***Original Research Article***

**Phytochemical Screening, GC-MS Analysis and *In Vitro* Antioxidant Studies of Ethanolic Extract of *Icicinia mani* (Earth balls) Tubers**

**ABSTRACT**

**Introduction:** *Icacinia mani* also known as *Efik-isong* in Ibibio is a potential feed material for animals including humans. There are reports that commercial producers of *garri,* a major staple food in Southern Nigeria combine large quantities of *Icacinia mani* tubers with cassava to increase their production. In this study, we conducted the phytochemical screening, GC-MS analysis and *in vitro* antioxidant activity of *Icicinia mani* (Earth balls) tubers using standard methods to ascertain the safety or otherwise of this plant material.

**Methodology:** Finely ground *Icicinia mani* tubers (1000 g) was extracted with 80% ethanol and the filtrate was concentrated using a rotary evaporator (LabTech EV400H). The dried extract was refrigerated at 4 oC until required for use. Qualitative and quantitative phytochemical screening was conducted using standard protocols. The extract was further analyzed by gas chromatography-mass spectrometry (GC-MS) to identify the important functional groups and phytochemical constituents. *In vitro* antioxidant activity of the extract was evaluated using ferric-reducing antioxidant power (FRAP), 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging, and nitric oxide (NO) scavenging assays.

**Results:** The results of phytochemical screening indicate the presence (g/100g) of alkaloids (29.703), flavonoids (8.911), tannin (5.455), steroids (0.007), saponin (13.269), cardiac glycosides (18.889), cyanogenic glycosides (0.002), oxalate (0.0004) and anthocyanin (10.00). GC-MS analysis revealed the presence of one hundred and five (105) compounds of which 1,2-Benzisothiazole, 3-(hexahydro-1H-azepin-1-yl)-, 1,1-dioxide had the highest retention time (23.712), Ethyl 2-(2-chloroacetamido)-3,3,3-trifluoro-2-(4-fluoroanilino) propionate had the highest molecular weight (356.70), while n-Hexadecanoic acid the highest peak area (4.92). The FRAP, DPPH, and NO scavenging assays indicated that the extract was capable of neutralizing free radicals.

**Conclusion:** Ethanol extracts of *Icicinia mani* tubers contains useful phytochemicals which synergistically confers strong antioxidant potentials on it, hence, the extract may be considered a potential natural source for developing additives in the food and pharmaceutical industries, offering an alternative to synthetic compounds for enhancing health benefits and mitigating oxidative stress. Further investigations on the minerals and proximate analysis as well as the effects of the extracts on biochemical parameters are on-going in our laboratory.

**Keywords:** *Icicinia mani*, phytochemicals, antioxidants, Gas chromatography-mass spectrometry

**INTRODUCTION**

The ever increasing population in developing countries places enormous burden on the availability and cost of staple foods. In order to meet the challenging food and nutritional requirements of both animals and humans by the growing population, there has been recourse to unconventional sources in recent times [1]. Research efforts targeted at identifying potential cheap and readily available feed sources have widely been reported [2, 3]. There are unconfirmed reports that commercial producers of *garri,* a major staple food in Southern Nigeria combine large quantities of *Icacinia mani*, a tuber crop that grows in the wildwith cassava to increase their production. However, there are safety concerns regarding the use of these unconventional supplements, hence the need for biochemical and toxicity studies.

*Icicinia mani* is a shrub or a small plant that thrives both in tropical and subtropical regions. It is commonly known as “earth ball” and *Efik-isong* by the *Efik/Ibibios* of South- south geopolitical zone of Nigeria [4]. Its underground part is tuberous and develops into large size tubers. It is an all season plant, locally abundant in the humid tropics of Akwa Ibom and Cross River State, Nigeria and is not commonly and directly consumed by humans [5]. Previous Studies reported that *Icicinia mani* tubers is mainly made up of carbohydrates and little proteins. Its phytochemical screening indicated the presence of oxalates, alkaloids, hydrogen cyanide, phytic acid and tannins [6] However, there is currently no information on the quantitative phytochemicals, gas chromatography - mass spectrometry (GC-MS) analysis and in vitro antioxidant potentials of this plant.

**MATERIALS AND METHODS**

**Chemicals and Reagents**

All chemicals and reagents used for this research were of analytical grade. Ethanol, 1- Diphenyl 2-picrylhydrazyl (DPPH) and butylated hydroxytoluene (BHT) were obtained from Sigma-Aldrich, St. Louis, USA.

**Collection of Plant Materials**

Samples of the plant materials *Icicinia mani* tubers were obtained from locations in Abiakpo Ikot Essien in Ikot Ekpene Local Government Area of Akwa Ibom State in Nigeria between November, 2024 and January 2025, and authenticated by a taxonomist of the Department of Botany and Ecological Studies, University of Uyo. A voucher specimen with was deposited in the herbarium of the University. The samples were washed under clean gently running tap water to remove dirt on the tubers. After the tubers were kept for 2 hours for the water to dry off. A sharp stainless steel knife was used to cut the tubers into small pieces. The cut pieces were air-dried at room temperature (25 ± 2 oC) until a constant weight was obtained. After drying, the tubers were ground using a desk top grinder (Model No: QBL-18L40, Turinar Corp, Shang-Hai, China) into fine particles and stored in a plastic container with screw cap.

**Extraction Procedure**

The finely ground *Icicinia mani* tubers (1000 g) were soaked in 1000 ml of 80% ethanol at room temperature for 24 hours in a 2000 ml reagent bottle with continuous shaking. After that, the mixture was filtered using a cheese cloth to obtain the filtrate. The residue was re-extracted with another 1000 ml of 80 % ethanol. The combined extract was evaporated at 45 oC in an open water bath until all the solvent was removed. The dried extract of the sample was refrigerated at 4 oC until required for use.

**Phytochemical Screening**

Chemical tests for the identification of bioactive chemical constituents in ethanol extracts of *Icicinia mani* tubers were carried out in the extracts using the standard procedures as described by Kokate [7], Sofowara [8], Trease and Evans [9], and Harborne [10].

**Qualitative Phytochemical Analysis**

**Test for Saponins**

**Froth Test: About 0.5 grams of the extracts were separately shaken vigorously with 2 ml of distilled water in different test tubes and allowed to stand for 15 minutes.** Persistent foaming or **the appearance of creamy mist of small bubbles (froth) showed the presence of saponins** [8, 10, 11]

**Test for Alkaloids**

**About 0.5 grams of the extracts were** successively dissolved in 10 ml of 2 % dilute hydrochloric acid (0.054M HCl), heated for 5 minutes and then filtered. Each of the filtrates (1 ml) was pipette into a test-tube and used to test for the presence of alkaloids as follows:

Mayer’s Test:Mayer’s reagent (Potassium mercuric iodide solution) was added successively to 1 - 2 ml of each of the filtrates and observed for 15 minutes. Formation of yellow precipitate showed the presence of alkaloids.

