https://doi.org/10.26651/allelo.j/2025-66-2-1558 0971-4693/94 Euro 20.00
Allelopathy Journal 66 (2): 233-246 (November, 2025) International Allelopathy Foundation 2025
Figs : 5, Tab: 5

Pharmacognostic characterization and phytochemical evaluation of *Curculigo capitulata* (Lour.) Kuntze leaves

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ABSTRACT

This study aimed to determine the pharmacognostic markers through comprehensive pharmacognostic, physicochemical and phytochemical evaluations, including chemical profiling by gas chromatography-mass spectrometry (GC-MS) and allelochemicals analysis of the leaves. Organoleptic examination revealed fibrous, lanceolate leaves with a slightly bitter and astringent taste and a mild earthy odour. Macroscopically, the fresh leaves measured 30-60 × 10-15 cm and were ribbed and glabrous. Microscopically, transverse sections exhibited dorsiventral symmetry, a cuticularized upper and lower epidermis, distinct palisade and spongy parenchyma and a collateral vascular bundle encased in a parenchymatous bundle sheath. Microscopic examination of the leaf epidermis exhibited a paracytic stomatal arrangement, characteristic of the species. The stomatal index was recorded as 14.27 % on the adaxial surface and 19.32 % on the abaxial surface. The determined physicochemical parameters, total ash (8.3 %), acid-insoluble ash (1.0 %), water-soluble ash (2.5 %) and moisture content (6.8 %). All values were expressed on an air-dried basis and demonstrated consistent and reliable pharmacognostic markers, indicative of the plant's authenticity and phytochemical integrity. Fluorescence analysis under UV and visible light revealed distinctive colour responses, aiding in the authentication of crude drugs. Phytochemical screening of leaf extracts revealed the presence of bioactive metabolites including flavonoids, alkaloids, glycosides, and phenolics. The methanolic extract exhibited a yield of 15 % w/w. Furthermore, GC-MS analysis of the methanolic extract identified multiple phytoconstituents, thereby, providing a chemical rationale for its observed biological activities. These findings establish comprehensive pharmacognostic and phytochemical profiles essential for the authentication, standardization and future phytopharmacological investigations of *C.capitulata (Lour.)* Kuntze.

Keywords: Allelochemicals, *Curculigo capitulata*, Pharmacognostic evaluation, Phytochemical screening, Standarization.

INTRODUCTION

India has legacy of indigenous medical systems, (Ayurveda, Unani, Siddha and Homeopathy), showing the therapeutic potential of natural products since ancient times in healthcare practices (2). In current pharmacopoeias, these natural sources of therapeutic chemicals remain essential (10,23). Hence, it is imperative to evaluate the phytoconstituents obtained from these conventional therapeutic treatments using a range of approaches, including phytochemical screening, pharmacological analysis and analytical techniques (15). An essential preliminary step in the standardization of medicinal flora involves the pharmacognostic characterization of the plant material, encompassing organoleptic profiling, macroscopic and microscopic evaluation and analysis of physicochemical constants to establish diagnostic benchmarks (14). In India, 7,000 -7,500 medicinal plants are used to cure various diseases (21).

