Bangladesh J. Bot. **54**(3): 593-599, 2025 (September) DOI: https://doi.org/10.3329/bjb.v54i3.84333

ISOLATION OF QUINOLONE ALKALOID WITH POTENTIAL ANTI-DIABETIC ACTIVITY FROM *ABROMA AUGUSTUM* (L.) L.F

SIRAJIS SALEKIN, SANIA ASHRAFI, MONIRA AHSAN, CHOUDHURY MAHMOOD HASAN, SHEIKH NAZRUL ISLAM[1] AND MOHAMMAD MEHEDI MASUD*

Department of Pharmaceutical Chemistry, University of Dhaka, Dhaka-1000, Bangladesh

Keywords: *Abroma augustum*, NMR, Antidiabetic, DPPH, Antioxidant, Phytochemicals.

Abstract

A chemical and biological investigation on *Abroma augustum* (Malvaceae) led to the isolation of a new alkaloid, 3-methoxy-4(1H)-quinolone (**1**), along with three known compounds: 4-methoxy cinnamic acid (**2**), taraxerol (**3**), and stigmasterol (**4**). Molecular docking studies revealed their varying binding affinities toward diabetes-related receptors. The methanol extract was partitioned into hexane (HSF), chloroform (CSF), ethyl acetate (EASF), and aqueous (AQSF) fractions, which were evaluated for antidiabetic, cytotoxic, thrombolytic, and antioxidant activities. In alloxan-induced rats, HSF, CSF, and EASF significantly reduced blood glucose up to 75.12% (Add source of this value in text). HSF showed moderate cytotoxicity (LC_{50}: 23.496 µg/ml), while EASF exhibited notable thrombolytic (27.77%) and strong antioxidant activity (IC_{50}: 5.61 µg/ml), surpassing standard BHT (IC_{50}: 14.57 µg/ml). These findings highlight the plant's medicinal potential, and warranting further investigation.

Introduction

Abroma augustum (L.) L.f., commonly known as Ulatkambal in Bengaliis, is an evergreen tree from the Malvaceae family. It thrives in warm regions of India (Sikkim, Uttar Pradesh, Assam, Khasi Hills), Bangladesh (Sylhet), Philippines, Java, and China (Rahman *et al.* 2016). Widely used in Ayurveda, *A. augustum* regulates menstrual flow and serves as an abortifacient and anti-fertility agent. In India, it is used for dysmenorrhea, while in Indonesia, it treats scabies, inflammation, dermatitis, and pain. In Bangladesh, traditional healers in Bogura use its leaves and stems, where as in Jashore, the roots are preferred for menstrual disorders (Hossan *et al.* 2010, Rahman *et al*. 2016). The plant also functions as a uterine tonic and emmenagogue, relieving diabetes, rheumatic pain, sinusitis, gonorrhea, anti-fertility and abortifacient (Babita *et al.* 2011, Das *et al*. 2012). Phytochemical studies reveal its major constituents, including alkaloids, abromine, sterol, friedelin, abromasterol, taraxeryl acetate, taraxerol, and β-sitosterol, highlighting its therapeutic potential for further investigation (Babita *et al.* 2011, Chowdhury *et al*. 2019).

The objective of this study was to isolate and characterize bioactive compounds from the leaves of *A. augustum* collected in Bangladesh, and to evaluate their antioxidant, cytotoxic, thrombolytic, and antidiabetic activities using in vivo, in vitro, and in silico approaches.

Materials and Methods

Abroma augustum leaves were collected from Gazipur, Bangladesh, and identified by a taxonomist of Bangladesh National Herbarium (Voucher: DACB-51715). The leaves were cleaned, shade-dried for seven days, and ground into coarse powder (1.2 kg) for analysis.

To extract bioactive compounds, 1.2 kg of dried *A. augustum* leaves powder was soaked in methanol for two weeks with regular agitation. The extract was filtered using a Buchi Rotavapour and concentrated. This cold extraction was repeated over six days, yielding 35.6 g of dried ethyl acetate extract (2.97% of the initial weight).

*Author for correspondence: <mehedi33@du.ac.bd>. [1]Institute of Nutrition and Food Science, University of Dhaka, Dhaka-1000, Bangladesh.