**Test for Flavonoids**

**Preparation of Test solution**: About 500 mg of the extract was dissolved in 100 ml of the respective solvent and then filtered through whatman filter paper No.1. Thus, the filtrates obtained were used as test solutions for the following preliminary screening tests.

**Sulphuric Acid (H2SO4) Test:** Dilute aqueous ammonia (5 ml) was added to 2 ml of each of the extracts followed by 1 ml of 2M H2SO4. An orange or yellow colouration that disappears on standing for 10 - 15 minutes indicates the presence of flavonoids.

**Test for Tannins**

**Ferric Chloride (FeCl3) Test:** About 0.2 g of the extracts were dissolved in 10 ml of the respective solvents and then filtered through Whatman filter paper No.1.To about 5 ml of each of the extracts in a test tube, 1 ml of 5 % FeCl3 in pyridine was added. The formation of dark green colour indicates the presence of tannin [12].

**Test for Cardiac Glycosides**

**Keller-Killani Test:** About 0.2 g of the extracts were dissolved in 10 ml of the respective solvent and then filtered through Whatman filter paper No.1. Glacial acetic acid (1 ml) was carefully added to 2 ml of each of the filtrates obtained and cooled. Thereafter, 1 ml of 1 % FeCl3 solution wad added and the contents were transferred carefully to a test tube containing 2 ml of concentrated H2SO4. A reddish brown ring was observed at the junction of two layers.

**Test for Anthraquinones**

**Borntrager’s Test:** About 0.5 g of the extracts was successively boiled with 5 ml of 10 % H2SO4 and filtered. Each of the filtrates was shaken with 2.5 ml of benzene, the benzene layer was separated and half its own volume of 10 % NH4OH added. A pink, red, or violet colouration in the ammonia phase showed the presence of anthraquinones.

**Test for Steroids**

**Salkowski’s Test:** About 0.5 g of the extracts were dissolved in 10 ml of their respective solvents and then filtered through Whatman filter paper No.1. Chloroform (2.0 ml) and 2.0 ml of concentrated H2SO4 was carefully added to 2.0 ml of each of the filtrates and shaken. The formation of a red colour by the chloroform layer and a greenish yellow fluorescence by the acid layer indicates the presence of steroids.

**Test for Oxalate**

About 0.5 g of the extracts were dissolved in 10 ml of dilute hydrochloric acid. Calcium chloride was then added to the resulting solution, shaken and allowed to stand for few minutes. The formation of a white precipitate (calcium oxalate) confirms the presence of oxalate.

**Test for Cyanogenic Glycosides**

**Borntrager’s Test:** About 0.5 g of the extracts was successively boiled with 5 ml of 10 % H2SO4 and filtered. Each of the filtrates was shaken with 2.5 ml of benzene, the benzene layer was separated and half its own volume of 10 % NH4OH added. The formation of a pink colour indicates the presence of glycosides.

**Test for Anthocyanins**

About 0.5 g of the extracts were dissolved in 10 ml of their respective solvents and then filtered through Whatman filter paper No.1. Thereafter, 2 ml of 2N HCl and aqueous ammoniawas successively added to2 ml of each of the filtrates. The formation of pink red colour which turns blue violet indicates the presence of anthocyanins.

**Quantitative Phytochemical Analysis**

**Alkaloids Determination**

Five grams (5g) of the sample was weighed into a 250ml beaker and 200ml of 20% acetic acid in ethanol was added and covered and allowed to stand for 4 hours at 250c. This was filtered with filter paper No. 42 and the filtrate was concentrated using a water bath (Memmert) to one quarter of the original volume. Concentrated ammonium hydroxide was added drop wise to the extract until the precipitate was complete. The whole solution was allowed to

settle and the precipitate was collected and washed with dilute NH4OH (1% ammonia solution). Then, filter with pre-weighed filter paper. The residue on the filter paper is the alkaloid, which is dried in the oven (precision electrothermal model BNP 9052 England) at 800c. The alkaloid content was calculated and expressed as a percentage of the weight of the sample analyzed [10, 13]

Calculation:

Gram % of alkaloid = x

**Flavonoids Determination**

10g of the plant sample was extracted repeatedly with 100ml of 80% aqueous methanol at room temperature. The whole solution was filtered through Whatmann filter paper No. 42 (125mm). The filtrate was later transferred into a crucible and evaporated into dryness over a water bath and weighed to a constant weight [14].

Calculation:

Gram % of flavonoids = x

**Tannin Determination by Follins Dennis Titration**

The Follins Dennis titrating method as described by Pearson [15] was used. To 20g of the crushed sample in a conical flask was added 100mls of petroleum ether and covered for 24 hours. The sample was then filtered and allowed to stand for 15 minutes allowing petroleum ether to evaporate. It was then re-extracted by soaking in 100ml of 10% acetic acid in ethanol for 4hrs. The sample was then filtered and the filter ate collected.

25ml of NH4OH were added to the filter ate to precipitate the alkaloids. The alkaloids were heated with electric hot plate to remove some of the NH4OH still in solution. The remaining volume was measured to be 33ml. 5ml of this was taken and 20ml of ethanol was added to it. It was titrated with 0.1M Na0H using phenolphthalene as indicator until a pink end point is reached. Tannin content was then calculated in % (C1V1 = C2V2) molarity.

Calculation

Data

C1 = conc. of Tannic Acid C2 = conc. Of Base

V1 = Volume of Tannic acid V2= Volume of Base

Therefore C1 =

Gram % of Tannic acid =

**Determination of Steroid Content**

1.0g of the powdered sample was weighed and mixed in 100ml of distilled water in a conical flask. The mixture was filtered and the filtrate eluted with 0.1N ammonium hydroxide solution. 2ml of the eluent was put in a test tube and mixed with 2ml of chloroform. 3ml of ice cold acetic anhydride was added to the mixture in the flask. 2 drops of (200mg/dl) standard sterol solution was prepared and treated as described for test as blank. The absorbance of standard and test was measured,zeroing the spectrophotometer with blank at 420nm.

