Plants naturally produce phytochemicals, physiologically active chemical compounds that serve as a natural defence mechanism and have considerable potential for treating a wide range of ailments. *Cyperus rotundus* and *Tinospora cordifolia* are the potent traditional herbs used in Ayurveda medicine, especially for diabetes. The current study aimed to isolate and characterize the bioactive compound β-sitosterol from the combined ethanolic extracts of the thizome of *Cyperus rotundus* (*C. rotundus*) and the stem of *Tinospora cordifolia* (*T. cordifolia*). Furthermore, the *in vitro* antioxidant and anti-diabetic activities of isolated compounds are tested by DPPH assay, alpha amylase inhibition assay, alpha glucosidase inhibition assay and glucose uptake activity in 3T3.L1 cells. The combined ethanolic extract of both medicinal plants was initially subjected to column and preparative thin layer chromatography for the isolation of bioactive compounds, followed by their characterization by spectral methods like UV, FT-IR, ^1^H and ^13^C NMR. The structure of the isolated compound is identified as β-sitosterol and further confirmed by structural elucidation. Similarly, the isolated compound β-sitosterol exhibited higher antioxidant scavenging activity of 64.54±1.38 μg/ml against DPPH at a concentration 100μg/ml. The study also confirmed that β-sitosterol showed good inhibitory activities towards alpha-amylase (28±1.25 μg/ml) and alpha-glucosidase (65.48±1.47 μg/ml). β-sitosterol showed significantly increased glucose uptake (28% at 100μg/ml). Based on the conclusion that the organic compound β-sitosterol exhibited good antioxidant and anti-diabetic efficacy, it could have been used in the treatment of free radical disease and can be utilized in the management of diabetes mellitus.

**Keywords:** *Cyperus rotundus*, *Tinospora cordifolia*, Isolation, Characterization, Anti-oxidant activity, Anti-diabetic activity

**INTRODUCTION**

Plants are a significant source of potentially beneficial bioactive components for the creation of novel chemotherapeutic drugs. Many plants’ biological and pharmacological characteristics are yet unknown. Scientists are investigating the prospect of using pharmacologically active chemicals from medicinal plants all over the world. 80% of individuals use herbal medicines because of their great efficacy and lack of negative side effects. In comparison to traditional therapies; modern synthetic pharmaceuticals are more expensive. Herbal plants are the only source that consistently provides the active ingredients used to create pharmaceuticals for modern therapies (Rakesh K Joshi et al., 2015, Dayana Jeyaleela et al., 2019). Globally, researchers in microbiology, biochemistry, botany, pharmacology and the chemistry of natural products are interested in studying medicinal plants to find more and more bioactive components and potential lead molecules that might be used to treat a wide range of ailments. (Abdel Nasser Singab et al., 2014). In the current scenario, scientists and researchers are turning to herbs for natural products and chemicals, which have led to a rise in the demand for herbal remedies and other alternative treatments. (Bailey et al., 1989;Elavarasi et al., 2014.). Hyperglycemia and improper insulin secretion or action is complicated metabolic condition of diabetes mellitus. 5–10% of people with DM have type 1 diabetes, formerly known as juvenile diabetes, occurs due to the damages in the insulin-producing β cells in the pancreas. (Mahabir et al., 1997, Dayana Jeyaleela et al., 2017). Type 2 diabetes mellitus (T2DM) is characterized by insulin resistance, a reduction in hepatic glucose production and impaired glucose uptake by body cells. Type 2 diabetes affects 90% of elderly people; however, it steadily rises in youth due to obesity and inactivity. Large-scale consequences like heart disease, renal disease and stroke may result from it if left untreated. Patients with diabetes mellitus experience great exhaustion, weight loss, thirst, hunger and blurred eyesight as symptoms (Ripsin et al., 2009,Chung-Hung et al., 2012). Alpha-amylase and alpha-glucosidase inhibition are key therapeutic objectives for the treatment of diabetes mellitus (DM). Both enzymes play an essential role in carbohydrate digestion and regulate postprandial glucose levels in individuals with diabetes. Long-chain carbohydrate digestion by alpha amylase is complex, and the conversion of starch and disaccharides to glucose by alpha glucosidase is also complex. Oral anti-diabetic drugs suddenly decrease blood sugar levels and produce side effects such as nausea, abdominal pain, diarrhoea, and weight gain. Herbal medicines are in great demand because of their efficacy, safety, and better compatibility with human beings without any side effects (Grover et al., 2002). *Cyperus rotundus* also known as motha, purple nutseed or nutgrass, Kora kizhangu in Tamil language belongs to the Cyperaceae family which is widely spread in the regions of Southern Europe, Africa, Central Europe and then Southern Asia (Gupta et al., 1971). The extract of *C. rotundus* is mostly used in traditional folk medicine for the treatment of inflammatory diseases, stomach ailments, bowel disorders, wounds, boils and blisters, dysentery, diarrhoea, fever, malaria, skin disease, loss of memory, insect bites and food poisoning. (Dhillon et al., 1993; Yu J et al., 2004; Sivapalan et al., 2013). According to research, *C. rotundus* extracts have biological properties that are anti-diabetic, anti-microbial, anti-inflammatory, anti-cytotoxic, anti-mutagenic, anti-pyretic and anti-diarrheal. ( Sharma et al., 2011, Sivapalan et al., 2012) Likewise, *Tinospora cordifolia*, of Menispermaceae origin, is distributed in the tropical and subtropical regions of India. *Tinospora cordifolia*, also known as guduchi and “Shindilakodi,” in Tamil (Singh et al., 1970; Kirti Sinha et al., 2004; Patel MB et al., 2012). The extract of *Tinospora cordifolia* reported many medicinal evaluations in which it is more commonly used in fever, diabetes, vaginal discharge, diuretic, dyspepsia, stomachic, urethral discharge, allays thirst and enriches the blood and cures jaundice (Vaibhav et al., 2010, Bhawya et al., 2010). Also, the pharmaceutical activities of anti-stress, anti-periodic, anti-arithmetic, anti-malarial, anti-spasmodyc, anti-allergic, anti-neoplasic and anti-leprotic drugs were reported in the previous studies. (Upadhaya et al., 2010; Spandana et al., 2013). Due to the medicinal properties of both plants, *Cyperus rotundus* and *Tinospora cordifolia* were chosen to explore the synergistic effects on free radical scavenging activities and diabetic and as well as to identify the potential bioactive compound that may be the source of the combined extract's therapeutic effects. The pharmacological effects such as anti-oxidant and anti-diabetic activities of combined ethanolic extracts of the plants *Cyperus rotundus* and *Tinospora cordifolia* were previously studied and compared with the individual extracts. The combined extract exhibits the highest potential compared with the individual ethanolic extract of *Cyperus rotundus* and *Tinospora cordifolia*.
cordifolia. Based on the previous results, it was aimed to isolate the bioactive compound which is responsible for the pharmacological effects.

