 21 days.

Statistical Analysis: Mean ±Standard deviation were used to express the data. Utilizing the programme Graph Pad Prism 9.3.1, data analysis was carried out. All data were evaluated using a

one-way Analysis of Variance (ANOVA), using Newman-Keuls test. It was thought that a value of $p < 0.001$ was more statistically significant.

RESULTS:

Preliminary Phytochemical Screening: Preliminary phytochemical screening revealed the presence of carbohydrate, phenolic compounds, sterols, alkaloids, glycoside and flavonoids in ethanolic and aqueous extract of leaves.

Study on the Acute Toxicity of *Michelia champaca* Leaf: At the maximum dose (5000 mg/kg), orally ingested AEMC and EEMC did not result in any deaths or adverse responses within 4 hours and after 14 days.

Effect of *Michelia champaca* Leaf Extracts on BSL: Table 1 Fig. 1, demonstrate the impact of oral daily dose of *Michelia champaca* aqueous extract and ethanolic extract (250 mg/kg and 500 mg/kg) on the blood glucose level over the course of 21 days. By the end of treatment, the blood glucose level reduced from 279.16 mg/dL to 113.16 mg/dL (59.46%) in rats treated at a dose of 250 mg/kg ($p < 0.001$) and blood glucose level reduced from 277.66 mg/ dL to 108.16 mg/dL (61.04%) in rats treated at a dose of 500 mg/kg ($p<0.001$) for the oral administration of aqueous extract. For the oral administration of 250 mg/kg of the ethanolic extract, the blood glucose level reduced from 276.83 mg/dL to 102.5 mg/dL (62.97%) at 21 days ($p < 0.001$) and blood glucose level reduced from 275.0 mg/ dL to 95.33 mg/dL (65.33%) in rats treated at a dose of 500 mg/kg ($p<0.001$) for the oral administration of ethanolic extract of *Michelia champaca*. For Glibenclamide (600 µg/kg), the blood glucose level reduced from 272.0 mg/dL to 92.16 mg/dL (66.11%) ($p < 0.001$. Orally ingested ethanolic extract of *Michelia champaca* leaves at a dose of 500 mg/kg ($p<0.001$) yields more significant results when compared to the hyperglycemia group**.**

TABLE 1: IMPACT OF VARIOUS EXTRACTS OF *MICHELIA CHAMPACA* LEAVES ON BLOOD GLUCOSE LEVEL OF STREPTOZOTOCIN NICOTINAMIDE CAUSED DIABETES IN RATS

Group(n)	0 Day	7th Day	14th Day	21st Day
Normal Control	80.5±6.97	81.0±8.85	81.83±9.15	82.33±9.58
Diabetic Control	282.33±18.7^{z}	275.16±18.98^{z}	265.33±21.46^{z}	209.83±16.20^{z}
Standard Drug	272.0±18.25	232.83±16.30	118.0±13.39	92.16±8.89^{c}
AEMC 250mg/kg	279.16±18.72	253.16±18.34	142.66±16.71^{b}	113.16±6.30^{c}
AEMC 500mg/kg	277.66±18.43	238.83±18.10	136.66±14.26^{c}	108.16±5.75^{c}
EEMC 250 mg/kg	276.83±18.55	201.5±17.96^{a}	130.66±11.35^{c}	102.5±6.04^{c}
EEMC 500mg/kg	275.0±18.29	195.33±17.15^{b}	124.0±13.13^{c}	95.33±6.42^{c}

The data represent as mean ± standard deviation of 6 animals in each group. $^{b}p<0.01$ and $^{c}p < 0.001$ compared to diabetic control group. $^{z}p< 0.001$ as compared to control group.