Calculation (mg/100 ml) = x

**Determination of Saponin**

Exactly 5g of the sample was put into 20% acetic acid in ethanol and allowed to stand in a waterbath at 500c for 24hours. This was filtered and the extract was concentrated using a waterbath to one-quarter of the original volume. Concentrated NH4OH was added drop-wise to the extract until the precipitate was complete. The whole solution was allowed to settle and the precipitate was collected by filtration and weighed. The saponin content was weighed and calculated in percentage [13].

Calculation:

Gram % of saponins = x

**Cardiac Glycosides Determination**

Wan g and Filled method was used. To 1ml of extract was added 1ml of 2% solution of 3,5-DNS (Dinitro Salicylic acid) in methanol and 1ml of 5% aqueous NaOH. It was boiled for 2 minutes (until brick-red precipitate was observed) and the boiled sample was filtered. The weight of the filter paper was weighed before filtration. The filter paper with the absorbed residue was dried in an oven at 500c till dryness and weight of the filter paper with residue was noted. The cardiac glycoside was calculated in %.

Calculation:

Gram % of cardiac glycosides = x

**Oxalate determination by Titration method**

This determination involves three major steps digestion, oxalate precipitation and permanganate titration.

**Digestion**

1. 2g of sample is suspended in 190ml of distilled water in a 250ml volumetric flask.
2. 10ml of 6m HCl is added and the suspension digested at 1000c for 1 hour.
3. Cool, and then make up to 250ml mark before filtration.

**Oxalate precipitation**

Duplicate portions of 125 ml of the filtrate are measured into beakers and four drop of methyl red indicator added. This is followed by the addition of NH4OH solution (dropwise) until the test solution changes from salmon pink colour to a faint yellow colour (pH4-4.5). Each portion is then heated to 900c, cooled and filtered to remove precipitate containing ferrous ion. The filtrate is again heated to 900c and 10ml of 5% CaCl2 solution is added while being stirred constantly. After heating, it is cooled and left overnight at 250c. the solution is then centrifuge at 2500rpm for 5minutes. The supernatant is decanted and the precipitate completely dissolved in 10ml of 20% (v/v) H2S04 solution.

**Permanganate titration**

**At** this point, the total filtration resulting from digestion of 2g of flour is made up to 300ml. aliquots of 125ml of the filtrate is heated until near boiling and then titrated against 0.05M standardized KMNO4 solution to a faint pink colour which persists for 30s. The calcium oxalate content is calculated using the formula:

Amount of Oxalate (mg/100g) =

Where T is the titre of KMn04(ml), Vme is the volume-mass equivalent (i.e. 1ml of 0.05m KMn04 solution is equivalent to 0.00225g anhydrous oxalic acid). Df is the dilution factor Vt/A (2.4 where Vt is the total volume of titrate (300ml) and A is the aliquot used (125ml), ME is the molar equivalent of KMn04 in oxalate (KMn04 redox reaction) and Mf is the mass of sample used [10].

**Determination of Anthocyanin using the gravimetric method of Harborne, 1973**

**Principle**

Acid hydrolysed sample when filtered reacts with ethylacetate to enable extraction of anthocyanin. Upon addition of amyl alcohol, anthocyanin was extracted and after drying, the percent composition was determined in relation to weight of original sample gravimetrically.

**Procedure**

5.0g of the powdered sample (water of life) was boiled in 100ml of 2MHCl for 30minutes. The hydrolysate was filtered using Whatman filter paper. The filtrate was transferred into separation funnel and equal volume of ethylacetate added, mixed and allowed to separate into two layers. The ethylacetate layer was recovered while the aqueous layer was discarded.

The extract was dried over a steam bath. The dry extract was then treated with 10ml of conc. Amylalcohol to extract the anthocyanin. After filtration, the alcohol extract was dried. The weight of anthocyanin was determined and expressed as percentage of original sample.

Calculation % = x

**Gas Chromatography Mass Spectrum (GC-MS) Analysis**

GC-MS analysis was carried out using 7890A GC system, 5675C Inert MSD with triple-Axis detector. The column has a length of 30 m with an internal diameter of 0.2 µm and a thickness of 250 µm, treated with phenyl methyl silox. Other GC-MS conditions are ion source temperature (EI), 250 oC , interface temperature; 300oC, pressure; 16.2 psi out time, 1.8mm, 1μl injector in split mode with split ratio 1:50 with injection temperature of 300 oC, the column temperature started at 35oC for five minutes and changed to 150 oC at the rate of 4 oC per minutes, the temperature was raised to 250 oC at the 162 rate of 20 oC per minutes and held for five minutes. The total elution was 47.5 minutes. MS Solution software provided by supplier was used to control the system and to acquire the data. Identification of the compounds was carried out by comparing the mass spectra obtained with those of the standard mass spectra from National Institute of Standard and Technology (NIST) database. The identity of the spectra above 95% were selected and used to ascertain the name, molecular weight and structure of the components in the ethanol extracts of *Icicinia mani* tubers.

**Antioxidant evaluation of *Icicinia mani* tubers extracts**

The antioxidant evaluation of the extract was carried out using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, nitric oxide (NO) scavenging and ferric reducing antioxidant power (FRAP) assay.

**Determination of 2, 2-Diphenly-1-Picrylhydrazyl (DPPH) Radical scavenging activity**

The ability of ethanol extractof *Icicinia mani* tubers to scavenge the DPPH radical was tested in a rapid dot-plot screening and quantified using a spectrophotometric assay.

**Principle**

DPPH radical reacts with an antioxidant compound that can donate hydrogen, and gets reduced. DPPH, when acted upon by an antioxidant, is converted into diphenylpicryl hydrazine. This can be identified by the conversion of purple to light yellow colour.

**Dot-plot rapid assay**

The rapid screening assay was performed by the method of Soler-Rivas *et al*.[16].

**Reagents**

1. TLC plates (silica gel 60 F254-Merck)

2. DPPH (0.4mM) in methanol

**Procedure**

Aliquots of sample samples (3:1) were spotted carefully on TLC plates and dried for 3 minutes. The sheets bearing the dry spots were placed upside down for 10 seconds in a 0.4mM DPPH solution and the layer was dried. The stained silica layer revealed a purple background with yellow spots, which showed radical scavenging capacity.

**DPPH spectrophotometric assay**

The scavenging ability of the natural antioxidants of the ethanol extractof *Icicinia mani* tubers towards the stable free radical DPPH was measured by the method of Mensor *et al*.[17].