MATERIALS AND METHODS

Collection and authentication of plant materials

The rhizome part of C. rotundus and stem part of T. cordifolia were collected in January 2019 from Alagudi area, Tiruchirappalli district, Tamil Nadu, India. The collected plant samples were authenticated (voucher specimens 2958, 2959) and deposited at the Rapinat Herbarium, St. Joseph’s college (Autonomous), Tiruchirappalli, Tamil Nadu India

Preparation of ethanol extracts

The collected plant materials were washed with distilled water to remove dirt and impurities and then dried under shade. The dried plant samples were ground using a mechanical grinder and sieved. The dry powder of the rhizomes of C. rotundus and the stem of T. cordifolia were equally mixed in a ratio of 1:1. 400g of each plant material are mixed together and denoted as ‘CT Combination’. The CT combination powder was extracted with ethanol by the soxhlet extraction method. The final extract was filtered and concentrated by evaporation. The final crude extract is stored at 4°C in the refrigerator for further analysis (Pradeep Singh et al., 2015).

Identification of Bioactive Compounds in the CT Combination by GC-MS Analysis

The formulation of ethanolic extract of C. rotundus and T. cordifolia were subjected to identify bioactive compound by GC-MS. This analysis was performed on a “Thermo GC-Trace Ultra ver; 5.0” gas chromatography attached with a “Thermo MS DSQ II” for mass evaluation. Components were detached on a “ZB 5-MS Capillary Standard Non-Polar Column” with 200 mm length with a 0.25-µm film thickness. During the experiment, temperature was elevated from 70 to 260°C. The flow-rate of carrier gas, helium, was 10 mL/min and the injection volume of the samples was 1 µl. The identification of the chemical components was performed on the basis of comparison of their respective retention time and mass spectra with those attained from authentic sample. Analysis of the mass spectrum, the compound was identified using National Institute of Standards and Technology (NIST) database.

Phytochemical screening

Liebermann-Burchard Test

2mg of combined ethanolic extract of C. rotundus and T. cordifolia was dissolved in chloroform. Then acetic anhydride and concentrated sulphuric acid was poured from the tube's side. Sterol was present because of a brief colour change from red to blue to green.

Identification of compound in the CT combination by HPTLC

Sample preparation

2g of the crude extract of the CT was dissolved in 10 ml of ethanol and filtered through Whatmann filter paper No. 41. The filtrate was subjected to HPTLC analysis for the identification and the quantification of β-sitosterol (Ridhi Joshi et al., 2020).

Standard solution preparation

The stock samples were made by weighing 10 mg of β-sitosterol standard and carefully diluted with 10 ml of ethanol to obtain standard stock concentration solutions.

HPTLC Analysis of standard and CT combined Extract

1µl to 6µl of standard solutions of β-sitosterol and 1µl to 6µl of the CT combined extract were uniformly loaded on the precoated silica gel 60 F₄₅₄ HPTLC plate (preparative) under a semiautomatic spotter under a nitrogen stream. Toluene: Ethyl acetate: Formic acid (5:4:1) was the mobile phase. The HPTLC plate and sample applicator is used in the analysis. A temperature of 25°C was used for the chromatographic circumstances, which also comprised the ascending separation technique, a trough chamber for plate growth and a migration distance of 10 cm. The sample and the standard-loaded plates were dried in hot air and then scanned densitometrically at UV light and a short wavelength of 254nm using TLC Scanner. The calibration curves of the sample and the standard were studied by plotting the peak area versus concentration of the sample.

