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Provision of Some Useful Herbal Pharmacopoeia Standards for the Leaf of *Terminalia mantaly* H. Perrier (Combretaceace) [Madagascar Almond Tree]

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ABSTRACT

Terminalia mantaly H. Perrier (Combretaceae) has several medicinal uses, but with limited data on quality control parameters. Hence, this study was designed to help establish some quality control parameters that are useful for accurate identification, standardization, and the development of a monograph. Pharmacognostic evaluation was done using standard methods of analyses; while chromatographic profiling was done using Gas Chromatography–Mass Spectrometry (GC–MS) and High Performance Liquid Chromatography (HPLC) methods. Macroscopic examination revealed that the leaf is obovate, had obtuse apex, symmetrical base, entire margin, and smooth surface. Microscopical examination showed dorsiventral tissue arrangement, presence of anisocytic stomata, adaxial straight walled epidermal cell, abaxial slightly wavy epidermal cell wall and calcium oxalate crystals. Chemomicroscopy showed the presence of fixed oil, lignin, phenolics, proteins, cellulose and starch, in the powdered leaf. Proximate composition of the leaf was; moisture content (8.98%), total ash (7.40%), crude fat (7.41%), protein (31.07%), crude fiber (4.86%) and carbohydrate (40.28%). Elemental analysis revealed calcium as the most dominant mineral. Phytochemical screening showed the presence of glycosides, flavonoids, tannins, saponins, and terpenoids. GC – MS profiling identified twenty (20) bioactive constituents, with 9 - octadecanamide, undecane, 1 – undecene – 11 - nitro, tetradecanamide, and oxirane, being the most abundant. HPLC analysis detected twenty-three (23) compounds, of which quercetin, caryophyllene, gallic acid, corilagin, and casuarin, were dominant. In conclusion, essential herbal diagnostic markers for the authentication, quality assessment, and standardization of *T. mantaly* leaf have been provided. These data could be used for monograph development, for the leaf of *T. mantaly*.

Keywords: *Terminalia mantaly*, Pharmacognostic Evaluation, Phytochemicals, Bioactive Constituents, GC – MS Profiling.

Introduction

The predilection for herbal therapy in treating various disorders extends back millennia, with an increasing tendency in its utilization in both poor nations with restricted access to contemporary healthcare facilities, and industrialized countries, due to individuals' understanding of their own needs (Busia, 2024). About 75% of the medical requirements in the developing world are fulfilled by over six thousand (6,000) plants utilized in traditional, folk, and herbal medicine in India (Bauer and Tittel, 1996). These plants are known to contain numerous components, some of which are present in very little quantities. These components present in minute quantities in plants are called secondary plant metabolites or phytochemical constituents. They are responsible for the use of these plants in the treatment of various ailments. In order to ensure the safety, efficacy and quality of these plants when used, there is a need for the standardization of herbs and herbal medicines. Standardization entails the establishment of a framework of regulations or inherent characteristics, uniform criteria, and recognized subjective and quantitative metrics that ensure quality, adequacy, safety, and reproducibility (Pathrikar *et al*., 2025).

Some quality control parameters for establishing the inherent characteristics of plants include; macro- and microscopical examinations, chemomicroscopy, phytochemical screening, proximate composition, elemental analysis, chromatographic profiling using

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High performance liquid chromatography (HPLC) and gas chromatography - mass spectrometry (GC-MS). One of such plants frequently used in ethnomedicine that is of interest in this study is *Terminalia mantaly.*