**Reagent**

1. DPPH – 2,2-diphenyl-2-picryl hydrazyl hydrate (0.3mM in methanol)

2. Methanol

**Procedure**

The ethanol extractof *Icicinia mani* tubers (20μl) were added to 0.5ml of 0.1mM methanolic solution of DPPH and 0.48ml of methanol. The mixture was allowed to react at room temperature for 30 minutes. Methanol served as the blank and DPPH in methanol, without the ethanol extractof *Icicinia mani* tubers samples, served as the positive control while butylated hydroxytoluene (BHT) served as reference. After 30 minutes of incubation, the discolouration of the purple colour was measured at 518nm in a spectrophotometer (Genesys 10-S, USA). The radical scavenging activity was calculated as follows:

Scavenging Activity % = x

**Nitric Oxide (NO) Scavenging Activity of ethanol extract of *Icicinia mani* tubers**

The extent of inhibition of nitric oxide radical generation *in vitro* was carried out using the method of Green *et al.*[18].

**Principle**

Sodium Nitroprusside in aqueous solution, at physiological pH, spontaneously generates nitric oxide which interacts with oxygen to produce nitrite ions that are estimated spectrophotometrically at 546nm.

**Reagents**

1. Sodium Nitroprusside (100mM)

2. Phosphate buffered saline (pH 7.4)

3. Griess reagent (1% sulphanilamide, 2% H3PO4 and 0.1% Naphthylethylene diamine dihydrochloride)

**Procedure**

The reaction was initiated by adding 2.0ml of sodium nitroprusside, 0.5ml of PBS, 0.5ml of ethanol extract of *Icicinia mani* tubers (50mg) and incubated at 250C for 30 minutes. Griess reagent (0.5ml) was added and incubated for another 30 minutes. Control tubes were prepared without the samples. The absorbance was read at 546nm against the reagent blank, in a spectrophotometer (Genesys 10-S, USA).

**Ferric Reducing Antioxidant Power (FRAP) Assay**

**Principle**

The principle of the assay is the quantification of ferric degradation product by its condensation with the extract.

**Method**

The FRAP activity of the ethanol extractof *Icicinia mani* tubers was determined by the method of Pulido *et al.*[19].

**Procedure**

Various concentrations (20, 40, 60, 80, 100 ug/mL) of the ethanol extractof *Icicinia mani* tubers were mixed individually with the mixture containing 2.5 mL of 0.2 M Sodium Phosphate buffer (pH 6.6) and 2.5 mL of Potassium ferricyanide (K2Fe(CN)6) (1% w/v). The resulting mixture was incubated at 50 oC for twenty minutes, thereafter, 2.5 mL of trichloroacetic acid (10% w/v) was added. The resulting mixture was centrifuged at 2000 rpm for ten minutes. The upper layer (supernatant) of the solution (2.5 mL) was mixed with 2.5 mL of distilled water and 0.5 mL of ferric chloride (0.1% w/v). The absorbance was measured at wavelength 700 nm against a blank sample. Garlic was used as the reference compound.

**RESULTS**

**Phytochemical screening of ethanol extracts of *Icicinia mani* tubers**

The results of the qualitative and quantitative phytochemical profile of ethanol extracts of *Icicinia mani* tubers are presented in Tables 1 and 2.

The results of the qualitative phytochemical screening of ethanol extracts of *Icicinia mani* tubers the indicates the presence of alkaloids, flavonoids, tannin, steroids, saponin, cardiac glycosides, cyanogenic glycosides, oxalate and anthocyanin (Table 1).

The results of the quantitative phytochemical analysis of ethanol extracts of *Icicinia mani* tubers in (Table 2) showed that alkaloids contents (g/100 g) was the highest (29.703), followed by cardiac glycosides (18.889), saponins (13.265), flavonoids (8.911), tannins (5.455), while oxalate was the least (0.0004).

Table 1. Qualitative phytochemical screening of ethanol extracts of *Icicinia mani* tubers

|  |  |  |
| --- | --- | --- |
| S/N | Phytochemicals | Ethanol Extract |
| 1 | Alkaloids | +++ |
| 2 | Flavonoids | ++ |
| 3 | Tannin | ++ |
| 4 | Steroids | + |
| 5 | Saponin | +++ |
| 6 | Cardiac glycosides | +++ |
| 7 | Cyanogenic glycoside | + |
| 8 | Oxalate | + |
| 9 | Anthocyanin | +++ |

Key: + = **+++** = strongly present, **++** = present in high concentration, **+** = trace

Table 2. Quantitative phytochemical analysis of ethanol extracts of *Icicinia mani* tubers

|  |  |
| --- | --- |
| Phytochemicals | Composition  (g/100g) |
| Alkaloids  Flavonoids  Tannin  Steroids  Saponins  Cardiac glycosides  Cyanogenic glycoside  Oxalate  Anthocyanin | 29.703  8.911  5.455  0.007  13.265  18.889  0.0016  0.0004  10.00 |

**GC-MS profile of ethanol extracts of *Icicinia mani* tubers**

The results of the GC-MS analysis of ethanol extracts of *Icicinia mani* tubers at spectra above 95% revealed the presence of ten (10) compounds (Fig. 1). The names, molecular weight and structure of the compounds are shown in Table 3.

Table 3. Identified compounds from GC-MS analysis of ethanol extract of *Icicinia mani* tubers

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S/N | Retention time | Compound Name | Molecular Formula | Molecular weight | Area (%) |
| 1 | 13.151 | Hexadecanoic acid, methyl ester | C17H34O2 | 270.4507 | 1.16 |
| 2 | 13.913 | n-Hexadecanoic acid | C16H32O2 | 256.4241 | 4.92 |
| 3 | 16.413 | Oleic Acid | C18H34O2 | 282.4614 | 4.45 |
| 4 | 16.413 | trans-13-Octadecenoic acid | C18H34O2 | 282.4614 | 4.45 |
| 5 | 16.413 | cis-13-Octadecenoic acid | C18H34O2 | 282.4614 | 4.45 |
| 6 | 16.866 | Octadecanoic acid | C18H36O2 | 284.4772 | 1.81 |
| 7 | 13.763 | 1,2-Benzenedicarboxylic acid | C8H6O4 | 166.1308 | 0.63 |
| 8 | 15.085 | Cyclopropaneoctanal, 2-octyl- ester | C19H36O | 280.50 | 0.06 |
| 9 | 23.712 | 1,2-Benzisothiazole, 3-(hexahydro-1H-azepin-1-yl)-, 1,1-dioxide | C₁₃H₁₆N₂O₂S | 264.35 | 0.18 |
| 10 | 13.763 | Ethyl 2-(2-chloroacetamido)-3,3,3-trifluoro-2-(4-fluoroanilino) propionate | C13H13ClF4N2O3 | 356.70 | 0.63 |