Isolation of β-Sitosterol by Column and TLC

Column and Preparative Thin-layer chromatography

The ethanolic extract of the CT combination was subjected to TLC and column chromatography to separate the bioactive compound β-sitosterol, followed by the methods of Arjun et al., (2010) and Rand et al., (2018). The column chromatography was packed with activated silica gel and the concentrated extract was loaded on top of the column. Then, the column was first eluted with n-hexane (a low-polar solvent), then different ratios of ethyl acetate and n-hexane were poured into the column (1:9 to 9:1), and finally the un-eluted compound was separated with the methanol solvent. At the end, several fractions were obtained. The fractions with isolated compounds were further separated by TLC. 5 µl of the isolated compound was applied to silica gel plates, Merck (Germany), 20 x 20 cm, 0.25 mm in thickness. Plates were developed using the solvent system n-hexane-ethyl acetate (70:30 v/v). The compound was detected on TLC plates by spraying with Libermann-Burchard reagent and heating at 100°C for 10 minutes.

Purification of isolated compounds from HPLC

The analytical HPLC system was equipped with a diode array detector, a 20 µl of sample injector and a 200 x 4.6 mm C18 column. The mobile phase consisting of methanol and water (75:25 v/v), was filtered through a membrane filter and pumped into the column at a flow rate of 1.0 ml/min. The column temperature was 30°C. 40 µl of the isolated compound was injected into the column and detected at 284 nm.

Characterization and structural elucidation study of isolated compound

Different kinds of spectroscopic methods were used to analyse the structure of the isolated compound CT-1, which were UV, FTIR, 1H NMR, and 13C NMR. All these methods were used to explain the structure of the CT-1 isolated compound. The UV-visible spectrum of the compound CT-1 was screened with methanol using the Shimadzu 160A UV-visible spectrophotometer. The FT-IR spectra of CT-1 were recorded with a resolution of 4 cm⁻¹ within the wave number range of 400 to 4000 cm⁻¹ using the KBr pellet method. 1H and 13C NMR spectra were acquired on Bruker WP 200 SY and AM 200 SY instruments (1H, 200.13 MHz; 13C, 50.32 MHz) using TMS (tetra methyl silane) as an internal standard in CDCl₃, solvent (deuterated chloroform) (Muhammad Aurang Zeb et al., 2017, Pierre et al., 2015, Habib et al., 2007).

In Vitro Antioxidant Activity

DPPH assay method

The antioxidant activity of the isolated compound CT-1, i.e., β-sitosterol, was examined by the low-cost and effective DPPH method. A 0.05 mM concentration of DPPH reagent was prepared with 100 µl of ethanol. The different concentrations of 20, 40, 60, 80 and 100 µg/ml of sample and the standard ascorbic acid were prepared. Around 3 ml of freshly prepared DPPH reagent was added to the sample and the standard test tubes were left separately for 30 minutes. The absorbance of each sample and the standard was measured spectrophotometrically at 517nm. The radical scavenging activity of the standard and the isolated compound was observed and the percentage of inhibition of DPPH was calculated by following the method of Arif Hussain Bhat et al., (2019).

Percent (% of inhibition of DPPH = (A-B)/A x 100.

A - absorbance values of blank

B – absorbance values of sample

In vitro antiadhesive activity

Alpha-Amylase Inhibition Assay

The inhibition of alpha-amylase enzyme was used to assess the anti-diabetic effect of the isolated compound CT-1. The isolated compound CT-1 was prepared in different concentrations of 20, 40, 60, 80 and 100 µg/ml. 250 µl of different concentrations of the isolated compound were taken in a test tube; 200 µl of 0.02 M sodium phosphate buffer and 1 ml of alpha amylase solution (0.5 g/ml) were added at a pH of 6.9. The reaction mixture was pre-incubated at room temperature for 10 minutes. After that, 400µl of 1% starch solution in 0.02M sodium phosphate buffer was added at regular time intervals and then further incubated at 25°C for 10 minutes followed by 1 ml of dinistosalicic acid, which was added and incubated in a boiling water bath for 5 minutes, then cooled at room temperature. Finally, the reaction mixture was further diluted by adding 10 ml of double distilled water, and the absorbance of the test and standard samples was measured at 540 nm by a spectrophotometer Manigandan et al., (2021). The alpha-amylase inhibitory potential was calculated in terms percentage inhibition.

% Inhibition = (|Abs control – Abs test| / Abs control) x 100
Alpha-glucosidase inhibition assay

Alpha-glucosidase inhibition was used to assess the anti-diabetic effect of the isolated drug CT-1 by the following method of Saraf et al., (2015). 20 mM concentration of the reagent p-nitro phenyl glucopyranoside (p-NPG) was prepared and the pH of the reaction was maintained at 6.9. To do that, 50 µl of alpha-glucosidase was mixed with 60 µl of the different concentrations of 20, 40, 60, 80 and 100 µg/ml of the isolated compound β-sitosterol. Then it was left for 10 min for a complete reaction, and then 50 µl of 3.0 mM (pNPG) substrate was dissolved in 20 mM phosphate buffer (pH 6.9). The reaction mixture was incubated at 37°C for 20 min and stopped by adding 160 µl of 0.1 M sodium carbonate. The yellow alpha-p-nitro phenol was measured at 405 nm.

