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Review Article

Pharmacological Values and Phytochemical Analysis of Aquatic Plant Genus Aponogeton: A Review

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Abstract: Aponogeton is an aquatic genus of about fifty seven species belongs to the family Aponogetonaceae. Aponogeton is widely distributed throughout the Africa, Asia and Australia. Literature review revealed that Aponogeton species are widely used in Ayurvedic medicine as a constituent of an important drug, i.e. Useerasava. This asava is useful in haemothermia, anemia, diabetes and the impurity of blood. The extract and preparation from various species exhibited various biological effects, e.g. antioxidant, antitumor, anti-inflammatory, hepatoprptective, antimicrobial, antidiabetic, thrombolytic, cytotoxic and wound healing. Biochemical profiling of different species of this genus revealed the presence of some important phytochemicals like flavonoids, flavonols, glycosides, phytol, sitosterol, campesterol, stigmasterol, gallic acid, hexadecanoic acid, cycloartenol, tetradecanoic acid, ethyl ester, 9-desmethylherbarine, 7-desmethyls-corpinone, 7-desmethyl-6-methylbostrycoidin, fusarubin, anhydrofu- sarubin, javanicin and cerevesterol. This review encompasses the potential application of the above genus in the pharmaceutical field due to its wide pharmacological activities. The nutrient composition of Aponogeton genus shows that it can provide an adequate supply of carbohydrate, protein and some minerals and served as a nutrient supplement. The present review is an overview of phytochemistry, ethnomedicinal as well as pharmacological properties of this genus for the first time.
Keywords: Aponogeton, Aquatic, Traditional medicine, Phytochemicals.

1. Introduction

Aquatic plants have lots of unparallel biological features and are dynamic for its agricultural, nutritional and medicinal importance. In traditional medicine, many plant species of aquatic origin have worthy folklore utilization [1]. Medicinal plants have a long-upstanding history in many internal communities and continuously providing fruitful tools for medicating in various illnesses [2]. Thousands of plant species in Bangladesh have exhibited medicinal properties and lots of complex diseases are treated with the help of various medicinal plants for over 5000 years [3].

The Aponogetons are genuinely an aquatic genus with species allotted in the tropical and subtropical regions of Africa, Asia and Australia [4, 5]. There are several species in this genus. This is the most ubiquitous floating-leaved groups, belonging to the family Aponogetonaceae and is represented by approximately 57 species all over the world [6].

Among them few species namely *Aponogeton undulates*, *Aponogeton ulvaceus*, *Aponogeton natans*, *Aponogeton crispus*, *Aponogeton appendiculatus*, *Aponogeton dystachois* are well known [4]. Locally, these species are used for multi-medicinal purposes. These species are

used for treating cuts and wounds, fungal infections, cough, tuberculosis, acne, cancer, diarrhea, dysentery, jaundice, snake bite etc and constitute of a well-known ayurvedic drug formulation named useerasava.

Plants produce a spacious range of bioactive constitutes that are enriched source of medicines. The phytochemical constituents of the Aponogeton species are found to be comprised of various polyphenolic compounds flavonoids, flavonols alkaloids, tannin, saponin, sesquiterpene and glycosides [7, 17].

The Aponogeton is an important genus whose species are cultivated widely as an ornamental aquatic plant. It is constituted with some of the commercially important aquatic species which are used in the aquatic plant trade [8, 9]. Aponogeton species are an essential item for low earning people.

The rootstock of the plant is an important source of food that may be useful as a nutrient supplement in numerous areas of the world and also available in the flooding time and is a food security during the times of stress and scarcity in low-lying areas [10].

In Asia, many of the indigenous aquatic plants of the genus Aponogeton are extensively used in traditional medicine and various research works were done to investigate their bioactivity and their phytochemical constituents till now. The present study aimed to highlight the significance and the importance of such floating plant as ethnomedicine.

2. Distribution and description

The Aponogetons are a truly aquatic genus with species distributed throughout the tropical and subtropical regions of Africa, Asia and Australia. It is distributed widely through tropical Asia as far East as India and as far north as South Korea. The most popular aquarium species (e.g. *A. crispus, A. undulatus* and *A. natans*) come from the Indo-Malayan area.

Another suitable aquarium species, *A. elongatus* is found in Australia. Aponogetons are also found throughout Africa. In Europe, these species are used in outdoor ponds where their requirements can be met. Suitable aquarium species are also found on Madagascar, notably *A. ulvaceus* and *A. madagascariensis*.

Aponogetons differ from most other aquarium plants in that they originate from tubercles. An Aponogeton from Asia will have a single bloom, while those with African heritage (including Madagascar) have multiple blooms on the same stalk. Most Asian species remain submerged year round, while the starchy tubercles of the African species are able to survive the dry season by shedding their leaves and going dormant.