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Curculigo capitulata (Lour.) Kuntze (syn. *Molineria capitulata* (Lour.) (family Hypoxidaceae) called palm grass, whale back, or weevil lily is perennial plant of significant ethnobotanical importance (17). It is distributed in tropical and subtropical bioregions of India, China, Indonesia and northern Australia. Morphologically, it grows nearly 1.0 m tall, bearing stout, tuberous rhizomes, pleated oblong-lanceolate leaves and stoloniferous extensions that facilitate vegetative propagation (Figure 1). Wang *et al.* (28) documented its distinctive reproductive features: actinomorphic, star-shaped yellow flowers with prominent perianth segments. Its fruits are edible, while its fibrous leaves have been traditionally used for food wrapping and net weaving. Figure 1 shows the major plant parts of *Curculigo capitulata*, including (a) the whole plant, (b) leaves, (c) flowers and (d) rhizomes and roots. Ethnomedicinal literature by Muthiam *et al.* (16) and Taufik *et al.* (24), reported its therapeutic applications viz., treatment of metabolic and infectious conditions such as diabetes mellitus, hemorrhagic disorders, viral infections, hemorrhoids, asthma, jaundice, diarrhea, abdominal colic, gonorrhea, spermatorrhoea, erectile dysfunction and kidney asthenia. These diverse ethnobotanical uses underscore the genus's pharmacological relevance, particularly in the management of chronic inflammatory and metabolic syndromes. Furthermore, ecological studies by Umaru *et al.* (26) have revealed the species' adaptability to varied photic environments, with a preference for moist, well-drained loamy substrates exhibiting mildly acidic pH. Optimal vegetative performance has been observed under moderate temperature regimes ranging from 16 to 24 °C, suggesting the plant's amenability to cultivation across diverse agroclimatic zones.

Phytochemical investigations by Muthiam *et al.* (16) and Wang *et al.* (28) have revealed a diverse spectrum of secondary metabolites in *Curculigo capitulata*, including alkaloids (e.g., pilosidine), flavonoids, phenolic acids, phenolic glycosides (e.g., crassifoside A, crassifoside D, curcapital), triterpenes and their glycosidic derivatives, tannins, saponins, reducing sugars and steroidal constituents (12,27). Notably, triterpenoids, phenolic glycosides and norlignans such as breviscaside A, crassifogenin C, 2,6-dimethoxybenzoic acid, isocurculigenin and methyl-4-O-coumaroylquinate are regarded as the principal bioactive compounds underlying the plant's pharmacological activity (Figure 2). Shah *et al.* (19) demonstrated its antioxidative and antidiabetic efficacy using *in-vitro* and *in-silico* models, highlighting its potential in attenuating oxidative stress and hyperglycemia. Muthiam *et al*. (16) further reported significant anti-inflammatory, analgesic, cytoprotective and thrombolytic activities, attributable to its rich phytochemical profile. Recent pharmacological and computational studies have corroborated its antioxidant, anti-inflammatory, thrombolytic and analgesic properties (5,25). *In-silico* analyses have identified potent antiviral phytoconstituents from *C. capitulata* exhibiting activity against the varicella-zoster virus, thereby expanding its therapeutic scope (3). Recent studies demonstrate that the crude extract of *C. capitulata*, enriched with chlorophenolic glycosides including orcinol glucoside and curculigoside, significantly enhances osteoblast proliferation and differentiation (29). Such pharmacological evidence aligns with traditional medicinal applications, reinforcing its ethnopharmacological significance. Comparative phytochemical and pharmacological investigations of related *Curculigo* species-namely *C. orchioides*, *C. pilosa* and *C. latifolia* have documented a spectrum of bioactivities, including anti-osteoporotic, nephroprotective, antibacterial and antidiabetic effects (17,28). These collective insights contribute to a predictive framework

elucidating the therapeutic potential of *C. capitulata*, underscoring its value as a reservoir of novel allelochemicals and bioactive compounds for drug development.

(a) Whole plant

(b) Leaves

(c) Flowers

(d) Roots and Rhizomes

Figure 1. Different parts of *Curculigo capitulata.* (a) Whole plant, (b) Leaves, (c) Flowers and (d) Roots and Rhizomes

Given its extensive ethnopharmacological significance and diverse phytochemical composition, *C. capitulata* holds considerable potential as a source of novel therapeutic compounds (22). This study focused on the leaves of *Curculigo capitulata*, systematically documenting their organoleptic characteristics, macro- and microscopic anatomy, physicochemical parameters, leaf constants, phytochemical profile, fluorescence behavior and percentage yield. These comprehensive evaluations establish a robust foundation for quality assessment of the raw plant material, essential for its standardized use in medicinal applications. Such meticulous pharmacognostic characterization is critical for advancing *C. capitulata* as a valuable candidate in therapeutic research and development.