The alpha-glucosidase inhibitory potential was calculated by percentage inhibition. % Inhibition = [(Abs control – Abs test) / Abs control] x 100

Cell culture

3T3-L1 (Mouse fibroblast cell) cell line was purchased from NCCS, Pune and were cultured in liquid medium (RPMI) supplemented with high glucose, 10% Fetal Bovine Serum (FBS), 100 µg/ml penicillin, and 100 µg/ml streptomycin, and maintained under an atmosphere of 5% CO₂ at 37°C.

Materials Required

RPMI medium, Fetal Bovine Serum (FBS) and antibiotic solution were from Gibco (USA), DMSO (Dimethyl sulfoxide) and D-Glucose and HEPEs were from Sigma, (USA), 1X PBS was from Himedia, (India). The tissue culture plate and wash beaker were from Tarson (India).

Glucose uptake activity

The effect of extracts on glucose uptake assay was measured using 3T3-L1 cells according to the methods described by Murad Alsawalha et al., (2019) with slight modifications. The cell cultures with 70-80% confluency in 40 mm petri plates were allowed to differentiate by maintaining in RPMI with 2% FBS for 4-6 days. The differentiated cells were serum-starved overnight and at the time of the experiment, cells were washed with HEPEs buffered Krebs Ringer Phosphate solution (KRP buffer) once. Then cells were incubated with KRP buffer with 0.1% BSA for 30 min at 37°C. The differentiated 3T3-L1 preadipocytes were incubated with 100µg/ml of metformin and/ or β-sitosterol at various concentrations. 50 mM concentration of glucose solution was added simultaneously to each well and incubated at 37°C for 30 min. After incubation, the uptake of the glucose was terminated by aspiration of solutions from wells and washing thrice with ice-cold KRP buffer solution. Cells were lysed with 0.1M NaOH solution and an aliquot of cell lysates was used to measure the cell-associated glucose. The glucose levels in cell lysates were measured using glucose oxidase method by measuring the OD at 520 nm using a micro plate reader. (Thermo fisher Scientific, USA). Three independent experimental results were taken to determine the percentage enhancement of glucose uptake over controls.

RESULTS AND DISCUSSION

Medicinal plants offer a naturally occurring supply of drugs for the treatment of illness as well as prospects for the discovery of novel medications. Identifying the various biological activities of plants would therefore benefit from an examination of their elements. The presence of such phytoconstituents in medicinal plants can be determined through a variety of techniques. Chromatography and spectroscopic techniques are the most standard tools used for this purpose. Gas chromatography plays a significant role in the determination of phytoconstituents. However, spectroscopic approaches (UV-VIS, FT-IR) are simple, accurate, and can be used as standard methods for detecting phytoconstituents.

Identification of Bioactive compounds in the CT combined Extract by GC-MS Analysis

The GC-MS chromatogram of ethanolic extract of C. rotundas and T. cordifolia were determined by their retention time (RT), peak area (%), height (%) and concentration (%) are represented in Table 1 and Figure 1. According to the GC-MS analysis, 54 chemical compounds were found in the combined plant extract. Among the identified bioactive compounds, β-sitosterol is majorly present in the combined extract with an area percentage of 12.51 and the retention time value of the compound is 45.567. This compound has antioxidant and anti-candidal activity. 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy has antioxidant, antimicrobial, anticancer, anti-inflammatory, and cytotoxic activities. Xiangying Yu et al., (2013), 1, 2, 3-Benzenetriol (Pyrogallol) has antimicrobial, anti-inflammatory, antioxidant, analgesic, insecticide, anticancer, cytotoxic, anti-septic, antibacterial, antidermatitis, fungicide and pesticide properties. Narayana V. V. et al., (2014). Stigmastanol is an abundant phytoesterol compound that has anticancer, antimutagenic, hyperglycemic, antioxidant and anti-inflammatory properties. Zeb MA., et al., (2017). N-hexadecanoic acids have antioxidant, pesticide, flavour, 5-alpha reductase inhibitor, antifibrinolytic, hemolytic, lubricant, nematicide and antialopecic.