Most Asian species have a dormant period too, but this is temperature related, not a response to drought conditions. The characteristics of Aponogeton species differ from one another. Like *A. rigidifolia* is the only member of the genus to possess a rhizome rather than a tubercle. It has long strap-like leaves and is propagated mainly from seeds where the *A. undulatus* leaves are a truer green; 16 inches long with ruffled edges and rarely produces flowers. *A. ulvaceous* has attractive yellow double-spiked flowers that are self-fertile.

Leaves of *A. crispus* grow up to 20 inches long. Leaf edges are rippled and extremely wavy. Single-spiked flowers are white, self-fertile and easy to propagate. *A. nateshii* has a globular embryo with 16–20 spirally arranged appendages [4, 11, 12].

Figure 1. Different species of genus Aponogeton

3. Nutritional value

The Aponogeton genus contains nutritional values which are also a favorable aspect of this genus. Many species of this genus carries nutrient components. The nutrient value of tuber of the *A. appendiculatus* is assessed by chemical analysis. The carbohydrate value is 77±0.71% which is the principal component in the tuber. The total caloric value is 274.89± 0.07%. The nutritional quality depends on the protein content of the tuber which is 11.74±0.37%. It is the second major component. The percentage of crude fat is 0.94±0.1%. The root tuber *of A. appendicualtus* is an important source of ascorbic acid (0.003 ±0.001%), calcium 0.84±0.05% and phosphorus 0.7±0.06 % [13]. *A. undulatus* also comprises nutrient components. The nutrient composition of rootstock of *A. undulatus* Linn. provides an adequate supply of carbohydrates 42.8g/100g, protein 8.3g/100g, fats 0.7g/100g, iron 18.2g/100g, calcium 37.2g/100g [14].

4. Aponogeton species in traditional medicinal use

Since ancient times, thousands of species have been known in Bangladesh to have medicinal values and the use of different parts of several medicinal plants for the prevention and treatment of complex diseases. The literature review exposed that the leaf pastes of *Aponogeton undulatus* are used with hot water to treat cuts and wounds and in Ayurveda, the plant is claimed to be effective against a cough, tuberculosis, acne, cancer, diarrhea, dysentery, jaundice etc [15]. *Aponogeton ulvaceus* is a commercially important ornamental aquatic plant species with traditional medicinal uses. *A.ulvaceus* is reported to have medicinal properties such as antidiabetic activity. It is also used for treating stomach disorder as well as reviving the digestive system [16]. The leaf pastes of *Aponogeton natans* are consumed with hot water to treat cuts and wounds. Fresh tuber is ground into a paste and boiled with 200 ml of coconut oil and applied on hair before bath for three days to get rid of fungal infection [2]. *A. natans (Linn.)* is an important ingredient in preparation an important ayurvedic formulation, Useerasava. This asava is useful for raktapitha (Haemothermia), anemia, diabetes and the impurity of blood [17]. *Aponogeton appendiculatus* is a folkloric valued

medicinal plant. The folkloric medicinal plants are rich sources of secondary metabolites and are responsible for the various therapeutic activities. The genus *A. appendiculatus* is reported to have medicinal properties as anti-diabetic, anti-inflammatory, anti-microbial activities, used for treating stomach disorder, reviving the digestive system [13]. A*ponogeton* crispus is an ayurvedic medicine and used for the treatment of burning sensation of the body, wounds, heart disease, excessive thirst, nausea and diabetes mellitus. Parts used in the treatment are tubers and whole plants. It has medicinal properties includes reduces aggravation of pitha dosha and increases vatha and kapha dosha and improves vision [18].

5. Reported pharmacological activity

5.1. Antioxidant activity

Medicinal plants have always been acknowledged as a powerful source of natural antioxidants from an ancient period of times. Among Aponogeton species *A. undulatus* Roxb, *A. natans*, *A. appendiculatus* [13] has been reported to have antioxidant property. A recent study indicated that the crude methanol extract of *A. undulatus*, in addition to its various organic fractions represented potent antioxidant capacity determined by 1,1- diphenyl -2- picrylhydrazyl (DPPH). Different types of assay methods have been used for determining antioxidant activity including the total antioxidant capacity, lipid peroxidation inhibition assay, ferrous reducing power assessment, DPPH free radical scavenging assay, the determination of total phenol, flavonoid and flavonol content. All the fractions exhibited their activity as hydrogen donor. In DPPH free radical scavenging assay, the extract exhibited potent antioxidant activity with IC_{50} values of 2.43±1.06 µg/ml while in ascorbic acid, the value becomes 2.14±0.11 µg/ml [7]. Another study identified that ethanolic extract of *Aponogeton undulatus* demonstrated the highest antioxidant activity, with 175.80±0.41 µg/ml plant extract of *A. undulatus*. Free radical scavengers, including phenolic compounds, flavonoids and flavonols, which possess antioxidant activities, are present in the extract of EAU [19].