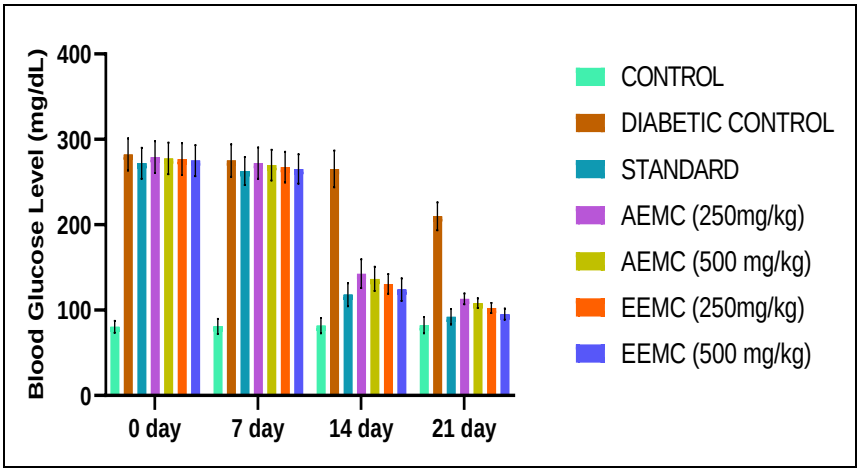

FIG. 1: EFFECT OF AEMC AND EEMC ON BLOOD GLUCOSE LEVEL

Table 2 and **Fig. 2** shows a significant increase in GSH, GST, GPx, and CAT and SOD in the Liver on the oral administration of *Michelia champaca* extracts at dose level 250 mg/kg and 500 mg/kg.

TABLE 2: THE EFFECT OF *MICHELIA CHAMPACA* EXTRACTS ON *IN-VIVO* ANTIOXIDANT ENZYMES OF LIVER

Group(n)	GSH	GST	GPx	CAT	SOD
Normal Control (Group I)	124.66±2.21	7.83±0.68	9.0±0.58	75.33±0.94	7.33±0.74
Diabetic Control(GroupII)	71.66±1.97	5.5±0.95	6.67±0.94	37.33±1.10	4.16±0.68
Standard Drug(Group III)	124±1.29^{c}	8.17±0.68^{c}	8.5±0.76^{c}	72.5±5.02	7.0±0.81^{c}
AEMC 250mg/kg(Group IV)	113.83±2.67^{b}	4.83±0.68	4.83±0.68	68±3.41	5.66±0.74
AEPA500mg/kg (Group V)	118.5±1.5	6±0.58	5.83±0.68	70.0±3.31	6.83±0.89
EEPA 250 mg/kg (Group VI)	120.67±1.79	7.17±0.69	7±0.57	72.33±2.98	7.66±0.74
EEPA 500mg/kg (Group VII)	122.5±1.70^{c}	8.33±0.75	8.33±0.74^{c}	74.66±2.80^{c}	8.66±0.74^{c}

The value represents mean ± SD for 6 rats per group. $^{b}p < 0.01$ and $^{c}p < 0.001$ compared to diabetic control group. zp< 0.001 compared versus normal control.

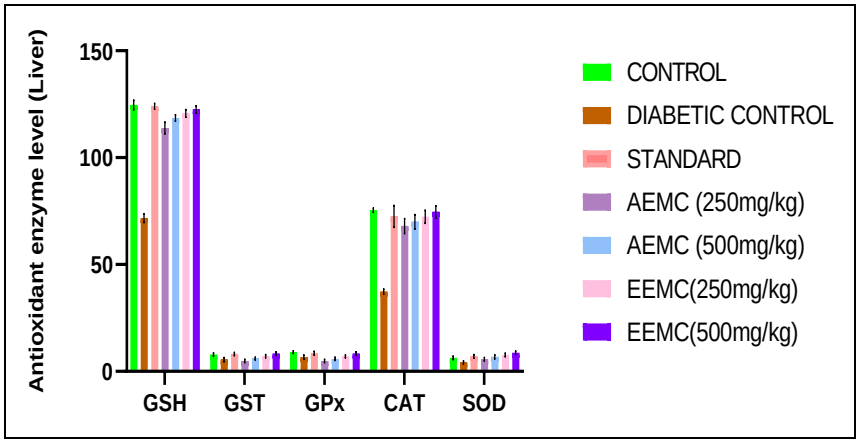

FIG. 2: EFFECT OF AEMC AND EEMC ON *IN-VIVO* ANTIOXIDANT ENZYMES IN LIVER

Table 3 and **Fig. 3** shows a significant increase in GSH, GST, GPx, sand CAT in the kidney on the oral administration of *Michelia champaca* extracts at dose level 250 mg/kg and 500 mg/kg.