![Figure 1 GC-MS analysis of ethanolic extract of combination of C. rotundas and T. cordifolia](image-url)

**Table 1 Retention Time, Compounds, Molecular Formula, Molecular Weight, area% and activity of combination of ethanolic extract of C. rotundas and T. cordifolia**

<table>
<thead>
<tr>
<th>Peak#</th>
<th>R.Time</th>
<th>Area</th>
<th>Area%</th>
<th>Molecular formula</th>
<th>Molecular Weight (g/mol)</th>
<th>Name</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.988</td>
<td>343643</td>
<td>2.56</td>
<td>C₈H₈N₂O₂</td>
<td>126.11</td>
<td>Thymine</td>
<td>2-Butanone, 4,4-dihydroxy-3-methyl phenyl</td>
</tr>
<tr>
<td>2</td>
<td>7.726</td>
<td>742899</td>
<td>5.53</td>
<td>C₆H₁₂O₂</td>
<td>194.22</td>
<td>4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>8.150</td>
<td>227513</td>
<td>1.69</td>
<td>C₆H₁₂O₂</td>
<td>144.12</td>
<td>Hexane, 2-bromo-</td>
<td>2-[(1-Hydroxymethyl)-2-methyl-1,3-oxathiolan</td>
</tr>
<tr>
<td>4</td>
<td>10.354</td>
<td>190919</td>
<td>1.42</td>
<td>C₆H₁₂Br</td>
<td>165.07</td>
<td>4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6 methyl</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>11.317</td>
<td>344207</td>
<td>2.56</td>
<td>C₆H₁₂O₂Si</td>
<td>148.23</td>
<td>2-Methyl-1-dif(tert-butyl)benzyloxypropane</td>
<td>100%</td>
</tr>
<tr>
<td>6</td>
<td>12.456</td>
<td>176353</td>
<td>1.31</td>
<td>C₆H₁₂O₂Si</td>
<td>144.12</td>
<td>2-methoxy-4-vinylphenol</td>
<td>100%</td>
</tr>
<tr>
<td>7</td>
<td>12.731</td>
<td>136514</td>
<td>1.02</td>
<td>C₃H₅(OH)Si</td>
<td>216.15</td>
<td>Eugenol</td>
<td>1,2,3-benzenerit</td>
</tr>
<tr>
<td>8</td>
<td>13.820</td>
<td>128360</td>
<td>0.96</td>
<td>C₆H₁₂O₂</td>
<td>150.17</td>
<td>3-Methoxy-[4-(3-oxo-3-pyrrolidin-1-yl)propoxy benzaldehyde</td>
<td>100%</td>
</tr>
<tr>
<td>9</td>
<td>15.216</td>
<td>100460</td>
<td>0.75</td>
<td>C₆H₁₂O₂</td>
<td>164.2</td>
<td>3-azabicyclo[3.2.2]nonane</td>
<td>100%</td>
</tr>
<tr>
<td>10</td>
<td>15.693</td>
<td>1098168</td>
<td>8.17</td>
<td>C₆H₁₂O₂</td>
<td>126.11</td>
<td>(E)-2,5,5-trimethyl-hepta-3,6-dien-2-ol</td>
<td>100%</td>
</tr>
<tr>
<td>11</td>
<td>16.589</td>
<td>115734</td>
<td>0.86</td>
<td>C₆H₁₂F₃NO₄</td>
<td>345.31</td>
<td>(1R,2R,4S,6S,8S)-8-isopropyl-1-methyl-3- methylenericyclo[4.4.0.2,7]dec-4-ol</td>
<td>100%</td>
</tr>
<tr>
<td>12</td>
<td>16.976</td>
<td>236275</td>
<td>1.76</td>
<td>C₆H₁₂N</td>
<td>125.21</td>
<td>Tricyclo[5.1.0.0²,4]oct-5-one-5-propanolic 3,3,8,8-tetramethyl-N-(5-hydroxy-7-oxabicyclo[4.1.0]hept-2-yl</td>
<td>100%</td>
</tr>
<tr>
<td>13</td>
<td>17.705</td>
<td>80553</td>
<td>0.60</td>
<td>C₆H₁₂O₂</td>
<td>154.15</td>
<td>Hexadecanoic acid</td>
<td>100%</td>
</tr>
<tr>
<td>14</td>
<td>21.086</td>
<td>103564</td>
<td>0.77</td>
<td>C₆H₁₂O₂</td>
<td>220.35</td>
<td>Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1- (1-methylheyl)-, 1-cis-</td>
<td>100%</td>
</tr>
<tr>
<td>15</td>
<td>21.966</td>
<td>81279</td>
<td>0.60</td>
<td>C₆H₁₂O₂</td>
<td>234.33</td>
<td>8-isopropyl-1,5-dimethylenetri[cyclo[4.4.0.2,7]dec-4-ol]</td>
<td>100%</td>
</tr>
<tr>
<td>16</td>
<td>23.040</td>
<td>94363</td>
<td>0.70</td>
<td>C₆H₁₂N₂O₂</td>
<td>219.28</td>
<td>Cyperotundone</td>
<td>-3(3ar,4R,7R)-1,4,9,9-Tetramethyl-3,4,5,6,7,8 hexahydro-2H-3,7-methanoazulen-2-one</td>
</tr>
<tr>
<td>17</td>
<td>23.169</td>
<td>360889</td>
<td>2.69</td>
<td>C₆H₁₂O₂</td>
<td>256.64</td>
<td>Bicyclo[5.2.0]nonane, 2-methylene-4,8,8-tri methyl-4-vinyl-</td>
<td>100%</td>
</tr>
</tbody>
</table>
The combined ethanolic extract of *C. rotundus* and *T. cordifolia* was subjected to preparative TLC chromatography. Through trial and error, the solvent system was identified. The silica gel plates were reactivated by heating them in an oven set to 100°C for 15 minutes, followed by 10 minutes of cooling. The mobile phase for phytoestrogens was n-hexane: ethyl acetate (70:30 v/v). The fractions with isolated chemicals (CT-1) were added to the baseline of TLC plates and subsequently further separated by TLC. The isolated compound CT-1 was compared with the standard β-sitosterol and detected on TLC plates by spraying with Libermann-Burchard reagent and heating at 100°C for 10 minutes. The Rf values of the isolated compound were found to be 0.50, which indicated the steroid group. Then, the isolated compound CT-1 was subjected to column chromatography and the column was first eluted with n-hexane, increasing the amount of ethyl acetate in n-hexane and finally with methanol, yielding a number of fractions. The fraction collected in the ethyl acetate-methanol (40:60) ratio shows positive results for terpenoids. Also, it showed a similar Rf value to the standard β-sitosterol and it was further taken for the purification process.