5.2. Antidiabetic property

Diabetes is a serious complication attributed to several metabolic disorders. Among Aponogeton species *A. appendiculatus, A. natans, A. crispus* possesses antidiabetic property [13, 20, 21]. A literature review revealed that *Aponogeton natans* Linn. leaf extracts can be used as an antidiabetic agent. This activity is experimented by Oral Glucose Tolerance Test in alloxan-induced diabetic rats. This study revealed that methanol extract (ANME) of *Aponogeton natans* Linn. at the dose of 200 mg/kg and Glibenclamide exhibited significant reduction in blood glucose concentration to 84.83±2.23 mg/dl ($p \leq 0.05$) and 73.83±1.42 mg/dl ($p \leq 0.01$), respectively in comparison to diabetic control group 91.58 mg/dl from 2nd hour. The antidiabetic activity of the methanolic extract of *Aponogeton natans* Linn. could be attributed to its constituents like phenolic acids and flavonoids, which possess antioxidant activity and have been reported to beneficially improve pancreatic β-cell function by preventing β-cell dysfunction [20]. *Aponogeton crispus* also possess oral hypoglycemic activity. Overnight fasted Wistar rats at doses of 22.5, 45, 90 and 180 mg/kg were subjected to glucose challenge after 30 minutes and serum glucose concentration was determined two hours after the administration of the extract. The results showed that the extract possessed significant oral hypoglycemic activity ($p<0.05$). Thirty minutes following administration of the extract, a glucose load (3g/kg) was given. Blood was collected 30 min, 60 min and 120 min after the glucose load and serum glucose concentrations were determined. The highest reduction in the serum glucose concentration was observed 120 min after the administration of glucose. The hypoglycaemic activity of the crude aqueous extract was found to be comparable to that of metformin [21].

5.3. Anti-inflammatory activity

The leaf and leaf-stalks of the various extracts of *Aponogeton appendiculatus*, *A. natans* Linn are used for its anti-inflammatory activity. The evaluation of anti-inflammatory activity of *A. natans* using acute inflammatory models like carrageenan-induced paw edema, histamine-induced paw edema and chronic inflammatory model like cotton-pellet induced granuloma models in rats. The oral administration of the methanolic extract at the doses 200 mg/kg body weight was found to be effective against carrageenan and histamine-induced paw edema and showed maximum inhibition of 60.89% and 53.97%, respectively at late phase. In the case of cotton pellet induced inflammation study in rats showed a significant decrease in wet weight and dry weight of granuloma tissue formation by 52.72% and 43.76%, respectively.

The anti-inflammatory effect of *A. natans* Linn extracts was calculated by the following equations:

$$\% \text{ of inhibition} = \frac{VC-VT}{VC} \times 100$$

Where VC and VT are the paw volume in control rats and treated group of rats respectively. The anti-inflammatory effects in Borg acute and chronic phases of inflammation that may be mediated through inhibition of cell mediators such as bradykinin and prostaglandin [22].

5.4. Thrombolytic activity

Thrombus (blood clot) developed in the circulatory system due to a failure of hemostasis causes vascular blockage and leads to serious consequences in thrombolytic diseases such as acute myocardial or cerebral infarction which may cause death [23]. Thrombolytic drugs are used to dissolve blood clots in a procedure termed thrombolysis [24]. Alteplase, anistreplase, streptokinase, urokinase and tissue plasminogen activator (TPA) are commonly used thrombolytic agents to dissolve clots [25]. The in vitro thrombolytic potential was evaluated from *Aponogeton undulatus* by the clot lysis assay method using streptokinase as the standard substance. The crude methanolic extract was found to have significant ($p<0.001$) thrombolytic activity at a dose of 10 mg/ml with a moderate activity with 18.27 ± 1.97%, 20.23±1.56% and 17.82 ± 1.97% colt lysis of samples collected from volunteer 1, 2 and 3, respectively while the standard streptokinase showed 46.13±3.87% clot lysis activity. *A. undulatus* has phytoconstituents namely tannin and alkaloid which possesses thrombolytic activity [7].