MATERIALS AND METHODS

I. Procurement and Authentication of Plant material

Plant specimens were procured in December 2024 from the Botanical Garden, NOIDA. Taxonomic identification and authentication were done by Scientist Dr. Priyanka Ingle, with the identification number (NO.BSI/BGIR/1/TECH./2024/168). The collected leaves were shade-dried, coarsely powdered, sieved using mesh no. 40 and stored in an air-tight container for subsequent analysis. All chemicals and reagents employed were of analytical grade.

II. Organoleptic Properties

Its leaves were examined in accordance with WHO recommendations to ascertain their organoleptic properties and to evaluate their impact on different sensory organs (30). The following attributes were noted and observed: color, taste, texture, odour, size, form and appearance.

III. Macroscopic and Microscopical Analysis

The leaves of *C. capitulata* were subjected to detailed morphological evaluation using both macroscopic and microscopic approaches. For macroscopic analysis, standard methods were employed to assess key leaf characteristics, including type, shape, apex, margin, lamina, base, venation and texture (1,8). Microscopic examination involved preparing transverse sections of the leaf. Specimens were sandwiched between layers of potato and carefully sectioned using a sharp blade. The thin sections obtained were stained with a 0.1% w/v safranin dye solution prepared in distilled water to enhance tissue contrast. The stained slides were then observed and photographed at different magnifications using a Nikon Lab Photo 2 microscope, allowing visualization and documentation of internal anatomical features (13).

IV. Analysis of Leaf Constants

Various leaf constants (Stomatal index and stomatal number), were analyzed following established standardized procedures. These constants provided essential information about the leaf's anatomical and physiological characteristics, aiding in the characterization and understanding of its structure and function. Therefore, they were determined using methods prescribed by the Ayurvedic Pharmacopoeia (31).

V.Physicochemical Analysis

Moisture content and ash values were evaluated following Indian Pharmacopoeia guidelines (9), serving as key indicators of the plant's quality and purity.

VI. Fluorescence Analysis

The fluorescence examination of leaf powder was subjected to variety of chemicals and observed exclusively using visible light and ultraviolet wavelengths (254 nm and 365 nm) to observe distinctive color presentation (11).

VII. Preliminary phytochemical Screening

Different extracts obtained from *C. capitulata* leaves underwent a comprehensive phytochemical analysis. This analysis involved a series of identification tests for the qualitative detection of key phytochemical constituents in the plant sample. The tests aimed to detect the following classes of compounds, namely alkaloids, flavonoids, glycosides, saponins, terpenoids, tannins, steroids and carbohydrates (4,7).

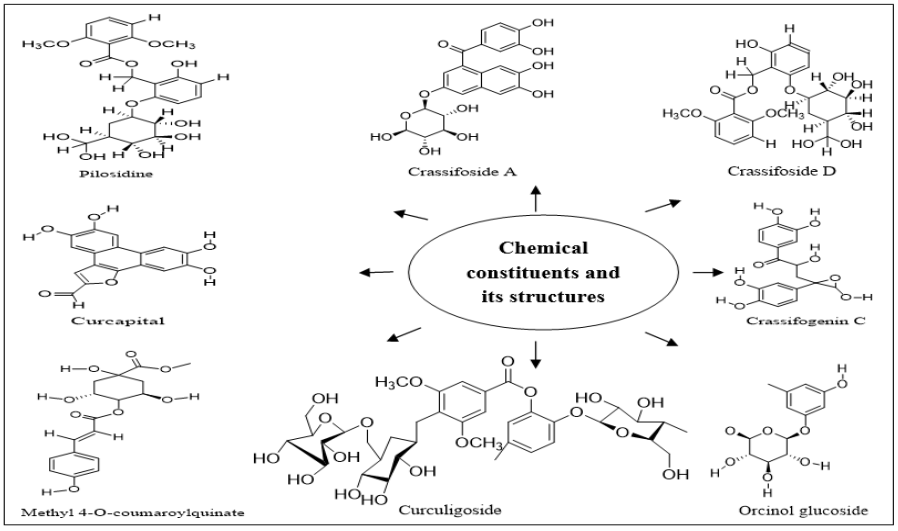

Figure 2. Chemical structures of pharmacologically active Phytoconstituents in *Curculigo capitulata*.