**HPTLC Analysis of the β-sitosterol rich fraction (CT-1)**

![HPTLC chromatogram of 1 µl to 5 µl of standard β-sitosterol and 1 µl to 5 µl of isolated compound CT-1](image)

**Figure 2 HPTLC chromatogram of 1 µl to 5µl of standard β-sitosterol and 1 µl to 5µl of isolated compound CT-1**

**Table 1**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rf Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitosterol</td>
<td>0.59</td>
</tr>
<tr>
<td>Octadecanoic acid</td>
<td>0.26</td>
</tr>
<tr>
<td>Ethanolic acid</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**Separation and Isolation of β-Sitosterol by Chromatographic Methods:**

HPTLC fingerprint patterns have been evaluated for the isolation of compounds from the ethanolic extracts of *C. rotundus* and *T. cordifolia*. The isolated compound was quantitated accurately using silica gel F$_254$ HPTLC pre-coated plates with the mobile phases toluene, ethyl acetate, and formic acid (5:4:1). The chambers are saturated with mobile phase for 60 min. The development time of the isolated compound was 15 minutes. After development, the plate was air-dried for 5 minutes. To attain the greatest resolution and peak, the chromatographic conditions had previously been tuned. The peak area versus concentration (ng/spot) for each spot was plotted to create the calibration curve. The maximum Rf values of both the standard and the isolated compound CT-1 are 0.50 in figure 2. The isolated compound is β-sitosterol and correlation curves for the isolated compound β-sitosterol in combined plant extracts were regression via height x = 626.0117+16.922x and r = 0.92985 sdv = 2.80 and regression via area y = 8624.057 + 2202.518 x and r = 0.99996, sdv = 0.31 in figures 3 and 4.

**Figure 3 HPTLC chromatogram images of standard β-sitosterol**

![HPTLC chromatogram images of standard β-sitosterol](image)
Characterization of isolated component of β-sitosterol:

UV visible of spectroscopy

A spectrophotometer is helpful in the study of photon spectroscopy within the UV-VIS range. The absorption in the visible range is directly influenced by the colour of the compound used. The isolated compound CT-1 [β-sitosterol] is a white powder with a MW of 414.7 g/mol and a melting point of 136°C, which corresponds to the molecular formula C29H50O. The UV λmax value of compound β-sitosterol was 216 nm in Fig. 5.

FTIR spectra of isolated compound β-sitosterol

For characterizing and identifying chemicals or functional groups (chemical bonds) present in the combination of plant extracts, the FT-IR has proven to be an invaluable method. It is a quick, non-destructive method that requires little sample preparation. As a result of the bands seen in the infrared spectrum, it enables the qualitative identification of chemical molecules.

IR: (KBr): νmax: The IR absorption spectrum showed absorption peaks at 3433.72 cm-1 (O-H stretching), 2937.46 cm-1 and 2868.48 cm-1 (aliphatic C-H stretching), 1642.92 cm-1 (C=O absorption peak), and other absorption peaks includes 1463 cm-1 (CH2), 1379.54 cm-1 (OH of δ), 1058.75 cm-1 (cycloalkane) and 881.50 cm-1 in Fig. 6.

Proton NMR of isolated compound β-sitosterol

H NMR (CDCl3, 300MHz) has given signals at δ 3.506 (m, 1H of C3), 5.337 (t, 1H of C6), 0.661 (dd, 2H of C23), 0.679 (dd, 2H of C22), 0.787 (d, 1H of C24), 0.800 (dd, 2H of C28), 0.811 (d, 1H of C25), 0.827 (d, 1H of C20), 2.263&2.268 (dd, 2H of C7), 4.695 (dd, OH of C3), 0.898 (d,3H of C26&C27, J=6.6), 0.823 (d, 3H of C29, J= 6.4 H2), 0.789 (d, 3H of C19, J= 6.4), 1.670 (s, 3H of C18) and 0.990 (s, 3H of C21). The previous studies suggested that the 1H NMR spectrum of the isolated compound β-sitosterol showed the presence of six methyl signals that appeared as two methyl signals at δ 0.78 (C19) and 1.67 (C18). Three methyl doublets at δ 0.99 (C21), 0.82 (C29) and 0.89 (C26 & C27) and a methyl triplet at δ 0.81 correspond to the methyl protons. The 1H NMR spectrum of this substance also showed one olefinic proton at δ 5.33 in Fig. 7. Its 1H NMR spectrum showed a proton corresponding to the hydroxyl group which appeared as a multiplet at δ 4.695 ppm (OH of C3).