TABLE 3: THE EFFECT OF *MICHELIA CHAMPACA* EXTRACTS ON *IN-VIVO* ANTIOXIDANT ENZYMES OF KIDNEY

Group(n)	GSH	GST	GPx	CAT
Normal Control (Group I)	119±2.65	7.33±1.05	5.83±0.68	37.66±1.37
Diabetic Control(GroupII)	47.33±1.79^{z}	4.83±1.07^{z}	3.5±0.5^{z}	22.66±1.59^{z}
Standard Drug(Group III)	96.0±3.21^{c}	7.5±0.95^{c}	7.5±1.25^{c}	38.16±1.34^{c}
AEMC 250mg/kg(Group IV)	88.35±2.35	4.5±0.95	4.16±0.68	27.83±1.06
AEPA500mg/kg (Group V)	91.33±3.39^{b}	5.33±1.05^{b}	5.5±0.95^{b}	29.66±0.94
EEPA 250 mg/kg (Group VI)	93.16±3.53^{c}	6.33±1.01^{c}	6.83±1.06	33.5±1.5^{c}
EEPA 500mg/kg (Group VII)	96.33±2.49^{c}	7.5±0.96^{c}	7.83±1.06^{c}	37.16±1.57^{c}

The value represents mean ± SD for 6 rats per group. $^{a}p < 0.05$, $^{b}p < 0.01$ and $^{c}p < 0.001$ compared to diabetic control group. $^{z}p<$ 0.001 compared versus normal control.

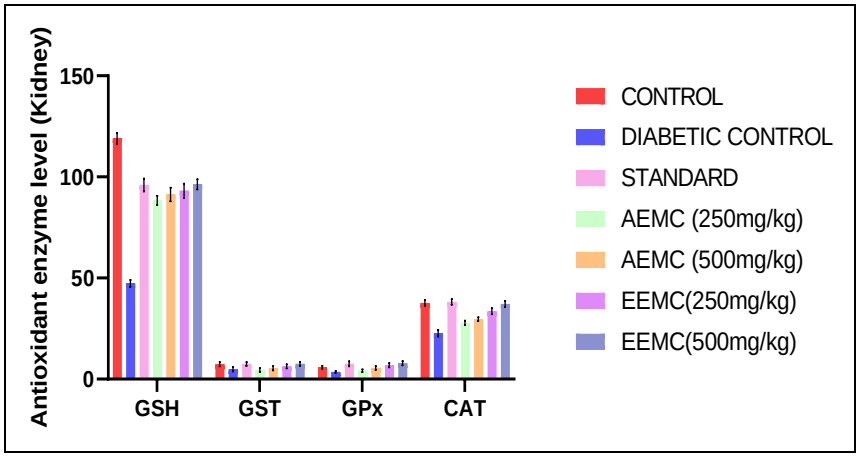

FIG. 3: EFFECT OF AEMC AND EEMC ON *IN-VIVO* ANTIOXIDANT ENZYMES IN KIDNEY

Table 4 and **Fig. 4** demonstrate the triglyceride level in the STZ Nicotinamide-treated group was 71.17 mg/dL in the normal control group and 113.5 mg/dL in the diabetic control group ($p < 0.001$); the cholesterol level was 75.5 mg/dL in the normal control group and 149.67 mg/dL in the diabetic control group ($p < 0.001$); the HDL level was 52.16 mg/dL in the normal control group and 27.0 mg/dL in the diabetic control group ($p < 0.001$) and the LDL level was 31.66 mg/dL in the normal control group and 42.33 mg/dL in the diabetic control group ($p < 0.001$).

TABLE 4: IMPACT OF SEVERAL *MICHELIA CHAMPACA* EXTRACTS ON LIPID LEVEL, TRIGLYCERIDE AND TOTAL CHOLESTEROL IN BLOOD SERUM AFTER 21 DAYS

Category	Triglycerides	Cholesterol	HDL	LDL
Normal Control	71.17±5.39	75.5±4.19	52.16±2.91	31.66±4.92
Diabetic Control	113.5±10.89^{z}	149.67±24.73^{z}	27.0±3.55^{z}	42.33±1.59^{z}
Standard Drug	80.67±8.86^{c}	79.33±8.35^{c}	53.66±1.97^{c}	26.66±2.68^{c}
AEMC 250mg/kg	105.67±11.33	99±11.46^{a}	39.0±2.94	38.16±1.95^{a}
AEMC 500mg/kg	98.5±9.11^{b}	92±9.50^{b}	41.33±2.86^{b}	35.66±1.97
EEMC250 mg/kg	91.17±8.13^{c}	85.16±8.78^{c}	47.0±2.44^{c}	32.33±3.09^{c}
EEMC 500mg/kg	86.5±8.69^{c}	80.67±7.82^{c}	50.5±1.70^{c}	30.66±2.86^{c}

The value represents mean ± SD for six animals in each group. $^{a}p < 0.05$, $^{b}p < 0.01$ and $^{c}p < 0.001$ compared to diabetic control group. $^{z}p < 0.001$ compared versus normal control.