5.5. Wound healing activity

Wound healing is the process of repair that follows injury to the skin and other soft tissues. It involves a complex series of interactions between different cell types, cytokine mediators and the extracellular matrix [26]. Among Aponogeton species *A. natans* has been traditionally used for the treatment of cuts and wounds. The wound healing profile of methanolic extract of *A. natans* leaf with leafstalk and its definite pro-healing action was evaluated in Wistar rats and was demonstrated by a significant increase in the rate of wound contraction and by enhanced epithelialization. A significant increase was also observed in skin breaking strength and hydroxyproline content of granulation tissue while treated methanol extract, which were a reflection of increased collagen levels and gain in granulation tissue breaking strength, an indication of higher protein content. The chloroform extract of *Aponogeton natans* also shown significant wound healing activity. The wound healing efficiency was evaluated employing three animal models - incision, excision and dead space wound model. The wound healing property of *A. natans* leaf with leafstalks may be attributed to the phytochemicals chiefly polyphenolics, flavonoids, tannins and triterpenoids [27].

5.6. Anti-tumor activity

Plant-derived extracts with antioxidant potential have demonstrated cytotoxicity against tumor cells. Recently few Aponogeton species are encountered for its antitumor activity. Among them, *A. undulatus* exhibited a significant antitumor activity which containing free radical scavengers like phenol compounds, flavonoids and flavonols which are responsible for such antioxidant and antitumor activities. A study showed that a rapid increase in ascetic tumor volume was observed in EAC tumor-bearing mice and the treatment with *A. undulatas* extracts reduced the interpretational tumor burden. Thereby, reducing the tumor volume, tumor weight and viable tumor cell count and thus increasing the life span of the tumor-bearing mice. So, it can think that the increase in lifespan of EAC- bearing mice in response to EAU at 200 mg/kg may be the decrease in nutritional fluid volume and a delay in cell division. Reductions in viable cell counts and increased nonviable cell counts towards normal in tumor hosts indicate antitumor effects against EAC cells in mice. Hematological parameters of tumor-bearing mice were altered and the treatment with 100 mg/kg body weight of MAU normalized the hematological profiles. The possible mechanism lies behind the antitumor activity are due to the decrease in lipid peroxidation and free radical scavenging effects and reducing power activity in EAU proved the potential of *A. undulatas* extract [28].

5.7. Hepatoprotective activity

The liver plays a significant role in the metabolism and detoxification of exogenous toxins and therapeutic agents [29]. There is a number of herbal extracts, which are reported to have antihepatotoxic activity [30, 31]. *A. natans* is reported as an important hepatoprotective agent. *A. natans* was screening for hepatoprotective activity against the carbon tetrachloride (CCl_4) induced hepatotoxicity in albino mice [32]. CCl_4 intoxication reduced the serum total protein and albumin levels and a significant increase in the liver marker enzymes (AST, ALT and ALP) which was observed after administration of CCl_4 in liver homogenate. It was exhibited that treatment with *A. natans* methanol extract (ANME) and chloroform extract (ANCE) at 200 mg/kg body weight increased significantly the level of biochemical parameter such as serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate transaminase (SGOT), alkaline phosphate (ALP), total bilirubin, total protein and reduction in the levels of AST. ALT and ALP towards the normal value which is the indication of stabilization of plasma membrane as well as repair of hepatic tissue damages caused by CCl_4 [33, 34].

ANME restored the total antioxidant enzymes SOD, catalase and GPX to protect the liver cells against oxidative stress condition and also the level of LPO was brought to a normal level which was elevated due to hepatotoxicant [35, 36]. *A. natans* methanol extract and CCl_4 revealed tremendous progression with the disappearance of fatty deposition, necrosis and inflammation around central vain which was caused by CCl_4 intoxication. It was suggested that the possible mechanism involved in this hepatoprotective effects against liver damage due to the free radical scavenging effect, inhibition of lipid peroxidation and increased antioxidant activity [37, 38].

5.8. Cytotoxic activity

Cytotoxic screening of plants in the preliminary method that seems to be capable of detecting natural anticarcinogenic agents present in crude extracts [1]. Literature review revealed that the leaf extracts of *A. undulatus* was found to be cytotoxic which was investigated by using brine shrimp lethality bioassay [39], where the result showed that the plant extract of *A. undulatus* was found to be highly effective with LC_{50} value of 2.24 µg/ml whereas 0.25 µg/ml was observed for the standard vincristine sulfate. Through performing this general bioassay, it can be considered that such valuable species of Aponogeton genus can be a potential source

of anticancer compound [7]. Another study revealed that bioactivity-guided fractionation of the ethyl acetate extract isolated from the culture of the endophytic fungus *Fusarium solani* from *A. undulatus* resulted in the isolation of some potential compounds. One new naphthoquinone derivatives, 9 desmethylherbarine and two azaanthraquinone derivatives, 7-desmethylscorpinone and 7-desmethyl-6-methylbostrycoidin, along with four known compounds are isolated. The cytotoxicity of new compounds was determined against four immortalized human tumor cell lines, the human cervical cancer cell line HeLa, triple-negative human breast cancer cell line MDA MB231, human pancreatic adenocarcinoma cell line MIA PaCa2, and human non-small-cell lung cancer cell line NCI H1975 were obtained from the American Type Culture Collection and LGC Standards. The compounds were tested against the non-tumor cell line WI-38 to determine their selectivity and explore their potential as anticancer compounds. Naphthoquinones are known to work by intercalating DNA and 2 and 3 have planar structures that can similarly intercalate DNA [40].