Figure 4 HPTLC chromatogram images of β-sitosterol isolated compound CT-1

Figure 5 UV spectra for β-sitosterol isolated compound CT-1

Figure 6 FTIR spectra for β-sitosterol isolated compound CT-1

Figure 7 1H NMR spectra for β-sitosterol isolated compound CT-1

13C NMR (CDCl3,100MHz) has given signal at 37.333(C-1), 31.971(C-2), 71.899(C-3), 42.398(C-4), 140.827(C-5), 121.802(C-6), 31.971(C-7), 31.722(C-8), 50.202(C-9), 36.586(C-10), 24.888 (C-11), 39.881(C-12), 42.369(C-13), 56.847(C-14), 24.388(C-15), 28.333(C-16), 56.847(C-17), 12.065(C-18), 19.486(C-19), 39.851(C-20), 21.161(C-21), 138.404(C-22), 129.337(C-23), 50.202(C-24), 36.586(C-25), 18.863(C-26), 19.192(C-27), 24.388(C-28), 11.941(C-29) in Fig. 8. The 13C NMR spectrum also showed twenty-nine carbon signals made up of six methyl, eleven methylene, nine methane and three quaternary carbon signals. The spectra showed signals of 140.827 ppm and 121.802 ppm, which are alkene double bonds. The values of 19.192 ppm and 11.941 ppm correspond to methyl carbon atoms. The signal at 71.899 ppm is the β-hydroxyl group attached to the carbon.

Figure 8 13C NMR spectra for β-sitosterol isolated compound CT-1

Purification of β-sitosterol isolated compound by HPLC

The isolated compound CT-1 from the ethanolic extract of sample was purified by HPLC method. The retention time of β-sitosterol was about 3.045 and was shown by HPLC peak in Fig. 9.

Figure 9 HPLC SPECTRA FOR ISOLATED β-SITOSTEROL
Antioxidant activity of isolated compound β-sitosterol from plant extracts by DPPH method

The antioxidant activity of the isolated compound β-sitosterol showed 64.54 % of inhibitory activity at a concentration of 100µg/ml while ascorbic acid exhibited 82.72% at a concentration of 100µg/ml. The IC50 value for the isolated compound β-sitosterol is 44.33µg/ml (Table 2).

Table 2 In vitro antioxidant activity of the compound β-sitosterol using DPPH method

<table>
<thead>
<tr>
<th>S. No</th>
<th>Concentrations (µg/ml)</th>
<th>Sample</th>
<th>Scavenging Effect (%)</th>
<th>Ascorbic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>43.63±0.92</td>
<td>48.18±1.40</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>47.27±1.42</td>
<td>60±1.42</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>55.45±1.55</td>
<td>70.9±1.38</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>60.90±1.49</td>
<td>79.0±1.47</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>200</td>
<td>64.54±1.38</td>
<td>82.72±1.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IC50 Value</td>
<td>44.33</td>
<td>18.81</td>
<td></td>
</tr>
</tbody>
</table>

In Vitro alpha amylase and alpha-glucosidase inhibitory assay

In this study, the in vitro alpha amylase inhibitory activities of the isolated compounds β-sitosterol from both plant extracts (ratio 1:1) were examined. The isolated compound showed the maximum inhibitory activity 62.21±1.25 at a concentration of 100µg/ml (Table 3). Acarbose, a standard drug for alpha amylase inhibitors, showed inhibitory activity of 81.51±1.25 at a concentration of 100µg/ml. The IC50 value for the isolated compound β-sitosterol was indicated as 45.45µg/ml. This indicates that the isolated compound β-sitosterol is a very potent alpha amylase inhibitor in the management of diabetes mellitus.

The results of antidiabetic activity using an alpha-glucosidase inhibitory assay of the isolated compound β-sitosterol are shown in Table 3. The isolated compound β-sitosterol showed inhibitory activity of 65.48±1.47 at a concentration of 100µg/ml. This indicates that the isolated compound β-sitosterol is a very potent alpha amylase inhibitor in the management of diabetes mellitus.