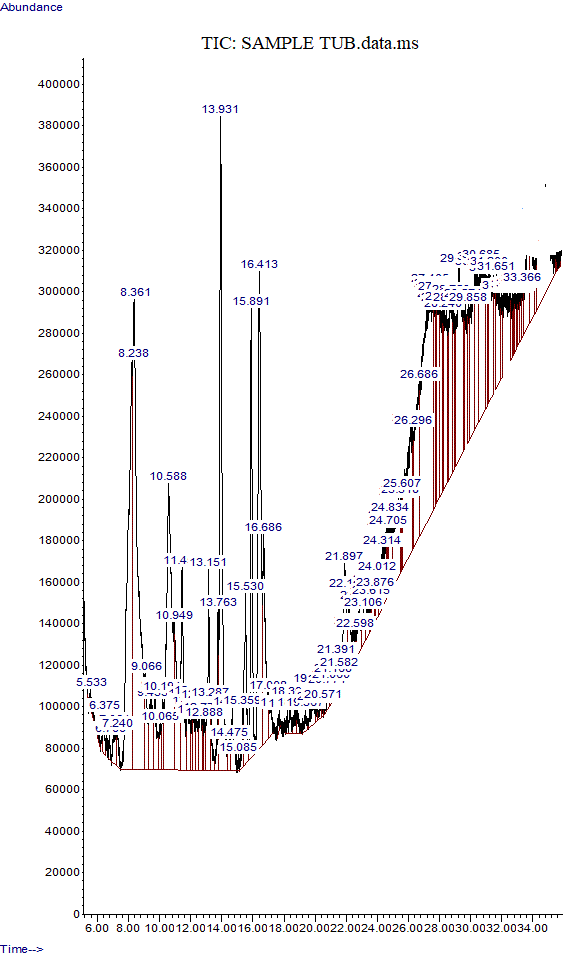
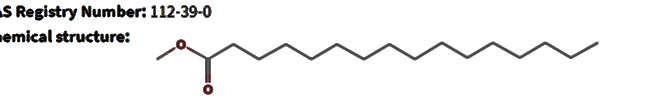
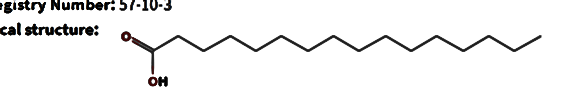


Fig.1. GC-MS spectra of ethanol extracts of *Icicinia mani* tubers

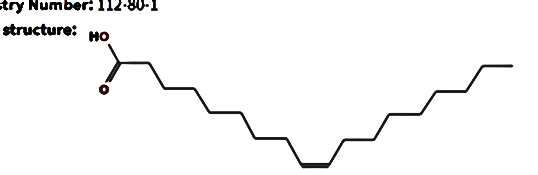
**Chemical structures of compounds from the ethanol extract of *Icicinia mani* tubers**

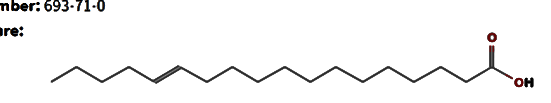
The chemical structures of the compounds found in ethanol extract of *Icicinia mani* tubers

Are as shown in figure 2 below.

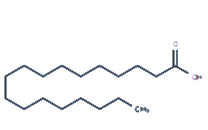


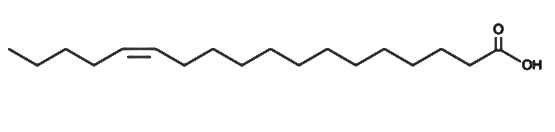
1. Hexadecanoic acid, methyl ester b. n-Hexadecanoic acid



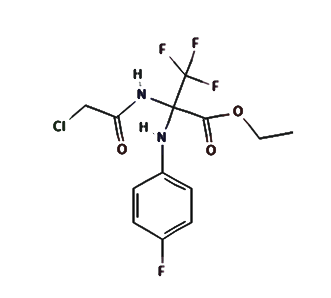


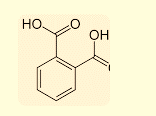
1. Oleic Acid d. Trans-13-Octadecenoic acid



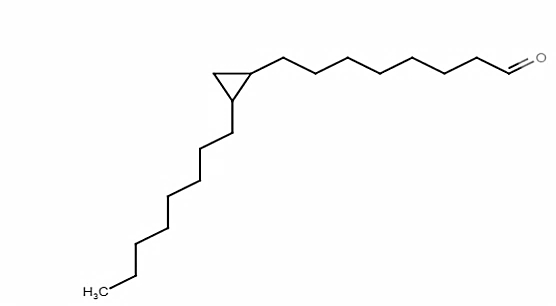


1. Cis-13-Octadecenoic acid f. Octadecenoic acid



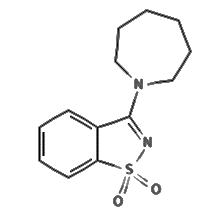


1. 1,2-Benzenedicarboxylic acid



h. Ethyl 2-(2-chloroacetamido)-3,3,

3-trifluoro-2-(4-fluoroanilino) propionate



1. Cyclopropaneoctanal, 2-octyl-

j. 1,2-Benzisothiazole, 3-(hexahydro-1H-azepin-1-yl)-,

1,1-dioxide

Fig. 2. Chemical structures of compounds identified from GC-MS analysis of ethanol extract of *Icicinia mani* tubers.

**In vitro antioxidant assessment of ethanol extracts of *Icicinia mani* tubers**

The results of the in vitro antioxidant assessment of ethanol extracts of *Icicinia mani* tubers are presented in Tables 4 - 6.

The DPPH [free radical](https://www.sciencedirect.com/topics/pharmacology-toxicology-and-pharmaceutical-science/free-radical) scavenging activity was expressed as percentage inhibition (Table 4). The percentage of DPPH activities of the ethanol extract of *Icicinia mani* tubers ranged from 77.50 - 87.90 %. These values were lower compared to the percentage DPPH activity of the standard butylated hydroxytoluene (BHT) at 10 mg/ml which was 98.50%. The highest percentage DPPH inhibition of the extracts was at 80 mg/ml where the percentage inhibition was 87.9 %. The IC50 of the ethanol extract of *Icicinia mani* tubers was 6.6 mg/ml which was less than that of the standard (4.8 mg/ml).