VIII. Extraction and Yield (%)

(i). Preparation of Extract: The collected plant material was washed, shade-dried and coarsely powdered using an electric grinder.

(ii). Extraction Method: A hot extraction technique was used using Soxhlet apparatus. Methanol (100%) served as the extraction solvent. 20 g powdered leaf material was subjected to extraction with 200 ml methanol at 40 °C for 12 h. The solvent containing phytoconstituents was concentrated using a rotary evaporator to remove excess solvent and obtain a semi-solid extract. The final extract was weighed and its yield (%) was determined in relation to initial dry weight of plant material. The extract was subsequently stored at -4 °C in a deep freezer for future pharmacological investigation (6,20).

IX. GC-MS Analysis

The methanolic extract of *Curculigo capitulata* was subjected to GC-MS analysis using Shimadzu's GC-MS QP2010 series with electron impact ionization mode and a BPX5 GC column (length, 30 m; thickness, 0.25 µm; dia, 0.25 mm) to analyze the

samples. Helium gas was used as the carrier gas (99.999 %) at a constant flow rate of 1 mL/min and an injection volume of 1 µL in a split ratio of 10:1. The ion source temperature was 200 °C, while the injector temperature was 250 °C. The oven temperature progressed from 60 °C, maintained for 1 min, to 300 °C and stayed elevated for 30 min at a rate of 15 °C/min. The solvent delay was adjusted from 0 to 45 min and the mass spectrometer was configured in positive electron ionization mode with an ionization energy of 70 eV. A scan interval of fragments from m/z 35 to 500 Da was used. The peak area/total peak area ratio was used to compute the relative percentage of each component. Lab Solution was the programme utilized, while NIST Coin 4.0 (National Institute of Standards and Technology) served as the library (18).

RESULTS AND DISCUSSION

This investigation provides novel pharmacognostic and allelochemical insights of *Curculigo capitulata* (L.) Kuntze offering a scientific basis for its identification and suggesting allelopathic potential based on the presence of relevant secondary metabolites. Key anatomical features such as dorsiventral leaf structure and paracytic stomata served as diagnostic parameters for crude drug standardization. Physicochemical parameters and characteristic fluorescence behavior support the quality and authenticity of the plant material. Preliminary phytochemical screening revealed flavonoids, phenolics and glycosides-compounds known for their ecological and allelopathic relevance. GC-MS analysis identified detailed chemical profile that complements the phytochemical findings and supports allelopathic potential. Although direct allelopathic interactions were not assessed in this study, the occurrence of these metabolites suggests scope for future allelopathy-oriented research. The 15 % methanolic extract yield highlights the richness of bioactive constituents and underscores the species' potential in natural products and ecological applications.

I. Organoleptic Properties

The organoleptic characteristics of *Curculigo capitulata* leaves were recorded in Table 1.

Table 1. Organoleptic characteristics of *C. capitulata.*

S.No.	Property	Description
1.	Colour	Green (for fresh leaves), dull green or brownish (for dried leaves)
2.	Odour	Mild, characteristic or slightly earthy aroma
3.	Taste	Bitter or slightly astringent
4.	Texture	Fibrous
5.	Shape	Leaves are typically lanceolate or elongated with pointed tips
6.	Size	Medium-sized leaves (usually 10-15 cm wide)
7.	Appearance	Fresh leaves appear glossy, slightly waxy; dried leaves brittle and rough