5.9. Antimicrobial activity

Medicinal plants have always been considered as potential sources for investigating antimicrobial properties which are intended for the new drug development [41]. Among Aponogeton species *A. undulatus*, *A. appendiculatus* [13] is reported to have antimicrobial properties. Modified agar diffusion method was used to determine the antimicrobial activity of the crude methanolic extracts of *A. undulatus* on nutrient agar medium, using 100 µl of a suspension containing 108 CFU/ml of bacteria, 106 CFU/ml of yeast and 104 spores/ml, spread on nutrient agar and subourand dextrose agar respectively. The antimicrobial activity of the test materials was determined by measuring the diameter of the clear zone of inhibition with antibiotic zone scale expressed in mm. The zone of inhibition range for gram-positive bacteria was found to be 7±0.45 to 12±0.65 mm in which the highest activity was shown against *Bacillus cereus* (zone of inhibition 12±0.65 mm). For gram-negative bacteria, *Escherichia coli* were to be more susceptible (zone of inhibition 10±0.71 mm) whereas *Salmonella paratyphi* showed more resistance to the extract (zone of inhibition 6±0.29 mm). The methanolic extract of *A. undulatas* showed remarkable antifungal activities against all the tested fungi and the range of zone of inhibition was to be 10±0.02 to 11±1.12 mm. The methanolic extract of *A. undulates* showed the maximum relative percentage inhibition against *Bacillus cereus* (45.34%) for bacteria and *C. albicans* (41.56%) for fungi whereas, lowest relative percentage inhibition against *S. paratyphi* (19.43%) for bacteria and *S. cerevaceae* (19.20%) for fungi. The antimicrobial activity showed by the methanolic extract of *A. undulatus* may be due to the presence of alkaloids, saponin and tannin. Because alkaloids, sesquiterpene, phenolic compounds and glycosides have been reported to inhibit bacterial growth and to be protective of plants against bacterial and fungal infections [7]. From GC-MS analysis, the most abundant bioactive component found in the leaf of *A. appendiculatus* was phytol with peak area 14.812%, reported that phytol has antibacterial activities against *Staphylococcus aureus* by damaging its cell membrane [13].

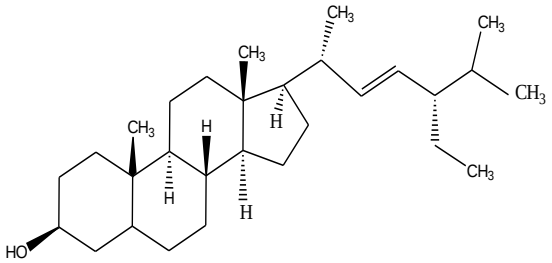
6. Phytochemical investigation

Therapeutic activity of vegetable drugs depends upon the type of constituents present in them. Plant material was screened for the presence of phytoconstituents using different chemical tests. Powder drug and different extracts were screened for different phytoconstituents [42, 43].

Identification and isolation of bioactive compound from *Aponogeton natans*

The presence of Phytochemicals present in *A. natans* was investigated by subjecting all the four extracts to phytochemical screening. From the preliminary phytochemical and HPTLC

analysis showed the presence of carbohydrates, proteins, phytosterol, glycosides, alkaloids, saponins, tannins, steroids, flavonoids triterpenoids and polyphenols. The methanol extracts were subjected to column chromatography for the isolation of the phytoconstituents. Two compounds namely ANSD-1 and ANSD-2 were isolated and purified from methanol extract by column chromatography. The structures were determined as stigmasterol and gallic acid by physical, chemical and spectral characteristics. These phytoconstituents of medicinal value may be responsible for the pharmacological action of the plant. The inorganic elements such as iron, sulfate, chloride and nitrates were found in the aerial parts [44, 45].