Table 4. DPPH radical scavenging activity of ethanol extracts *Icicinia mani* tubers

|  |  |  |
| --- | --- | --- |
| Dose (mg/ml) | DPPH Scavenging Activity Percentage Inhibition (PI) % | |
| *Icicinia mani* tuber extract | BHT |
| 10 | 79.89 | 98.50 |
| 20 | 80.92 |  |
| 40 | 77.50 |  |
| 80 | 87.90 |  |
| IC50 (mg/ml) | 6.6 | 4.8 |

The Nitric oxide scavenging activity of ethanol extracts *Icicinia mani* tubers (Table 5) revealed a dose-dependent rise in its scavenging ability with the highest scavenging activity 80 mg/ml. The IC50 of the ethanol extract of *Icicinia mani* tubers was 6.6 mg/ml which was less than that of the standard (4.8 mg/ml). The IC50 of 84 was obtained for nitric oxide scavenging activity of ethanol extract of *Icicinia mani* tubers against 18 for the garlic standard. This indicates that the extract has a moderate antioxidant potential against nitric oxide radicals, meaning it requires a relatively high concentration (84 mg/ml) to inhibit 50% of nitric oxide activity.

Table 5. Nitric Oxide scavenging activity of ethanol extracts *Icicinia mani* tubers

|  |  |  |
| --- | --- | --- |
| Doses (mg/ml) | Nitric Oxide (NO) Scavenging Activity | |
| *Icicinia mani* tuber extract | Garlic |
| 10 | 2.30 | 1.82 |
| 20 | 2.15 | 3.19 |
| 40 | 2.60 | 4.52 |
| 80 | 2.90 | 5.48 |
| IC50 (mg/ml) | 84 | 18 |

The Ferric Reducing Antioxidant Power (FRAP) of ethanol extracts *Icicinia mani* tubers showed a dose-dependent increase (Table 6). The highest FRAP activity was at a dose of 40 mg/ml. The IC50 for Ferric Reducing Antioxidant Power of the extract was 15.00 which was greater than that of the garlic standard (6.46).

Table 6. Ferric Reducing Antioxidant Power (FRAP) of ethanol extracts *Icicinia mani* tubers

|  |  |  |
| --- | --- | --- |
| Doses (mg/ml) | Ferric Reducing Antioxidant Power (FRAP) | |
| *Icicinia mani* tuber extract | Garlic |
| 10 | 45.74 | 76.95 |
| 20 | 53.19 | 77.48 |
| 40 | 58.16 | 87.99 |
| 80 | 54.26 | 93.62 |
| IC50 (mg/ml) | 15.00 | 6.46 |

**Discussion**

The results of the qualitative and quantitative phytochemical analysis of ethanol extracts of *Icicinia mani* tubers (Tables 1 and 2) revealed the presence of nine (9) phytochemical compounds thus: alkaloids (29.703 g/100g), cardiac glycosides (18.889 g/100g), saponins (13.265 g/100g), anthocyanin (10.000 g/100g), flavonoids (8.911 g/100g), tannins (5.455 g/100g), steroids (0.007 g/100g), cyanogenic glycosides (0.0016 g/100g) and oxalate (0.0004 g/100g).

Phytochemical constituents of plants have been reported to possess numerous therapeutic activities such as anti-HIV, anti-plasmodial, anti-diarrheal, anti-septic, anti-bacterial, anti-viral, anti-inflammatory, anti-microbial, hypoglycemic, antioxidant, analgesic and hepatoprotective properties as well as other physiological activities [8, 20, 21, 22]. They exhibit structure related biochemical and pharmacological actions capable of reducing the risk of multiple diseases [23, 24]. Flavonoids have been utilized to improve human health via their multiple biological functions including anti-inﬂammatory [25], antimicrobial [20], antioxidant [26], anticancer activities [27] and the prevention of osteoporosis [28]. Alkaloids have been used as an analgesic, antispasmodic or bactericidal agents [29]. They are known to inhibit certain mammalian enzymic activities such as those of phophodiesterase, prolonging the action of cAMP. They also affect glucagons and thyroid stimulating hormones [30]. Saponins have been reported to be useful in reducing inflammation of upper respiratory passage and also chiefly as foaming and emulsifying agents and detergents [29]. Tannins have astringent properties that hasten the healing of wounds and prevention of decay. Tannins also possess antimicrobial activities responsible for preventing and treating urinary tract infections and other bacterial infections [21].

The results of the GC-MS analysis of ethanol extracts of *Icicinia mani* tubers at spectra above 95% revealed the presence of ten (10) compounds (Table 3). These are: Hexadecanoic acid methyl ester, n-Hexadecanoic acid, Oleic Acid, trans-13-Octadecenoic acid, cis-13-Octadecenoic acid, Octadecanoic acid, Cyclopropaneoctanal, 2-octyl-ester, Ethyl 2-(2-chloroacetamido)-3,3,3-trifluoro-2-(4-fluoroanilino) propionate, 1,2-Benzisothiazole, 3-(hexahydro-1H-azepin-1-yl)-, 1,1-dioxide and1,2-Benzenedicarboxylic acid. Three of these have been reported to possess biomedical potentials.

Ethyl 2-(2-chloroacetamido)-3,3,3-trifluoro-2-(4-fluoroanilino) propionate has potential biomedical applications, particularly in medicinal chemistry, as its unique structure makes it a candidate for drug development. This compound can be a potential inhibitor or modulator of specific biological targets [31]. Its presence in plant extracts, suggests potential antiviral activity and cytotoxicity [32]. The compound 1,2-benzisothiazole, 3-(hexahydro-1H-azepin-1-yl)-, 1,1-dioxide has therapeutic potential for diseases related to Erythropoietin (EPO) insufficiency, Such as renal anemia by agonizing HIF-2 stabilization thus improving EPO production [33]. 1, 2-Benzenedicarboxylic acid is an allelochemical with strong allelopathic effect. It has antimicrobial properties particularly against extended-spectrum beta-lactamases (ESBL) [34].