Table 3 In vitro antidiabetic activity of the β-sitosterol and standard drug acarbose against alpha-amylase and alpha-glucosidase

<table>
<thead>
<tr>
<th>S. No</th>
<th>Concentrations (µg/ml)</th>
<th>Sample</th>
<th>Alpha amylase (%)</th>
<th>Acarbose</th>
<th>Sample</th>
<th>Alpha-glucosidase (%)</th>
<th>Acarbose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>45.37±1.24</td>
<td>50.42±1.42</td>
<td>31.85±1.20</td>
<td>52.32±1.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>59.73±1.47</td>
<td>61.34±1.47</td>
<td>41.95±1.35</td>
<td>61.94±1.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>57.94±1.37</td>
<td>67.22±1.37</td>
<td>56.44±1.24</td>
<td>69.91±1.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>69.30±1.35</td>
<td>73.1±1.25</td>
<td>72.4±1.42</td>
<td>78.10±1.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>200</td>
<td>73.21±1.25</td>
<td>81.51±1.34</td>
<td>75.48±1.47</td>
<td>80.53±1.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IC50 Value</td>
<td>25.94</td>
<td>14.82</td>
<td>46.02</td>
<td>10.55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Glucose uptake activity

In vitro glucose uptake activity of β-sitosterol in 3T3L1 cells was analysed at different concentrations (50, 100, 200 and 250 µg/ml) as shown in Table 4. The glucose uptake activity of isolated compound β-sitosterol was compared to that of the standard antidiabetic drug metformin (100 µg/ml). The glucose uptake was significantly increased in the metformin-treated cell lines (52%) over the untreated control group. However, β-sitosterol showed significantly increased glucose uptake compared to the standard drug metformin (28% at 100µg/ml) in a concentration-dependent manner.

Table 4 Percentage of Glucose uptake

<table>
<thead>
<tr>
<th>S. No</th>
<th>concentration (µg/ml)</th>
<th>Mean Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Metformin (100 µg/ml)</td>
<td>52.54945</td>
</tr>
<tr>
<td>3</td>
<td>10 µg/ml</td>
<td>18.36327</td>
</tr>
<tr>
<td>4</td>
<td>50 µg/ml</td>
<td>25.99837</td>
</tr>
<tr>
<td>5</td>
<td>100 µg/ml</td>
<td>28.23226</td>
</tr>
<tr>
<td>6</td>
<td>250 µg/ml</td>
<td>30.97423</td>
</tr>
<tr>
<td>7</td>
<td>500 µg/ml</td>
<td>32.86984</td>
</tr>
</tbody>
</table>

DISCUSSION

Phytochemicals, which are similar types of plant-based cholesterol, are essential in the therapeutic sector since there are more advantageous, less expensive, more accessible and without negative effects. β-sitosterol is one of the phytochemicals compounds and has been shown to possess various pharmacological activities in many diverse applications. The current study aimed to isolate and characterize β-sitosterol from the ethanolic extracts of C. rotundas and T. cordifolia and evaluate antidiabetic activity under in vitro condition. The combined ethanol extract of C. rotundas and T. cordifolia was subjected to column chromatography by using different mobile phase solutions. The CT-1 (white crystalline) compound was isolated. The isolated compound was identified by phytochemical analysis (Lieberman-Burchard test). The results of the phytochemical analysis indicated that the isolated compound may be a steroid or terepne. On HPTLC, the Rf values of both the standard and the isolated compound CT-1 are 0.50. Previous studies by Rajeshwari Prabha Lahare et al., (2019) reported that the Rf value of β-sitosterol in the leaves, stem and roots of Andrographis paniculata was visualised by the HPTLC method. The isolated compound's structure was proposed to be β-sitosterol based on the melting point and other relevant information (UV, FTIR, 'H NMR, and 'C NMR). β-sitosterol is a white crystalline substance, and these absorption frequencies coincide with the absorption frequencies observed for β-sitosterol, according to data from Arjun et al., (2010), Sangwan et al., (2019).
homeostasis and lipid accumulation. One of the important target mechanisms to achieve glucose homeostasis is the assay of glucose uptake activity in the 3T3-L1 adipocyte cell line through the translocation of GLUT4 on the plasma membrane. This assay is thought to be an effective target for the development of effective medications for diabetes and obesity. In the current research, the glucose uptake activity of the isolated compound β-sitosterol from C. rotundus and T. cordifolia was determined in vitro. Hence, β-sitosterol significantly enhanced glucose uptake in 3T3-L1 adipocytes comparable to the standard antidiabetic drug metformin. Metformin is a biguanide that improves the sensitivity of insulin by activating the AMP-activated protein kinase pathway (Lachin et al., 2021).

CONCLUSION

Plants contain phytosterols, which are essential bioactive substances. Among the various kinds, β-Sitosterol is one of the most renowned substances, with a structure resembling that of cholesterol. The main function of an isolated organic compound is to maintain the membrane's fluidity. The present study demonstrates that β-sitosterol was isolated and characterised from a combined ethanolic extract of the stem and the stem part of Tinospora cordifolia. As an isolated compound, it exhibited inhibitory activity against alpha amylase and alpha glucosidase and enhanced glucose uptake in 3T3-L1 adipocytes. The results indicated that an isolated compound is considered a potential drug and has promising antioxidant and antidiabetic effects. The therapeutic potential of β-Sitosterol could be utilized as a novel drug for the treatment of type 2 diabetes mellitus by regulating postprandial hyperglycemia.


Sunil Kumar, Vipun Kumar, Om Prakash (2013). Enzymes inhibition and antidiabetic effect of isolated constituents from Dilleniinudica, BioMed Research International, 382063. DOI: 10.1155/2013/382063