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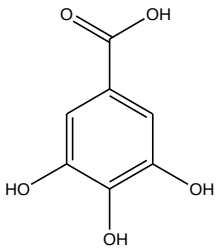

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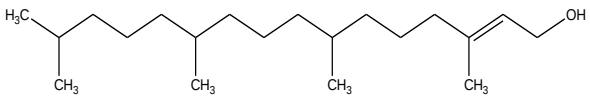
Figure 2. Isolated compounds detected from *A. natans*
Stigmasterol (ANSD-1) (1) and Gallic acid (ANSD-2) (2).

Identification and isolation of bioactive compound from *A. appendiculatus*

The GCMS analysis of ethanol crude leaf extract was done to reveal the presence of 36 bioactive compounds with significant biological activities. The identified compounds possess many biological properties and give therapeutic activities. The major abundant chemical constituents in the crude leaf extract are determined as phytol. The other major chemical bioactive components are γ-sitosterol, n-hexadecanoic acid, hexadecanoic acid, ethyl ester from *Aponogeton appendiculatus.* Among the major identified chemical compound in the ethanolic crude extracts, 4 are steroid compounds, 3 are ester compounds, 2 are fatty acid and one compound of each terpene alcohol and fatty acid ester. The γ-sitosterol, stigmasterol, cycloartanol compounds have antioxidant, antimicrobial, antidiabetic and anticancerous property [46].

Hexadecanoic acid, ethylester, n-hexadecanoic acid and tetradecanoic acid can be an anti-oxidant, hypocholesterolemic, nematicide, pesticide and lubricant activities. 1, 2-benzenedicarboxylic acid; diisooctyl ester; 3-Cyclopentyl propionic acid; 2-dimethylaminoethylester showed anti-microbial and antifouling properties. 9, 12, 15-Octadecatrienoic acid; 2, 3-bis [(trimethylsilyl) oxy] propyl ester has cancer preventive, anti-

oxidant, antidiabetic, anti-inflammatory, nematicide and anti-arthritic properties [47]. The other identified major chemical bioactive component are 2-pentyne-1, 4-diol, 4-methyl-1-(2-thienyl)-(4.95%), Campestral, Tetraethyl silicate, Benzoic acid, Naphthalene, 3-Oxo-4-phenylbutyronitrile, Isopropylidene-5-methylhex-4-enal, Benzyl oxy tridecanoic acid, 2(4H)-Benzofuranone,5,6,7,7a-tetrahydro-4,4,7a-trimethyl-,(R)-, Dodecanoic acid,13-Oxadispiro [5.0.5.1] tridecan-1-one, 1,6,6-Trimethyl-7-(3-oxobut-1-enyl)-3,8- dioxatricyclo [5.1.0.0(2,4)] octan-5-one, Tetradecanoic acid, 2-Pentyne-1,4-diol, 4-methyl-1-(2-thienyl), 2-Cyclohexen-1-one, 4-hydroxy-3,5,5- trimethyl-4-(3-oxo-1-butenyl)-, 3,7,11,15-Tetramethyl-2-hexadecen-1-ol, Dibutyl phthalate, Phen-1,4-diol, 2,3-dimethyl-5-trifluoromethyl, 2(3H)-Furanone, 5-dodecyldihydro, Ethyl 9.cis.,11.trans.-octadecadienoate, Ethyl Oleate, Hexadecanamide, 3-Cyclopentylpropionic acid, 2-dimethylaminoethyl ester, 1,10-Cycloeicosanedione $C_2H_{36}O_2$ 308.498 1.626, Cyclopentadecanone , 1H-Indene, 1-hexadecyl 2,3-dihydro, Calconcarboxylic acid and Stigmasta-3, 5-dien-7-one [13].



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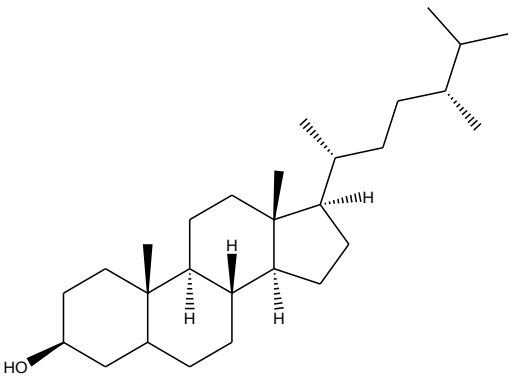

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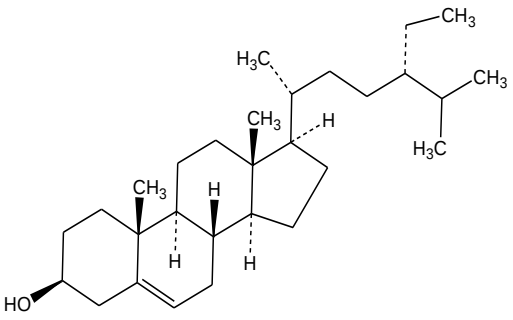