The 35.6 g of soluble extract underwent vacuum liquid chromatography (VLC) on silica gel using petroleum ether, EtOAc, and MeOH of increasing polarity, yielding 42 fractions (Pelletier *et al*. 1986). VLC fraction F14 was further purified via Sephadex LH-20 column chromatography and preparative TLC, leading to the isolation of four compounds.

Fifty Wistar albino rats (weight: 130±25 g, average age: 2-3 months) were obtained from Jahangirnagar University, Dhaka, and housed under standard conditions at INFS, University of Dhaka. They received a standard diet and water ad libitum and were acclimatized for a week. The study followed FELASA guidelines (Davis 2001) and was approved by the Ethical Review Committee, Faculty of Pharmacy, University of Dhaka. Skilled researchers ensured ethical handling, and euthanasia was performed using ketamine HCl (100 mg/kg) and xylazine (7.5 mg/kg) (Zimmermann 1983, Vinadé *et al*. 2005). The oral acute toxicity test was conducted following the 'Organization for Economic Cooperation and Development' (OECD) Guidelines 420, using a fixed-dose procedure (Van den Heuvel 1984). Mice received 2000 mg/kg of test substances and were monitored for 72 hrs for behavioral or physiological changes. No toxicity or adverse effects were observed for *A. augustum* crude methanolic extract (CME) and its fractions (HSF, CSF, EASF, AQSF). Based on safety data, 250 mg/kg b.w./day was selected for antidiabetic studies.

The crude methanolic extract (CME) was fractionated using the modified Kupchan partitioning method (VanWagenen *et al*. 1993), yielding hexane (HSF), chloroform (CSF), ethyl acetate (EASF), and aqueous (AQSF) soluble fractions based on solvent polarity.

The free radical scavenging activity of plant extracts was evaluated using DPPH assay. A 3.0 ml solution of 20 µg/ml DPPH in methanol was mixed with 2.0 ml of plant extract at varying concentrations (500-0.977 µg/ml). The decolorization of DPPH was compared to BHT, the reference compound, to assess antioxidant potential (Süzen 2007, Singh and Singh 2018).

The cytotoxicity of the plant extract was assessed using the brine shrimp lethality test. Brine shrimp eggs were hatched in artificial saltwater (38 g NaCl/L, pH 8.0). Nauplii were exposed to test samples containing diluted DMSO at concentrations of 400-0.78125 µg/mL, with vincristine sulfate (VS) as the reference standard. Cytotoxic effects were evaluated based on nauplii survival (Jasiewicz *et al*. 2021).

For thrombolytic assay, venous blood from healthy volunteers was incubated at 37°C for 45 min to form clots. After serum removal, clots were treated with 100 µL of extract solutions, streptokinase (positive control), or distilled water (negative control) and incubated for 90 min. Clot lysis percentage was determined by measuring weight differences before and after incubation (Ahmed and Rahman 2016).

Diabetes was induced in rats via intraperitoneal injection of alloxan (80-100 mg/kg body weight). Rats with blood glucose levels greater than 162 mg/dL were included in the study. Out of 50 rats, 35 survived and were divided into seven groups (n=5): a healthy control group, a diabetic untreated group, a diabetic group treated with Glibenclamide (5 mg/kg body weight/day), and four groups receiving HSF, CSF, EASF, or AQSF (250 mg/kg body weight/day) for three weeks. Fasting blood glucose levels were measured on days 0, 7, 14, and 24.

For molecular docking study, the 3D structures of L-Allylglycine, Relamorelin, Nateglinide, Sitagliptin, Pioglitazone, Soraphen A, Metformin, and isolated plant compounds (4-methoxy cinnamic acid, taraxerol, and stigmasterol) were obtained from PubChem in 2DSDF format. The new compound **(1)** was drawn in BIOVIA Draw and converted to 2DSDF format. Ligands were prepared in pdbqt format using PyRx for virtual screening against target proteins, Glutamate

decarboxylase 2 (GAD2), Ghrelin (GHRL), Insulin receptor (INSR), Dipeptidyl peptidase 4 (DPP4), Peroxisome proliferator-activated receptor gamma (PPAR-gamma), Acetyl-CoA carboxylase 2 (ACACB), and Glucagon-like peptide 1 receptor (GLP1R), whose 3D crystal structures were retrieved from the RCSB Protein Data Bank. Molecular docking was conducted using AutoDock Vina within PyRx (GUI v0.8), and binding affinities were assessed in kcal/mol. The lowest-energy conformations were analyzed using BIOVIA Discovery Studio to examine 3D interactions such as hydrogen bonds and bond lengths (Trott and Olson 2009).