The results of *in vitro* antioxidant assessment of ethanol extracts of *Icicinia mani* tubers showed that the extract had the highest percentage DPPH inhibition of 87.90 % at 80 mg/ml which was lower compared to the standard butylated hydroxytoluene (98.50 %). The IC50 of the ethanol extract of *Icicinia mani* tubers was 6.6 mg/ml which was less than that of the standard, BHT (4.8 mg/ml) (Table 4). The Nitric oxide scavenging activity of ethanol extracts *Icicinia mani* tubers revealed a dose-dependent rise in its scavenging ability with the highest scavenging activity 80 mg/ml and an IC50 of 6.6 mg/ml which was less than that of the garlic standard (4.8 mg/ml) (Table 5). Also, the Ferric Reducing Antioxidant Power (FRAP) of ethanol extracts *Icicinia mani* tubers showed a dose-dependent increase with the highest FRAP activity at a dose of 40 mg/ml and an IC50 of 15.00 which was greater than that of the garlic standard (6.46) (Table 6). Phongpaichit *et al*. [35] reported that the lower the IC50 value of a plant extract, the higher the antioxidant activity. Hence, the observed IC50 values indicate that the extract has strong antioxidant potential.

DPPH radical has been used extensively to test the reductive ability of plant extracts and foods and to evaluate their antioxidant activities [36]. The scavenging effect of plant extracts on DPPH has been shown to be related to the phenolic concentration of the extracts [37, 38]. Therefore, the free radicals scavenging activities of the extract could be attributed to the presence of flavonoids.

Antioxidant effects of nitric oxide radical (NO•) occurs when it reacts with alkoxy and peroxyl radical intermediates during lipid peroxidation thereby stabilizing the inhibition of LDL oxidation [39]. The ability of the extract to scavenge NO• is beneficial in biological system as peroxynitrite (ONOO•) and some other NO• metabolites have been implicated in various pathological conditions such as malaria, cardiovascular diseases, inflammation, cancer and diabetes. FRAP assay had been used to determine antioxidant activity as it is simple and quick. Besides that, the reaction is reproducible and linearly related to molar concentration of the antioxidants. Higher FRAP values give higher antioxidant capacity because FRAP value is based on reducing ferric ion, where antioxidants are the reducing agent [40].

**Conclusions**

Ethanol extracts of *Icicinia mani* tubers contains useful phytochemicals which synergistically confers strong antioxidant potentials on it, hence, the extract may be considered a potential natural source for developing additives in the food and pharmaceutical industries, offering an alternative to synthetic compounds for enhancing health benefits and mitigating oxidative stress.

**ETHICAL APPROVAL**

This study did not involve human or animal subjects. Therefore ethical approval was not applicable.