T. mantaly H. Perrier belongs to the Combretaceae family of flowering plants. It's classified under the order Myrtales, and is occasionally known as the "White mangrove" family. Combretaceae family consists of more than twenty (20) genera and six hundred (600) species of trees, shrubs, and plants; predominantly located in tropical and subtropical climates, particularly in Africa and Brazil (de Morais Lima *et al*., 2012). *Combretum* and *Terminalia* are the largest genera, comprising about three hundred (300) and two hundred (200) species, respectively. The Latin term "Terminus," from which "*Terminalia"* is derived, signifies that the leaves are located at the end of the branch. *T. mantaly* is indigenous to India, Madagascar, and several tropical locations (Zhang *et al*., 2019; Ewa *et al*., 2024). The root system is extensive, typically situated near pavements and structures. The tree trunk ascends vertically to a height of 20 - 25 m, often straight, with a trunk diameter of 30 - 60 cm. The tree features a distinctly tiered upright stem, and horizontal branches that create a pagoda-like crown. The plant's leaves are typically organized in whorls, measuring 4 - 6 cm in length, with a glossy and leathery texture, characterized by a vivid green hue (Green Cover Initiative, 2024). The plants yield diminutive, creamy white or yellow blooms, approximately 0.5 cm in diameter, and generate little, winged fruits measuring about 2 - 3 cm in length. They are rarely observed in arboreal gardens. Economically, the tree's bark is used for dyeing due to the tannins it contains (Ewa *et al*., 2024); while the wood is utilized in construction and industrial purposes due to its durability, strength, and longevity **(**Omole and Moshood, 2014; Ogunjobi *et al*., 2021) . Research indicates that the extract from the leaves, stem, and bark of *T. mantaly* contains phytochemicals with notable antimicrobial, antioxidant, antiplasmodial, and toxicological properties (McGam *et al*., 2001; Tchuenmogne *et al*., 2017; Mbouna *et al*., 2018; Tali *et al*., 2020; Yunusa *et al*., 2024). Due to the limited data available on quality control parameters needed for the correct identification of this plant, this study was designed to evaluate some pharmacopeia standards for the leaf of *T. mantaly* that will help for its' accurate identification. This is especially beneficial in averting the substitution and adulteration of the plant, given its significant application in traditional medicine.

Materials and Methods

Plant collection, authentication and preparation

The leaves of the plant were harvested from a cultivated tree growing in the premises of the Faculty of Pharmacy, University of Benin, in Egor Local Government Area of Edo State on April 16th, 2025. They were taken to the Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Benin City; for plant identification and authentication. It was assigned a voucher specimen number of UBH-T294 by a taxonomist, Prof. H. A. Akinnibosun.

Afterwards, the plant was air-dried under shade for seven (7) days, before it was placed into a hot air oven at 40ºC for 45 minutes. Then it was milled with an electric miller to a powdered form and stored in an air-tight container, at room temperature (25 ± 2^{O}C), for subsequent use.

Preparation of the leaf extract

The phytochemicals/bioactive constituents of the powdered leaf (1050 g) of *T. mantaly* was extracted with methanol using a Soxhlet extractor at 65°C, to get the methanol extract (Uwumarongie and Emmanuel, 2026). A rotary evaporator was used to concentrate the extract obtained; and then, the residual solvent was completely removed using previously weighed evaporating dishes, on a thermostatically controlled water bath maintained at 65°C.

Upon extraction of the powdered leaf with methanol, a total of 293.7 g of the extract was obtained. A little quantity (0.5 g) of the extract was used for the GC-MS analysis, while 10 g of the extract was used for HPLC analysis.

The remaining dried extract was stored or preserved in a labelled wide-mouth transparent bottle wrapped with aluminium foil, in a refrigerator until needed for analysis (Uwumarongie and Emmanuel, 2026) or use in other biological and microbiological experiments.

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Pharmacognostic studies

This includes various qualitative (macroscopy, microscopy, chemomicroscopy, and phytochemical screening) and quantitative (proximate analysis, elemental analysis, gas chromatography – mass spectrometry and high performance liquid chromatography) studies (Chakole *et al*., 2024).

Macroscopy

The fresh plant leaf was examined for its condition, margin, apex, odour, size, petiole, composition, shape, lamina base, surface colour, venation, taste, texture and leaf base characteristics (Wallis, 1985; Evans, 2009).

Microscopy

The powdered leaf of *T. mantaly* was used to carry out microscopical tests using the method of Evans (2009). The sample was cleared in chloralhydrate, mounted with glycerin and observed under a binocular compound microscope for the presence or absence and type of calcium oxalate crystals, epidermal cell wall, stomata and trichomes (epidermal hairs).

The transverse section through the midrib and lamina of the fresh leaf was also obtained, mounted and observed (Uwumarongie and Oyiana, 2017).

These were used to evaluate the plant material and the characteristic diagnostic features observed were noted.

Chemomicroscopy

The powdered leaves of *T. mantaly* were treated with various reagents respectively on separate glass slides, mounted and examined for the presence of cellulose, fixed oil, lignin, mucilage, phenolics, protein, and starch; using the methods described by Khandelwal (2008) and Evans (2009).