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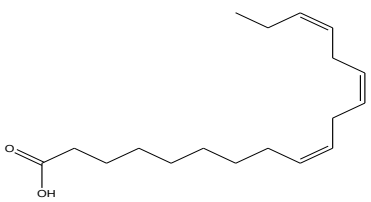

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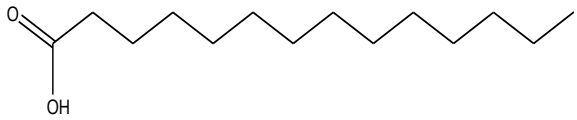

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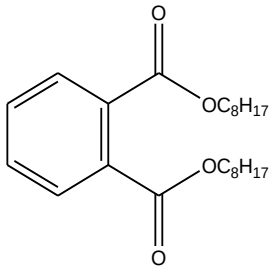

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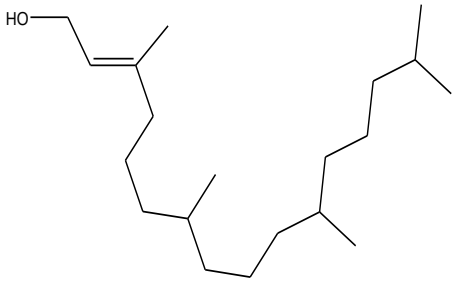

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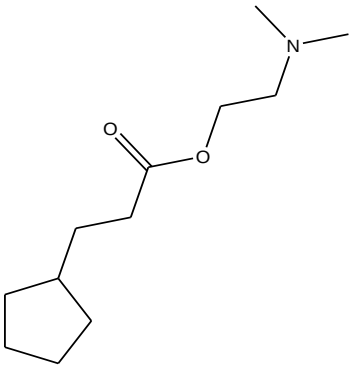

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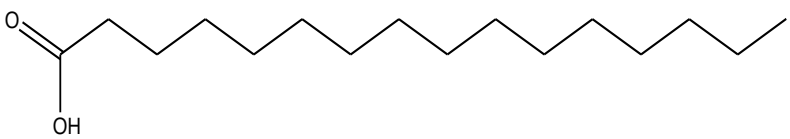

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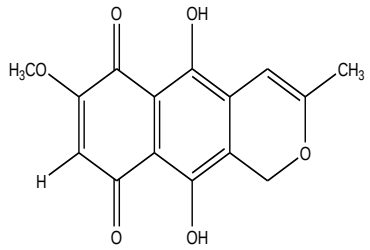
Figure 3. Isolated compound detected from *Aponogeton appendiculatus*

Phytol (3), Campesterol (4), γ-sitosterol (5), Stigmasterol (6), tetradecanoic acid (7), 1,2-Benzenedicarboxilic acid, diisooctyl ester (8), 3,7,11,15-Tetramethyl-2-hexadecen-1-ol (9), 3-Cyclopentylepropanoic acid, 2-dimethylaminoethylester (10), n-hexadecanoic acid (11).

Identification and isolation of bioactive compound from *A.undulatus*

Bioactivity-guided fractionation of the ethyl acetate extract obtained from the culture of the endophytic fungus *Fusarium solani* isolated from the plant *Aponogeton undulatus* resulted in the isolation of one new naphthoquinone, 9- desmethylherbarine and two azaanthraquinone derivatives, 7- desmethylscorpinone and 7-desmethyl-6-methylbostrycoidin, along with four known compounds fusarubin, anhydrofusarubin, javanicin and cerevesterol. Their structures were elucidated by spectral analysis, as well as a direct comparison of spectral data with those of known compounds.

Azaanthraquinones 2 and 3 showed cytotoxic activity against four human tumor cell lines, MDA MB 231, MIA PaCa2, HeLa, and NCI H1975. A molecular docking study suggested DNA interactions as the mode of action of these naphthoquinones and azaanthraquinone [40].



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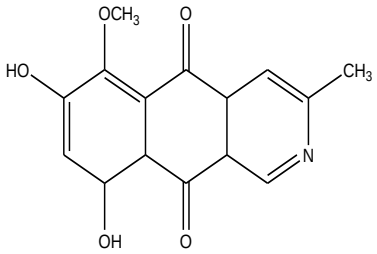

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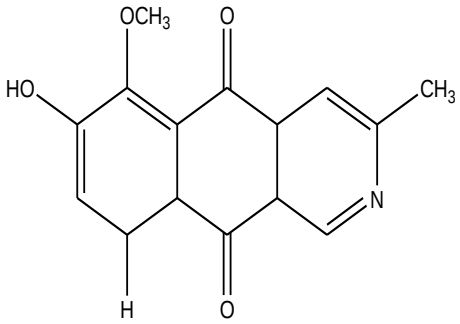