Results and Discussion

Four compounds were obtained from the crude MeOH extract: 3-methoxy-4(1*H*)-quinolone **(1)**, 4-methoxy cinnamic acid **(2)** (Sobolev *et al*. 2006), taraxerol **(3)** (Kwon *et al*. 2008), and stigmasterol **(4)** (Chaturvedula and Prakash 2012) (Fig. 1).

Abromone (1): White crystal; ^{1}H-NMR (400 MHz, in MeOD): δ_H7.98 (1H, s, H-2), 8.06 (1H, dd, *J*= 8.0, 1.6 Hz, H-5), 7.23 (1H, dd, *J* = 6.8, 6.8 Hz, H-6), 7.20 (1H, dd, *J*= 7.2, 7.2 Hz, H-7), 7.46 (1H, dd, *J*= 8.0, 1.6 Hz, H-8), 3.9 (3H, s, 3-OCH_3). ^{13}C-NMR (100 MHz, in MeOD): δ_C131.78 (C-2), 166.43 (C-3), 180.0 (C-4), 125.86 (C-4a), 120.47 (C-5), 121.06 (C-6), 122.29 (C-7), 111.54 (C-8), 137.0 (C-8a), 49.96 (3-OCH_3). HRESIMS: *m/z* 174.0559 [M]- (calcd for $C_{10}H_9NO_2$ - H, 174.1757).

Trans-4-methoxycinnamic acid (2): Yellow crystal; ^{1}H-NMR (400 MHz, in MeOD): δ_H6.82 (2H, d, *J*= 8.4 Hz, H-3 & 5), 7.47 (2H, d, *J*= 8.4 Hz, H-2 & 6), 7.64 (1H, d, *J* = 16 Hz, H-7), 6.35 (1H, d, *J*= 16 Hz, H-8), 3.7 (1H, s, 4- OCH_3).

Taraxerol (3): white crystal; ^{1}H-NMR (400 MHz, in pyridine-d_5): δ_H3.46 (1H, m, H-3), 5.64 (1H, dd, J = 8.04, 2.8 Hz, H-15), 1.26 (3H, s, H-23), 0.97 (3H, s, H-24), 1.14 (3H, s, H-25), 1.09 (3H, s, H-26), 1.01 (3H, s, H-27), 0.95 (3H, s, H-28), 1.02 (3H, s, H-29), 1.00 (3H, s, H-30).^{13}C-NMR (100 MHz, in pyridine-d_5): δ_C77.91 (C-3), 158.17 (C-14), 116.86 (C-15), 28.42 (C-23), 15.46 (C-24), 16.2 (C-25), 25.93 (C-26), 21.28 (C-27), 29.8 (C-28), 33.17 (C-29), 29.8 (C-30).

Stigmasterol (4): white crystal; ^{1}H-NMR (400 MHz, in $CDCl_3$): δ_H3.52 (1H, m, H-3), 5.35 (1H, t, *J* = 4.48 Hz, H-6), 0.96 (3H, d, J = 5.76 Hz, H-19), 5.04 (1H, m, H-20), 5.15 (1H, m, H-21), 0.84 (3H, H-24), 0.83 (3H, s, H-26), 0.80 (3H, s, H-27), 0.70 (3H, s, H-28), 1.01 (3H, s, H-29).