II. Macroscopic and Microscopic Analysis

The leaves of *Curculigo capitulata* were large, simple and basal, exhibiting an elliptic-lanceolate to sub-oblong form with a distinctly ribbed or folded appearance along the longitudinal axis. A perennial herb, approximately 0.6-1 m in height, it features a tuberous rhizome and a bulbous stem. Leaves were simple, about 30-60 × 10-15 cm, with an elliptic-lanceolate to sub-oblong blade that is longitudinally folded or ribbed and papery in texture. The apex was long and pointed, margins entire, and the petiole is long (ca. 20-50 cm), deeply grooved on its upper surface. Flowers were yellow, arranged in pedunculate heads measuring about 2.5-5 cm across, densely flowered, nodding and borne on peduncles 10-20 cm long, brown-villous at the base.

A transverse section of the leaf showed a dorsiventral configuration (Figure 3). The adaxial (upper) and abaxial (lower) epidermis were composed of a single layer of compact, rectangular cells covered by a thin cuticular layer. Both surfaces bear unicellular to multicellular trichomes, either glandular or non-glandular, more prominent on the lower side. A distinct separation of the mesophyll into palisade and spongy parenchymatous layers was observed. Palisade cells appear as elongated, in one to two layers beneath the upper epidermis; spongy cells are rounded, loosely packed with intercellular spaces and chloroplast-bearing. A centrally placed prominent vascular bundle was present in the midrib area, showing a collateral arrangement-xylem towards the upper epidermis and phloem on the lower side-surrounded by a parenchymatous bundle sheath. The midrib thickens due to mechanical tissue and vascular components.

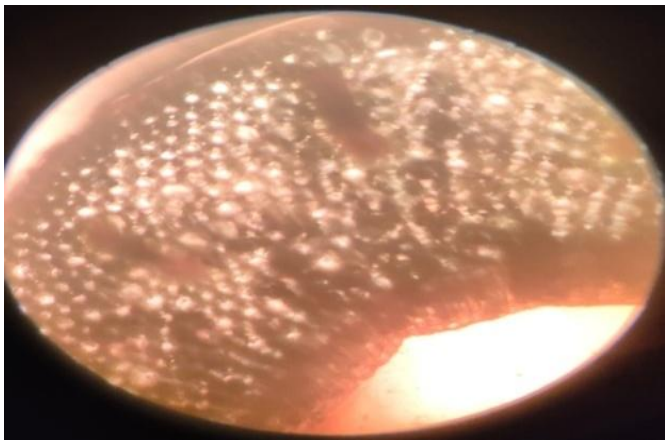

Figure 3. Transverse section of leaf of *C. capitulata* viewed at 10*10X showing Epidermis, Parenchymatous Tissue, Xylem Vessels, Phloem Tissue, Chollenchymatous Tissue and Vascular Bundles.

III. Leaf Constants

The observed leaf constant parameters were summarized in Table 2. Paracytic stomata were present on both adaxial and abaxial surfaces of the leaf. The stomatal numbers on the adaxial surface were7.16 ± 0.2**,** while on the abaxial surface, these were 9.66 ± 0.5. The stomatal index was calculated as 14.27 ± 0.07 **%** on the adaxial surface and 19.32 ± 0.1 %

on the abaxial surface, indicating a higher stomatal density on the lower surface of the leaf (Table 2).

Table 2. Leaf constants of *C. capitulata*

S.No.	Leaf Constants	Values (Mean ± SD)
1.	Stomatal number (Adaxial Surface)	7.16 ± 0.2
2.	Stomatal number (Abaxial Surface)	9.66 ± 0.5
3.	Stomatal index (Adaxial Surface)	14.27 ± 0.07
4.	Stomatal index (Abaxial Surface)	19.32 ± 0.1

IV. Physicochemical Analysis

The physicochemical parameters of the leaf samples were illustrated in Figure 4 and expressed as mean ± standard deviation (w/w %). The moisture content was 6.8 ± 0.2 %, total ash content was 8.3 ± 0.2 %, acid-insoluble ash was 1.0 ± 0.5 % and water-soluble ash was 2.5 ± 0.5 %. These findings provide essential baseline data for quality control and standardization of the plant material (Figure 4).