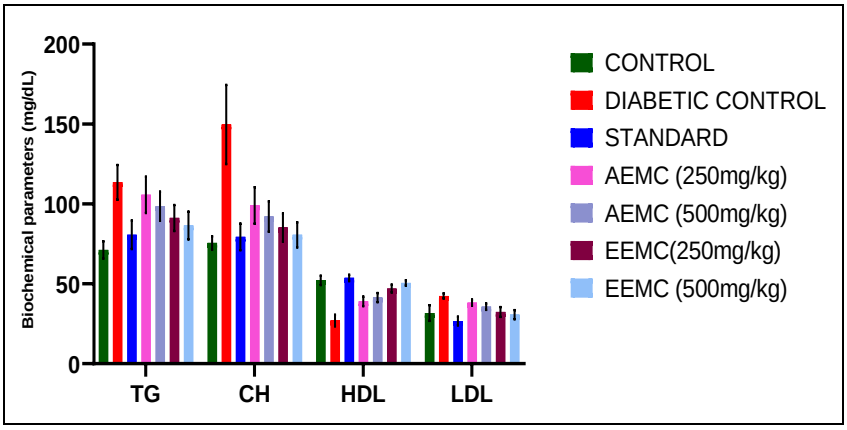

FIG. 4: EFFECT OF AEMC AND EEMC ON BIOCHEMICAL PARAMETERS

DISCUSSION: Diabetes is a severe, chronic condition that develops when the pancreas either generates insufficient amounts of insulin or when the body struggles to utilize the insulin that is produced. Diabetes prevalence has increased more quickly in low- and middle-income nations during the past ten years than in high-income nations. Type 2 diabetes affects the majority of persons who have the disease. This used to happen almost exclusively to adults, but today kids also experience it. All forms of diabetes raise the overall chance of premature death and can cause complications in various body parts. A heart attack, a stroke, kidney failure, eyesight loss, and nerve damage are all potential risks. Poorly managed diabetes during pregnancy raises the risk of complications, including foetal mortality. The combination of streptozotocin and nicotinamide in the type II diabetes model prevents pancreatic cells from becoming completely insulin-deficient. However, when nicotinamide is given first, it partially shields insulin-secreting pancreatic beta cells from the harmful effects of streptozotocin [18]. Streptozotocin alone fully destroys pancreatic beta cells and renders them insulin-deficient. Secondary metabolites such as alkaloids, flavonoids, and saponins reduced plasma cholesterol and triglycerides significantly, significantly decreased glucose levels and significantly increased hepatic glucokinase activity. This was most likely accomplished by increasing the release of insulin from pancreatic islets [19]. Increased enzymatic antioxidant activity was seen after treatment with *M. champaca*, which may be related to flavonoids. Due to their well-known antioxidant qualities, the flavonoids in the leaf extract scavenge the free radicals produced during diabetes. All the above observations suggest that *M. champaca* can be a promising antidiabetic and antioxidant drug.

CONCLUSION: We concluded that *Michelia champaca* extracts had anti-diabetic properties and significantly reduced blood glucose levels. It has been established that *Michelia champaca* is a reliable diabetes medication. It is possible that the observed antihyperglycemic activity of *Michelia champaca* leaves is related to the presence of flavonoids, sterols, phenols, glycosides, and alkaloids as active constituents. The current analysis has also paved the way for additional study, particularly in relation to the creation of effective herbal remedies for diabetes mellitus using *Michelia champaca* leaves.

ACKNOWLEDGEMENT: The authors are acknowledging Dr. Alok Mukerjee, Professor, United Institute of Pharmacy, Prayagraj, U.P., India, for providing facilities to carry out the pharmacological activity.

CONFLICTS OF INTEREST: The authors declare no conflicts of interest.

REFERENCES:

1. Global report on diabetes. (2016). https://www.who.int/publications-detail-redirect/9789241565257
2. Ng SH, Zain M, Zakaria MSF, Wan Ishak WR & Wan Ahmad WAN: Hypoglycemic and Antidiabetic Effect of *Pleurotus sajor-caju* Aqueous Extract in Normal and Streptozotocin-Induced Diabetic Rats. BioMed Research International 2015; 1–8. https://doi.org/10.1155/2015/214918
3. Prabhakar P and Banerjee M: A comprehensive Review on Opportunities and Challenges in Targeted Therapy for Herbal Drug Development. International Journal of Pharmaceutical Research 2020; 1: 1673-1696.
4. Harris ST, Patorno E, Zhuo M, Kim SC & Paik JM: Prescribing Trends of Antidiabetic Medications in Patients with Type 2 Diabetes and Diabetic Kidney Disease: A Cohort Study. Diabetes Care 2021; 44(10): 2293–2301. https://doi.org/10.2337/dc21-0529
5. Gupta S, Sharma H, Morsy M, Nair A, Kaur K, Kumar S & Dhanawat M: Protective Effect of *Plumeria obtusa* Leaves Extracts on Dexamethasone-induced Insulin-resistance Diabetes Mellitus in Rats. Indian Journal of Pharmaceutical Education and Research 2021; 55: 184–192. https://doi.org/10.5530/ijper.55.1s.49
6. Lan Bai, Xiaofang Li, Li He and Yu Zheng: Antidiabetic potential of flavonoids from traditional chinese medicine: a review. The American Journal of Chinese Medicine 2019; 47(5): 933–957. https://doi.org/10.1142/S0192415X19500496
7. Alona S and Ivanna M: Total flavonoid content in the herbal mixture with antidiabetic activity. Pharmacologyonline 2021; 2: 68-75
8. Ghorbani & Ahmad: Mechanisms of antidiabetic effects of flavonoid rutin. Biomedicine & Pharmacotherapy 2017; 96: 305-312. https://doi.org/10.1016/j.biopha.2017.10.001
9. Jarald, Edwin E, Joshi SB & Jain DC: Antidiabetic activity of flower buds of *Michelia champaca* Linn. Indian Journal of Pharmacology 2008; 40(6): 256-260.
10. Phatak RS, Khanwelkar CC, Matule SM, Datkhile KD & Hendre AS: Antihyperglycemic Activity of *Murraya koenigii* Leaves Extract on Blood Sugar Level in Streptozotocin-Nicotinamide Induced Diabetes in Rats. Biomedical and Pharmacology Journal 2019; 12(2): 597–602. https://doi.org/10.13005/bpj/1679
11. Wu J & Yan LJ: Streptozotocin-induced type 1 diabetes in rodents as a model for studying mitochondrial mechanisms of diabetic β cell glucotoxicity. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy 2015; 8: 181–188. https://doi.org/10.2147/DMSO.S82272
12. Mishra SB, Verma A, Mukerjee A and Vijayakumar M: *Amaranthus spinosus* L. (Amaranthaceae) leaf extract attenuates Streptozotocin-nicotinamide induced diabetes and oxidative stress in albino rats: A histopathological analysis. Asian Pacific Journal of Tropical Biomedicine 2012; 1647-1652.
13. Kumar R, Pate DK, Prasad SK, Sairam K & Hemalatha S: Antidiabetic activity of alcoholic leaves extract of *Alangium lamarckii* Thwaites on streptozotocin–nicotinamide induced type 2 diabetic rats. Asian Pacific Journal of Tropical Medicine 2011; 4(11): 904–909. https://doi.org/10.1016/S1995-7645(11)60216-2
14. Tropical Tree Seed Manual. U.S. Department of Agriculture, Forest Service 2002; 904
15. Gupta S, Mehla K,Chauhan D & Nair A: Anti-inflammatory activity from leaves of *Michelia Champaca* investigated on acute inflammation induced rats. Latin American Journal of Pharmacy 2011; 819-822
16. Saqib F, Mustaq Z, Janbaj KH, Imran I, Deawnjee S, Haq MZU and Dima L: Pharmacological basis for the medicinal use of Michelia champaca in gut, airways and cardiovascular disorders. Asian Pacific Journal of Tropical Medicine 2018; 292-296. doi: 10.4103/1995-7645.231470
17. Pari L and Murugan P: Antioxidant effect of tetrahydrocurcumin in streptozotocin-nicotinamide induced diabetic rats. Life Science 2006; 79: 1720-1728
18. Chi TC, Chen WP, Chi TL, Kuo TF, Lee SS, Cheng JT and Su MJ: Phosphatidylinositol-3-kinase is involved in the antihyperglycemic effect induced by resveratrol in Streptozotocin induced diabetic rats. Life Science 2007; 80: 1713-1720
19. Mishra SB, Rao Ch V, Ojha SK, Vijayakumar M and Verma A: An analytical review of plants for antidiabetic activity with their phytoconstituent & mechanism of action. International Journal of Pharmaceuticals Science Research 2010; 1: 29-46.

How to cite this article:
Nanda J, Mani M, Mishra SB and Verma N: *Michelia champaca* leaf extracts exhibit hypoglycemic effect and hypolipidemic activity in streptozotocin-nicotinamide-induced diabetic rats. Int J Pharm Sci & Res 2022; 13(12): 5200-06. doi: 10.13040/IJPSR.0975-8232.13(12).5200-06.