Compound **1** was obtained as white crystalline needles. Accurate mass measurement of compound **1** obtained by ESI-MS yielded a parent mass at m/z 174.0559 in negative ionization mode, corresponding to molecular formula of $C_{10}H_9NO_2$ (calcd. Mass 174.1757, $[C_{10}H_9NO_2 - H]^-$). The ^{1}H NMR spectrum showed five deshielded one proton signals at δ_H7.46 (dd, *J*= 8.0, 1.6), 8.06 (dd, *J*= 8.06, 1.6), 7.20 (dd, *J* = 7.2, 7.2), 7.23 (dd, *J*= 6.8, 6.8) and 7.98 (s) ppm. Presence of a methoxy group was also observed at δ_H3.90 ppm. The ^{13}C NMR spectrum displayed 10 carbon resonances, while DEPT experiment indicated the presence of four quaternary (δ_C166.43, 137.0, 125.86, and 180.0), five methines (δ_C131.78, 120.47, 121.06, 122.29, and 111.54) and one methyl (δ_C49.96) carbon. These data are characteristic of 4-quinolone derivative (Claret and Osborne 1977). The deshieded singlet at δ_H 7.98 (1H) confirms the placement of methoxy function at C-3 (Albini *et al*. 1980). This proton (H-2) is highly deshielded due to its β position with carbonyl group at C-4 and also being adjacent to nitrogen atom. From the above spectral data, the compound was identified as 3-methoxy-4(1*H*)-quinolone and given a trivial name Abromone (**1**). This is the first occurrence of **1** as a natural product, though it was previously reported as a photochemical product of 3-methoxy quinoline N-oxide (Albini *et al*. 1980).

Compound **2-4** have been characterised as *trans*-4-methoxycinnamic acid (Sobolev *et al*. 2006), taraxerol (Kwon *et al*. 2008, Nithyamol Kalappurakkal *et al*. 2018), and stigmasterol (Chaturvedula and Prakash 2012) respectively, by comparing their NMR data with the published values. Compound **2**, trans-4-methoxycinnamic acid, is reported for the first time from this species.

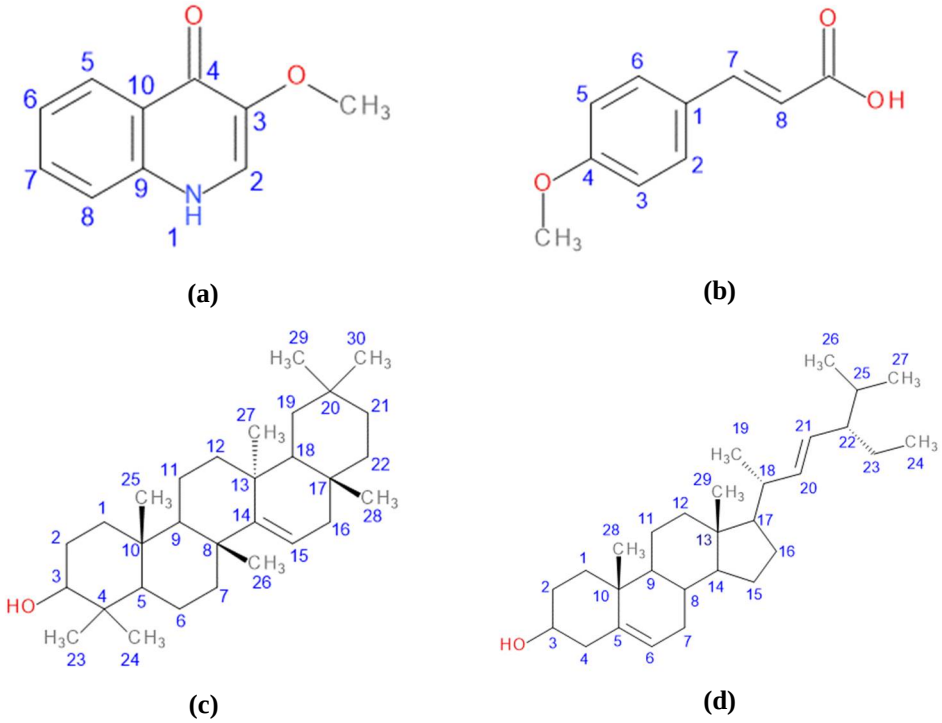

Fig. 1. Structures of isolated phytochemicals from *Abroma augustum* using NMR techniques: (a): 3-methoxy-4(1*H*)-quinolone, (b): 4-methoxy cinnamic acid, (c): Taraxerol and (d): Stigmasterol.

Table 1. Effects of *A. augustum* crude methanolic extract and its fractions on fasting blood glucose levels in Alloxan-induced diabetic rats.