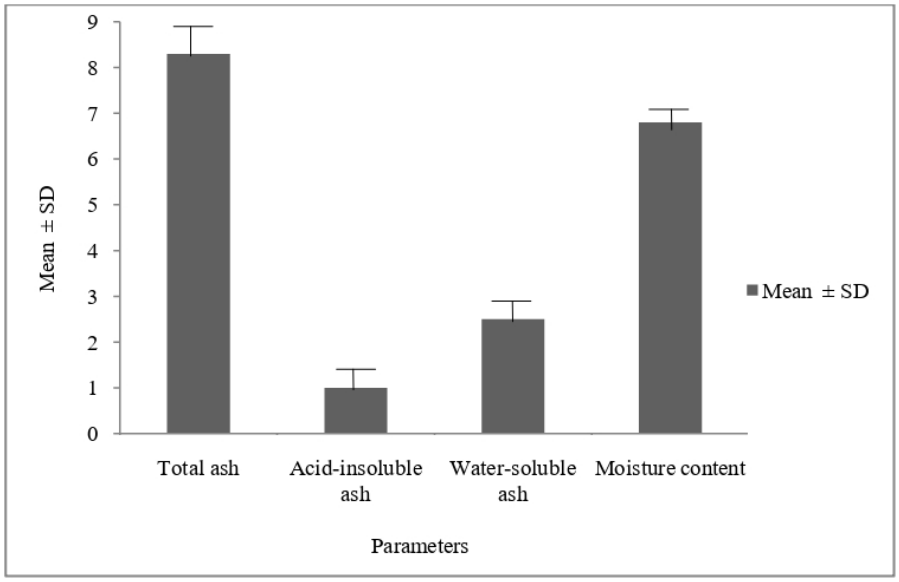

Figure 4. Mean ± standard deviation (w/w %) of physicochemical properties of leaf samples (n : 3). The moisture content was approximately 6.8 ± 0.2 %, total ash value 8.3 ± 0.2 %, acid insoluble ash 1.0 ± 0.5 % and water soluble ash 2.5 ± 0.5 %. Error bars represent the standard deviation. All values are expressed as weight/weight percentage (w/w %).

V. Preliminary phytochemical Screening

A preliminary phytochemical screening of different solvent extracts of the leaves was done to identify primary and secondary metabolites (Table 3). Among the tested extracts, the methanolic extract exhibited a broad spectrum of phytoconstituents such as phenolics,

terpenoids, alkaloids, flavonoids and glycosides indicating its potential for further pharmacological investigation (Table 3).

Table 3. Qualitative Phytochemical Screening of *Curculigo capitulata* in Different Solvents

Phytochemical	Test Name	Ethanol	Methanol	n-Hexane	Diethyl Ether	Hydro-alcoholic	Water
Alkaloids	Wagner's Test	+	+	-	-	+	+
	Mayer's Test	+	+	-	+	+	+
Phenols	Ferric Chloride Test	+	+++	+	-	+	+
Flavonoids	Shinoda's Test	++	++	-	+	++	+
Carbohydrates	Molisch's Test	+	+	-	-	-	+
Reducing Sugars	Fehling's Test	-	++	+	-	+	+
	Benedict's Test	+	+	-	-	-	-
Tannins	Ferric Chloride Test	+	+	+	-	-	+
Saponins	Foam Test	-	-	-	-	+	+
Glycosides	Keller–Killiani Test	+	++	+	+	+	-
	Borntrager's Test	+	+	-	-	-	+
Terpenoids	Salkowski's Test	+	++	-	+	-	-

+++Ve:strongly present; ++Ve:moderately present; +Ve:present; –Ve: absent.