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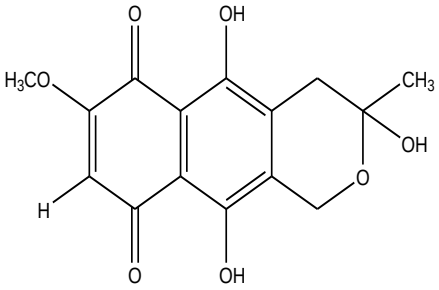

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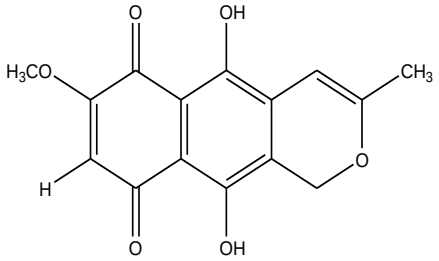

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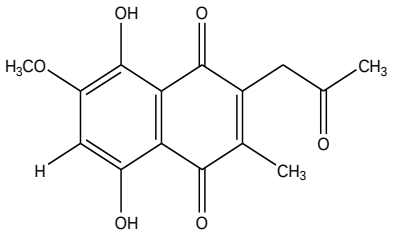

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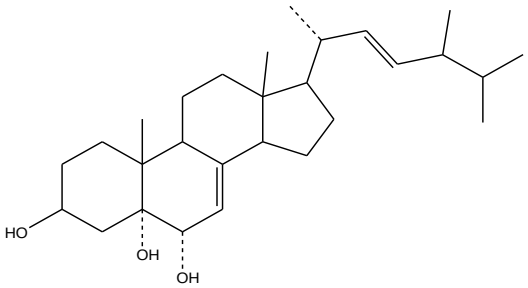

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Figure 4. Structures of isolated compounds from *A. undulates*

9-desmethylherbarine (12), 7-desmethyls- corpinone (13), 7-desmethyl-6-methylbostrycoidin (14), fusarubin (15), anhydrofu- sarubin (16), javanicin (17) and cerevesterol (18).

Identification of bioactive compound from *Aponogeton crispus*

Preliminary phytochemical screening and physiochemical analysis for the aqueous extracts of *A. crispus* were carried out as per WHO guidelines of quality control methods for medicinal plant materials. The total phenolic content of hot and cold aqueous extracts was also determined according to the method of Folin-Ciocolteau and calculated as gallic acid equivalents (GAE). Results show reducing sugar, amino acids, alkaloids, flavanones,

flavonoids and polyphenols were found as phytoconstituents in both hot and cold extracts [48].

7. Acute toxicity studies and safety

In the acute toxicity study, different extracts of *A. natans* (Linn.) at doses of 2000 mg/kg did not show any significant variation in the body weight increment, indicating that it did not have any adverse effects on body weight, which was used to assess the results to therapy of drugs and to indicate the adverse effects of drugs. The organs weight of the extracts treated groups remained normal, indicating that plants extracts were non-toxic to vital organs.

There were no significant variations in various hematological parameters compared to the control or untreated group, which indicates that test extracts may not be toxic and do not affect circulating red cells, hematopoiesis or leucopoiesis. Furthermore, there were no significant variations observed in any biochemical parameters as compared to the control or untreated group.

The results of the histopathology study revealed no specific sign and symptoms of damage on the isolated organs under study and therefore, it may be considered safe at the tested dosage regimen of the extracts under study. In conclusion, acute toxicity screening revealed no adverse motor or neurological changes, gastrointestinal tract disorder and respiratory distress or locomotors changes is observed [49].

8. Conclusion

Medicinal plants are the nature's gift to human being to have disease free healthy life. The genus Aponogeton is well known for its valuable pharmacological properties. A lot of research work has been done on the pharmacological properties on different species of Aponogeton. Among all of its medicinal properties, it is very promising due to its anticancer activities.

The phytoconstituents present in this genus are responsible for exhibiting their reported pharmacological activities. In ayurvedic medicine, it is an important ingredient in the preparation of an useful ayurvedic medicine named Useerasava. Aponogeton species are important phytomedicine for the local healers which are used in the treatment of various types of ailments. This genus is a rich source of nutrient components like protein, carbohydrates and minerals. This review demonstrated the diverse ethnomedicinal practices, phytochemical properties, pharmacological activities, nutritional importance and pharmaceutical applications of different Aponogeton species. The present data may support future multidisciplinary studies and promote rational use of this genus as a therapeutic resource.

Conflict of interest: Authors declare that there is no conflict of interest.

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