Test samples	Fasting blood glucose levels (mmol/l) (Mean ± SEM)			
	Day 0	Day 7	Day 14	Day 21
Normal control	3.78±0.193	4.44±0.306	4.38±0.215	4.22±0.18
Diabetic control	11.4±0.656	11.38±0.596	11.36±0.53	12.34±0.308
Glibenclamide	17.06±3.512	9.14±2.166 (46.42)	4.82±0.657 (71.75)	3.72±0.289 (78.19)
HSF	21.7±3.096	6.24±0.52 (71.24)	8.54±2.132 (60.65)	5.4±0.307[b] (75.12)
CSF	17.02±3.189	10.46±2.432 (38.54)	7.36±0.868 (56.76)	5.72±0.698[b] (66.39)
EASF	12.78±1.287	7.4±0.342 (42.1)	6.14±0.601[b] (51.96)	4.98±0.482[b] (61.03)
AQSF	21.46±3.58	8.84±2.211 (58.81)	6.92±0.381[b] (67.75)	8.92±1.568[a,b,c] (58.43)

P value < 0.05, a : statistically significant than Normal control group, b : statistically significant than Diabetic control group, c: statistically significant than Positive control group (Glibenclamide). % Reduction in blood glucose level is shown in brackets.

Table 2. Interactions between selected macromolecules and isolated compounds.

	Compound 1	Compound 2	Compound 3	Compound 4	Standard
Glutamate decarboxylase 2 (GAD2)	-7 kcal/mol HB: VAL214*, LYS442, GLY237*, GLU217*, HP: VAL214*	-6.2 kcal/mol HB: GLU217*, LYS442 HP: TYR218*, TYR437	-8.4 kcal/mol HB: LYS380, SER382 HP: PRO346, LEU348, PRO312, PRO346, ALA349, TRP379	-8 kcal/mol HB: ASP236*, HP: VAL219, LEU215, TYR218*, TYR437	L-Allylglycine: -4.4 kcal/mol HB: TYR218, GLU217, ASP236, ARG225, HP: VAL214
Ghrelin (GHRL)	-4.1 kcal/mol HB: GLN10, ARG15, E: GLU17	-3.9 kcal/mol HB: GLU8*, SER6, ARG11* HP: ARG11*	-6.1 kcal/mol HB: PRO7, HIS9*, HP: ARG11*, PHE4*	-5.6 kcal/mol HP: PHE4, HIS9*	Relamorelin: -6.6 kcal/mol HB: GLU8, SER6, HIS9, ARG11
Insulin receptor (INSR)	-6 kcal/mol E: ARG252, HP:VAL7, VAL28	-5.6 kcal/mol HB: ILE395, ARG454 E: ASP456, HP: TYR398	-9.7 kcal/mol HP: LEU696, LEU569, VAL570, LYS567, LYS460, PHE572*	-8.8 kcal/mol HB: CYS468, HP: LEU436, LYS460, LEU696, PHE572*	Nateglinide: -7.2 kcal/mol HB: GLU469, HP: PHE572, ARG577, LEU436
Dipeptidyl peptidase 4 (DPP4)	-7.1 kcal/mol HB: TYR666*, TYR631 HP: TYR662*, TYR666*	-5.9 kcal/mol HB: GLU205, TYR631, HP: TYR666*	-9.5 kcal/mol HP: TYR547, TRP627, TRP629*, HIS740*	-8.9 kcal/mol HP: ALA564, TYR547, TRP563, TRP627, TRP629*, TYR752	Sitagliptin: -9 kcal/mol HB: VAL546, ARG125,TRP629, HP: TYR662, TYR666
Peroxisome Proliferator-Activated Receptor Gamma (PPAR-γ)	-6.5 kcal/mol HB: HIS425, GLN430, PRO426, HP: LYS422, E: LYS422	-6.2 kcal/mol HB: CYS285*, E: ARG288* HP: ALA292, MET329, LEU330, LEU333	-8.6 kcal/mol HP:VAL450, VAL446, TYR320	-8.5 kcal/mol HP: VAL446, PRO366, ILE445, PRO398, PHE370,TYR320	Pioglitazone: -8.5 kcal/mol HB: ARG280, HP: ILE341, ILE262, CYS285, ARG288
Acetyl-CoA carboxylase 2 (ACACB)	-6.9 kcal/mol HB: ASN679 HP: MET594*, VAL648	-6.2 kcal/mol HB: PRO590, HP: TRP681*, PHE704, PRO590	-10.3 kcal/mol HB: PRO358, HP:PRO583, LYS385, LYS454, ILE464,	-9.4 kcal/mol HB: ASN599, HP: MET594*, PRO590, ILE270, VAL273, LYS274*, ARG277*, TRP681*	Soraphen A: -10.4 kcal/mol HB: LYS274, ARG277, GLU593 HP: TRP681, ARG281, MET594
Glucagon-like peptide 1 receptor (GLP1R)	-6.9 kcal/mol HP: TRP39, VAL36*	-6.7 kcal/mol HB: ASP67, ARG121 HP: TRP39, TYR88, TRP214	-10.7 kcal/mol HP: ARG215, VAL36, TRP39, TRP214	-11.1 kcal/mol HB: ASP67, HP: LEU218, VAL36, LEU217, TRP33,	Metformin: -4.7 kcal/mol HB: VAL95, PRO96, GLY98, CYS85, ALA92