VI. Fluorescence Analysis

The powdered leaf material was subjected to fluorescence analysis under visible light and ultraviolet light at wavelengths of 254 nm and 366 nm, following treatment with different chemical reagents. The results were tabulated in Table 4**.** The leaf powder exhibited distinct colour changes under different lighting conditions, potentially indicating the presence of diverse phytochemical constituents (Table 4).

Table 4. Fluorescence analysis of *C. capitulata* powder

Solvent used	Visible light	UV(254 nm)	UV(366 nm)
Saturated Picric Acid	Yellowish brown	Dark yellow	Bright yellow
Nitric acid	Dark orange	Yellow	Bright yellow
Hydrochloric Acid	Yellowish brown	Greenish black	Dull green
Sulphuric Acid	Dark reddish brown	Dull brown	Green
Iodine Solution	Brown	Dark brown	Pale yellow
Powder as such	No change	No change	No change
Methanol	Light yellow	Green	Bright green
Sodium Hydroxide	Dark brown	Green	Green
Acetic Acid glacial	Light brown	Yellowish green	Pale yellow
Ammonia	Pale brown	No change	No change

VII. Yield (%)

Dried parts of*C. capitulata*were extracted using methanol as a solvent in a Soxhlet apparatus.The dried extract was weighed and yield (%) was determined as under:

$$(\%)\ \text{Yield}\ (\%) = \frac{\text{Weight of plant extract}}{\text{Weight of dried plant material}} \times 100$$

Using the above formula, the calculated yield (%) was 15 % w/w on dry weight basis.

VIII. GC-MS Analysis

GC-MS profile of the hydro-methanolic extract of *Curculigo capitulata* revealed diverse phytochemicals, including carotenoids, alkaloids, phenolic glycosides and lignan-type compounds. Major constituents, such as orcinol glucoside, 2,6-dimethoxybenzoic acid and ψ,ψ-carotene derivatives, were listed **(**Table 5**)** and the corresponding chromatogram was shown **(**Figure 5**).** These bioactive molecules support the plant's potential for medicinal applications.

Table 5. Phytoconstituents of *Curculigo capitulata* identified by GC-MS analysis

S. No.	Name of the compound	RT	PP (%)	Mol. Weight (g/mol)	Mol. Formula	Putative Identification / Structure
1.	ψ,ψ-Carotene,1,1′,2,2′-tetrahydro-1,1′-dimethoxy	26.800	6.045	601.0	$C_{42}H_{64}O_2$	Carotenoid derivative
	Cholestane, 3,5-dichloro-6-nitro-, (3a,5a,5a)-	-	-	456.6	$C_{27}H_{45}Cl_2NO_2$	Halogenated steroid
	ψ,ψ-Carotene,3,4-didehydro-1,2,7′,8′-tetrahydro-1-methoxy-2-oxo	-	-	582.9	$C_{41}H_{58}O_2$	Oxidized carotenoid
	9-desoxo-9-x-acetoxy-3,8,12-tri-O-acetyl-lingo	-	-	36.66	$C_{28}H_{40}O_{39}$	Acetylated lignan derivative
	(5,6,7-Triacetoxy-4β,8-dimethyl-2-oxo-tetradecahydro-phenanthren-1-yl)-acetic acid, methyl ester	-	-	480.5	$C_{32}H_{36}O_9$	Acetylated phenanthrene derivative
2.	Prosta-5,13-dien-1-oic acid, 9,11,15-tris[(trimethylsilyl)oxy]-, trimethylsilyl ester (5Z,9α,11α,13E,15S)	32.488	2.187	643.2	$C_{32}H_{66}O_5Si_4$	Trimethylsilyl ether of prostaglandin
	(25S)-3β-Acetoxy-5α,22β-spirost-9(11)-en-12β-ol	-	-	472.27	$C_{29}H_{44}O_5$	Steroidal saponin
	Cholest-2-ene-2-carbothionic acid, 3-hydroxy-, O-ethyl ester (5α)	-	-	474.8	$C_{30}H_{50}O_2S$	Sulfur-containing sterol
3.	1,3-Dichloro-1,3-bis(norbornadien-2-yl)-1,3-bis(3-trimethylsilylpropyl) disiloxane	32.349	1.634	NR	NR	Siloxane derivative
	L-Valine, N-[N,O-bis(2,4-dinitrophenyl)-L-tyrosyl]-, methyl ester	-	-	117.15	$C_5H_{11}NO_2$	Amino acid ester derivative
4.	Orcinol glucoside	28.20	7.341	413.8	-	Phenolic glycoside
5.	2,6-Dimethoxybenzoic acid	27.40	6.802	378.6	-	Benzoic acid derivative
6.	Isocurculigenin	30.13	3.625	612.5	-	Lignan-like compound (Isoliquiritigenin type)
7.	Pilosidine	31.45	5.345	428.9	-	Hexahydropyridine alkaloid