**REFERENCES**

1. Lange, K. W. and Nakamura, Y. (2021). Edible insects as future food: chances and challenges. Journal of Future Foods, 1(1): 38-46. <https://doi.org/10.1016/j.jfutfo.2021.10.001>
2. Fanzo, J., McLaren R., Bellows, A. and Carducci, B. (2023). Challenges and opportunities for increasing the effectiveness of food reformulation and fortification to improve dietary and nutrition outcomes. *Food Policy*. 119(2023). 97-101. https://doi.org/10.1016/j.foodpol.2023.102515
3. Alawa, J.P. and Umunna, N.N (1993). Alternative feed formulation in the developing countries:Utilisation of Agro-industrial by-products. *Journal Animal Production Research*, 13(2): 63-98.
4. Ephraim, U. N., Godwin, U. U., Efiom, O. E., and Bassey, A. A. (2019). Effect of Ethanolic Extract of *Icicinia manni* Tuber on the Reproductive Parameters of Male Rats. *American Journal of Health Research*, 7(5), 89-99.
5. Asuquo, L. E., and Udedibie, A. B. I. (2012). Effects of Dietary Toasted *Icicinia manni* Meal on the Performance of Laying Hens. *International Journal of Agriculture and Rural Development*, 15(3); 1162-1168.
6. Antai, S. P., & Obong, U.S. (1992). The effects of fermentation on the nutrient status of some toxic components of *Icicinia manni*. *Plant Foods for Human Nutrition*, 42; 219-224Meenakshi, S.R. and Agarwal, R. (2013). Nitric oxide levels in patients with chronic renal disease. *J. Clin. Diagn. Res*. 7(7): 1288-1290.
7. Kokate, C. K., Purohit, A. P. and Gokhale, S. B. (2005). *Pharmacognosy*. 33rd edition. Nirali Prakashan, New Delhi, India. 108 - 109.
8. Sofowora, A. (1993). *Medicinal Plants and Traditional Medicine in Africa*, 2nd edition. Spectrum Books Limited, Ibadan, Nigeria. 134 - 156.
9. Trease, G. and Evans, W. (1989). *A Textbook of Pharmacognosy*, 13th edition. Bailliere Tindall Ltd., London. 19 - 21.
10. Harborne, J. (1973). Phytochemical Methods. In: Harborne, J. B. (Editors). *A Guide to Modern Techniques of Plant Analysis*. Chapman and Hall, London. 279 - 283.
11. Tiwari, P. Kumar, B., Kaur, M., Kaur, G. and Kaur, H. (2011). Phytochemical screening and extraction: A review. *Internacionale Pharmacuetica Sciencia*, 1(1): 98 - 104.
12. Santhi, N. K. and Sengottuvel, R. (2016). Qualitative and quantitative phytochemical analysis of *Moringa concanensis*. *International Journal of Currerent Microbiology and Applied Sciences*, 5(1): 633 - 640.
13. Obadoni, B. and Ochuko, P. (2001). Phytochemical studies and comparative efficacy of the crude extracts of some homeostatic plants in Edo and Delta States of Nigeria. *Global Journal of Pure Applied Sciences*,8: 203 - 208.
14. Boham, B. and Kocipal-Abyazan, R. (1994). Flavonoids and condensed tannins from leaves of Haiwaiian *Vaccinium vaticulatum* and *Vaccinium* *calycinium*. ***Pacific Science J****ournal*, 48: 458 - 463.
15. Pearson, D. (1974). The chemical analysis of foods. 6th edition. Churchill Livingstone, Edinburgh pp.451.
16. Espin, J. C., Soler Rivas, C., and Wichers, H. J. (2000). Characterization of the total free radical scavenger capacity of vegetable oils and oil fractions using 2,2-diphellyl-1-picrylhydrazyl radical. *Journal of Agricultural and Food Chemistry*, 43(3), 648-656.
17. Mensor, L.L., Meneze, F.S. and Leitao, L. (2001).Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. *Phototherapy Research* 15, 127-130.
18. Green, L.C., Wagner, D. A., Glogowski, J., Wishnok, J. S., Tannenbaum, S. R. & Skipper, P. L. (1982). Analysis of Nitrate, Nitrite, and [15N]Nitrate in Biological Fluids. *Analytical Biochem.* 126(13): 111-138.
19. Pulido, R., Bravo, L. & Saura-Calixto, F. (2000). Antioxidant Activity of Dietary Polyphenols as Determined by a Modified Ferric Reducing/Antioxidant Power Assay.  *Journal of Agricultural and Food Chemistry,* 48(8): 396-402. DOI: 10.1021/jf9913458
20. Cushnie, T. and Lamb, A. J. (2005) Antimicrobial activity of flavonoids. *International Journal of Antimicrobial Agents*, 26(5): 343 - 356.
21. Ebana, M. C., Ellong, A. and Owona, D. (2005). L’amblyopie chez le strabique en milieu Camerounais. *Bulletin of the Belgian Society of Ophthalmology*, 297: 39 - 44.
22. Evans, W. C. (2005). Trease and Evans Pharmacognosy. 15th edition. Elsevier India Private Limited, New Delhi, India. 20 - 22.
23. Savage, G. P. (1993). Saponins. In: Macre, R., Robinson, R. K. and Sadler, M. J (Editors). *Encyclopedia of Food Science, Food Technology and Nutrition*. Academic Press, London, 3998 - 4001.
24. Karimi, E., Jaafar, H. Z. and Ahmad, S. (2013). Antifungal, anti-inflammatory and cytotoxicity activities of three varieties of *Labisia Pumila* benth from microwave obtained extracts. *BMC Complementary and Alternative Medicine*, 24: 13 - 20.
25. Yamamoto, Y. and Gaynor, R. B. (2001). Therapeutic potential of inhibition of the NF-Κb pathway in the treatment of inflammation and cancer. *Journal of Clinical Investigation*, 107(2):135 - 142.
26. Iweala, E. E. J. and Ogidigo, J. O. (2015b). Effect of *Celosia argentea* F. Cristata (L.) Schinz on prostate specific antigen, antioxidant status and hematological parameters in rats induced with benign prostate hyperplasia. *Asian Journal of Biochemistry*,10: 42 - 51.
27. Ishola, I. O., Yemitan, K. O., Afolayan, O. O. Anunobi, C. C. and Duojaiye, T. E. (2018). Potential of *Moringa oleifera* in the treatment of benign prostate hyperplasia: Role of antioxidant defence systems. *Journal of Medical Principles and Practice*, 27: 15 - 22.
28. Selvaraj, G., Kaliamurthi, S., Ekambaram, R. and Thirugnanasabandan, R. (2014). Qualitative and quantitative phytochemical studies of *Acanthus ilicifolius*. *Research Journal of Phytochemistry*,8: 133 - 138.
29. Frantisek, S. S. (1991). *The Natural Guide to Medicinal Herbs and Plants*. Tiger Barks Cast, Twinkemhan, United Kingdom. 1 - 5.
30. Okaka, J. C., Enoch, N. J. and Okaka, N. C. (1992). *Human Nutrition: An Integrated Approach*. ESUT Publications, Enugu. 57 - 58.
31. Blake, J. F., Burkard, M., Chan, J., Chen, H., Chou, K., Diaz, D., Dudley, D. A., Gaudion, J. J., Gould, S. E., Grina, J. (2016). Discovery of (S)-1-(1-(4-Chloro-3-fluorophenyl)-2-hydroxyethyl)-4-(2-((1-methyl-1H-pyrazol-5-yl)amino)pyrimidin-4-yl)pyridin-2(1H)-one (GDC-0994), an Extracellular Signal-Regulated Kinase 1/2 (ERK1/2) Inhibitor in Early Clinical Development. *Journal of Medicinal Chemistry*,59(12):5650-5660.
32. Buhrke, T., Frenzel, F., Kuhlmann, J. & Lampen, A. (2015). 2-Chloro-1,3-propanediol (2-MCPD) and its fatty acid esters: cytotoxicity, metabolism, and transport by human intestinal Caco-2 cells. *Arch Toxicol*., 89(12):2243-51. doi: 10.1007/s00204-014-1395-3.
33. Song, W., Zhuang, J., Zhang, N., Ren, X., Xu, W., Guo, M., Diao, X., Liu, C., Jin, J., Wu, D. & Zhang Y. (2023). SAR study of 1,2-benzisothiazole dioxide compounds that agonize HIF-2 stabilization and EPO production. *Bioorg Med Chem*. 2023 Jan 1:77:117041. doi: 10.1016/j.bmc.2022.117041.
34. Shoge, M. 1., Garba, S. & and Labaran, S. (2016). Antimicrobial activity of 1,2-benzenedicarboxylic acid, butyldecyl ester isolated from the seeds and pods of *Acacia nilotica* Linn. *Basic Research Journals of Microbiology*, 3(2): 08-11.
35. Phongpaichit, S., Nikom J., Rungjindamai, N., Sakayaroj, J., Hutadilok-Towatana, N., Rukachaisirikul V. and Kirtikara, K. (2007). Biological Activities of Extracts from Endophytic Fungi Isolated from *Garcinia* Plants. *FEMS* *Immunol. Med. Microbiol*. 51 (3), 517-525. doi: 10.1111/j.1574-695X.2007.00331.x.
36. Manian, R., Anusuya, N., Siddhuraju, P. and Manian, S. (2008). The antioxidant activity and free radical scavenging potential of two different solvent extracts of *Camellia sinensis* (L.) O. Kuntz, *Ficus bengalensis* L. and *Ficus racemosa* L. *Food Chem*. 107: 1000-1007.
37. Sen, S., De, B., Devanna, N. and Chakraborty, R. (2013). Total phenolic, total flavonoid content, and antioxidant capacity of the leaves of *Meyna spinosa* Roxb., an Indian medicinal plant. *Chin J. Nat. Med*. 11(2): 149-157.
38. Das, N., Islam, M.E., Jahan, N., Islam, M.S., Khan, A., Islam, M.R. and Parvin, M.S. (2014). Antioxidant activities of ethanol extracts and fractions of *Crescentia cujete* leaves and stem bark and the involvement of phenolic compounds. *BMC Complement Altern. Med*. 14: 45. doi: 10.1186/1472-6882-14-45.
39. Andrabi, S. M., Sharma, N. S., Karan, A., Shahriar, S. M., Cordon, B., Ma, B. & Xie, J. (2023). Nitric Oxide: Physiological Functions, Delivery, and Biomedical Applications. *Adv Sci (Weinh).* 2023 Aug 26;10(30):2303259. doi: 10.1002/advs.202303259
40. Hodzic, Z., Pasalic, H., Memisevic, A., Scrabovic, M., Saletovic, M. and Poljakovic, M. (2009). The influence of total phenols content on antioxidant capacity in the whole grain extracts. *European Journal of Scientific Research* 28: 471- 477.