HB: Hydrogen bond, HP: Hydrophobic interaction, E: Electrostatic interaction

EASF exhibited the highest free radical scavenging activity, with an IC_{50} value of 5.61 µg/mL followed by CSF with an IC_{50} value of 12.04 µg/mL compared to the standard, BHT with an IC_{50} value of 14.57 µg/ml. In the brine shrimp lethality bioassay Vincristine sulfate (VS) was used as positive control and the LC_{50} was found 0.451µg/ml. Among all extracts, the highest brine shrimp lethality was given by HSF with LC_{50} value of 23.496 µg/ml. EASF showed moderate thrombolytic property (27.77%), while other fractions exhibited mild activity compared with standard, streptokinase (32.8%). Repeated oral administration of HSF, CSF, EASF and AQSF fractions of *A. augustum* into diabetic rats for different days caused significant reduction in blood glucose levels of 75.12, 66.39, 61.03, and 58.43%, respectively. Glibenclamide (STD) which reduced blood glucose by 78.19% (Table 1). Molecular docking studies of isolated compounds against GAD2, GHRL, INSR, DPP4, PPAR-gamma, ACACB, and GLP1R revealed significant binding affinities (Table 2). Compound **3** consistently exhibited the highest affinity across all targets, with -8.4 kcal/mol for GAD2 and -6.1 kcal/mol for GHRL, closely matching or surpassing control molecules. Binding involved hydrogen bonding, hydrophobic, and electrostatic interactions, often at the same sites as controls. These results highlight the potential of the compounds for further drug development targeting specific receptor pathways.

Diabetes mellitus (DM) is a complex condition marked by high blood glucose due to insulin deficiency or dysfunction (Zhang and Moller 2000). Standard treatment targets lipid and glucose metabolism, but existing hypoglycemic agents often have side effects (Ben Salem *et al*. 2017). Advancing research on novel therapeutic approaches is essential to improving diabetes management and reducing complications. The observed variations in the biological activities of different fractions suggest the presence of a range of bioactive compounds in the plant, making it a promising candidate for future research and exploration in the fields of natural product-based drug discovery and therapeutic applications

Acknowledgment

The authors are grateful to the Department of Pharmaceutical Chemistry, University of Dhaka, for providing essential laboratory facilities and support for this study.

References

Ahmed F and Rahman MS 2016. Preliminary assessment of free radical scavenging, thrombolytic and membrane stabilizing capabilities of organic fractions of *Callistemon citrinus* (Curtis.) skeels leaves. BMC Complement. Altern. Med. **16**: 1-8.

Albini A, Fasani E and Dacrema LM 1980. Photochemistry of methoxy-substituted quinoline and isoquinoline N-oxides. J. Chem. Soc. Perkin **1**: 2738-2742.

Babita G, Satish N and Sarita S 2011. *Abroma augusta* Linn f: a review. Der Pharm. Sin. **2**(4): 253-261.

Ben Salem M, Ben Abdallah Kolsi R, Dhouibi R, Ksouda K, Charfi S, Yaich M, Hammami S, Sahnoun Z, Zeghal KM and Jamoussi K 2017. Protective effects of *Cynara scolymus* leaves extract on metabolic disorders and oxidative stress in alloxan-diabetic rats. BMC Complement. Altern. Med. **17**: 1-19.

Chaturvedula VSP and Prakash I 2012. Isolation of stigmasterol and β-sitosterol from the dichloromethane extract of *Rubus suavissimus*. Int. Curr. Pharm. J. **1**(9): 239-242.

Chowdhury NS, Farjana F, Jamaly S, Begum MN and Zenat MEA 2019. Pharmacological values and phytochemical properties of Devil's cotton (Ulatkambal)-A review. Bangladesh Pharm. J. **22**(1): 109-116.