RT: Retention Time (Min), PP %: Peak percentage, NR: Not reported

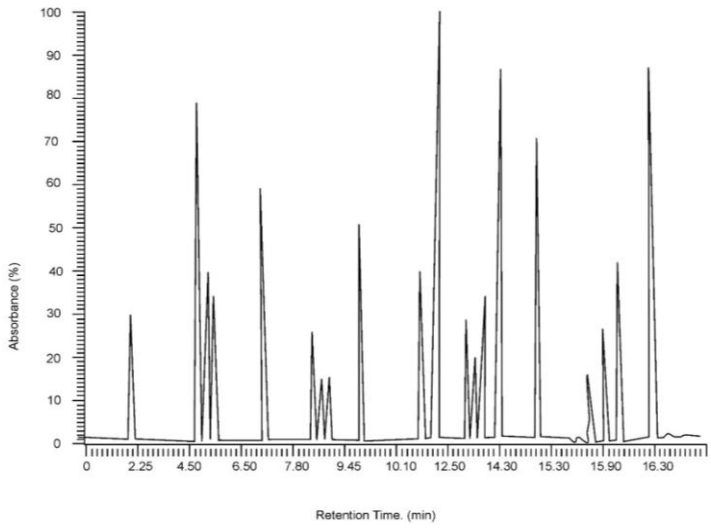

Figure 5. GC-MS chromatogram of the *Curculigo capitulata* methanol extract

CONCLUSIONS

This study provided a comprehensive pharmacognostic and physicochemical characterization of *Curculigo capitulata* leaves, establishing reliable pharmacognostic markersfor its identification, authentication and standardization. Microscopic features such as dorsiventral leaf structure and paracytic stomata, along with consistent physicochemical data and characteristic fluorescence patterns, served as dependable markers for crude drug quality assessment. The detection of diverse bioactive phytoconstituents including flavonoids, alkaloids, glycosides and phenolics reflects the chemical richness of the species. The GC-MS analysis of the methanolic extract revealed the presence of several important phytoconstituents, indicating the plant's potential therapeutic value. These findings reinforce the pharmacognostic profile of *Curculigo capitulata* and form a valuable foundation for future phytochemical and pharmacological investigations. Future research should focus on the isolation and detailed characterization of bioactive constituents, along with comprehensive evaluation of their pharmacological activities, to validate the medicinal potential of this species and promote its use in evidence-based phytotherapeutic formulations.

AUTHOR'S CONTRIBUTION

In this research, AG, performed all the experimental work, wrote the manuscript and compiled the results. SD, reviewed the manuscript, analyzed the results. AM, conducted the systematic evaluation and provided conclusion. The final version of the manuscript received approval from all contributing authors.

DECLARATION

The authors declare that the review paper contains table and figure are prepared originally and all references are cited throughout the manuscript.

CONFLICT OF INTEREST

None

ETHICAL APPROVAL

This manuscript did not involve any use of animals and human, hence, no ethical approval is required from the concerned committee.

ACKNOWLEDGEMENTS

The authors warmly thank the Department of pharmacology, Noida Institute of Engineering and Technology (Pharmacy Institute) for their valuable help, facilities and offered services.

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