Claret PA and Osborne AG 1977. NMR spectral studies of some quinolone derivatives. Part V. Further studies of the carbon-13 magnetic resonance spectra of 2-and 4-quinolone derivatives. spectrosc. Lett. **10**(1): 35-42.

Das S, Datta R and Nandy S 2012. Phytochemical screening and evaluation of anti-inflammatory activity of methanolic extract of *Abroma augusta* Linn. Asian Pac. J. Trop. Dis. **2**: S114-S117.

Davis JA 2001. Mouse and rat anesthesia and analgesia. Curr. Protoc. Neurosci. **15**(1): A-4B.

Hossan S, Agarwala B, Sarwar S, Karim M, Jahan R and Rahmatullah M 2010. Traditional use of medicinal plants in Bangladesh to treat urinary tract infections and sexually transmitted diseases. Ethnobot. Res. Appl. **8**: 61-74.

Jasiewicz B, Kozanecka-Okupnik W, Przygodzki M, Warżajtis B, Rychlewska U, Pospieszny T and Mrówczyńska L 2021. Synthesis, antioxidant and cytoprotective activity evaluation of C-3 substituted indole derivatives. Sci. Rep. **11**(1): 1-14.

Kwon J, Chang M, Seo H, Lee J, Min B, Na M, Kim JC, Woo MH, Choi JS and Lee HK 2008. Triterpenoids and a sterol from the stem-bark of *Styrax japonica* and their protein tyrosine phosphatase 1B inhibitory activities. Phytother. Res. **22**(10): 1303-1306.

Nithyamol Kalappurakkal V, Bhattacharya D, Chakravarty S and Venkata Uppuluri M 2018. Isolation, synthesis and AChE inhibitory potential of some novel cinnamyl esters of taraxerol, the major metabolite of the mangrove *Bruguiera cylindrica*. Chem. Biodivers. **15**(4): e1800008.

Pelletier SW, Chokshi HP and Desai HK 1986. Separation of diterpenoid alkaloid mixtures using vacuum liquid chromatography. J. Nat. Prod. **49**(5): 892-900.

Rahman SMA, Rahman MM, Hossain MA and Rashid MA 2016. Chemical and biological investigations of leaves of *Abroma augusta* Linn. Bangladesh Pharm. J. **19**(2): 233-236.

Singh TP and Singh OM 2018. Recent progress in biological activities of indole and indole alkaloids. Mini Rev. Med. Chem. **18**(1): 9-25.

Sobolev VS, Horn BW, Potter TL, Deyrup ST, Gloer JB and Wicklow DT 2006. Production of stilbenoids and phenolic acids by the peanut plant at early stages of growth. J. Agric. Food Chem. **54**(10): 3505-3511.

Süzen S 2007. Antioxidant activities of synthetic indole derivatives and possible activity mechanisms. Bioact. Heterocycles V. **145**(1): 178.

Trott O and Olson AJ 2009. Software news and update AutoDock Vina: Improving the speed and accuracy of docking with a new scoring function. Effic. Optim. Multithreading **31**: 455-461.

Van den Heuvel M 1984. A new approach to the classification of substances and preparations on the basis of their acute toxicity: a report by the British toxicology society working party on toxicity. Hum. Toxicol. **3**(2): 85-92.

VanWagenen BC, Larsen R, Cardellina JH, Randazzo D, Lidert ZC and Swithenbank C 1993. Ulosantoin, a potent insecticide from the sponge *Ulosa ruetzleri*. J. Org. Chem. **58**(2): 35-337.

Vinadé ER, Schmidt AP, Frizzo MES, Portela LV, Soares FA, Schwalm FD, Elisabetsky E, Izquierdo I and Souza DO 2005. Effects of chronic administered guanosine on behavioral parameters and brain glutamate uptake in rats. J. Neurosci. Res. **79**(2): 248-253.

Zhang B and Moller D 2000. New approaches in the treatment of type 2 diabetes. Curr. Opin. Chem. Biol. **4**(4): 461-467.

Zimmermann M 1983. Ethical guidelines for investigations of experimental pain in conscious animals. Pain **16**(2): 109-110.

(Manuscript received on 10 February, 2025; revised on 14 July, 2025)