Proximate analysis

This involved the determination of the total ash, moisture, crude fibre, fat, protein, and carbohydrate contents for the powdered leaf, using standard methods (Pearson, 1976; Osborne and Voogt, 1978; Muller and Tobin, 1980; AOAC, 1984).

Elemental analysis

The method of Isola *et al*. (2025) was used with a little modification. Here, the X – ray fluorescence (XRF) method of elemental analysis was used. The sample cup was cleaned and the filter was fixed into the cup. The sample was placed into the sample cup to cover the filter at the bottom to at least 3 mm thickness. The instrument was turned on and allowed to warm up for 30 min. A method for elemental analysis was selected (measurement of elemental composition); the sample's identity was labelled in the position of selected sample; and reading analysis was accepted. Upon pressing the start button, the instrument rotated to the sample's location on the tray for X-ray analysis, lasting about 6 - 7 min. Subsequently, the X-ray was turned off and the intensities were converted into concentrations (in mg/kg and not percentage). Ultimately, the results were printed out.

Phytochemical screening

Phytochemical tests were carried out on the extract of the powdered leaf, to confirm the presence/absence of alkaloids, anthracene derivatives, glycosides, cyanogenetic glycosides, phenolic compounds, saponins, steroids, and terpenoids; by using standard phytochemical procedures (Harborne, 1973; Brain and Turner, 1975; Bruneton, 1999; Sofowora, 2008, Evans, 2009).

Gas chromatography - mass spectrometry (GC-MS)

The methanol extract of *T. mantaly* underwent GC-MS analysis using a Shimadzu Japan GC-MS - QP2010 Plus equipment, with a column oven set at 60°C. The temperature program ranged from 60 to 280°C, initially held at 60°C for 0 min, then increased to 120°C for 2 min at a rate of 15°C/min, and finally reached 280°C for an additional 2 min at the same rate. The injection temperature was maintained at 200°C. Helium served as the carrier gas, operating at a pressure of 21.9 kPa and a flow rate of 6.2 ml/min. The column flow was 1.61 ml/min, injection was performed in split mode and flow control was regulated based on linear velocity. Purge flow was set at 3.0 ml/min and the split ratio was 1.0. Additionally, the ion source temperature was set to 200°C, with the interface temperature at 250°C. Equilibration time was 1.0 minute and solvent cut time was 1.50 minutes.

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The detector gain was configured at 0.96 kV + 0.00 kV, operating in relative gain mode with a threshold of 1000 (Uwumarongie *et al*., 2018). For mass spectrometry, the analysis began at 2.0 minutes and concluded at 17 minutes, with an event time of 0.5 seconds and a scan speed of 1428. The mass range spanned from m/z 45 to m/z 700 (Uwumarongie *et al*., 2018). Furthermore, the mass spectrometer was integrated with a computer that accessed mass spectra data from a NIST Ver2.1 MS data library, enabling the identification of compounds present in the methanol extracts through computer searches and comparison with the GC-MS-obtained spectrum.

High performance liquid chromatography (HPLC)

A Shimadzu (Nexera Mx) type HPLC equipment with column (ubondapak C18, 100mm long, 4.6mm internal diameter and 7µm thickness), 15 mpa pump pressure and UV 254 nm detector was used to perform the HPLC analysis. Acetonitrile was used in extracting 10 g of the material (methanol extract) and ethyl acetate was then used to stabilize the extract. It was prepared by making up to mark in a 25 mL steward flask. Five milliliters (5mL of the stabilized extract was injected at a flow rate of 2 mL/min. The carrier/mobile phase was a mixture of water and acetonitrile with a ratio of 30:70 (Imade and Osayamwen, 2025).

Results

The results of the macroscopical examination of the leaves are as shown in Table 1 and Figures 1a and 1b. Macroscopically, the leaves were fresh in condition, simple in composition with an average length of 4.9 cm and an average breath of 2.1cm, and had an obtuse apex, symmetrical base and reticulate venation.

Table 1: Macroscopical / Organoleptic characteristics of *T. mantaly* leaves

S/N	Plant character	Description
1.	Condition	Fresh
2.	Surface colour	Upper surface: Dark Green Lower surface: Light Green
3.	Margin	Entire
4.	Apex	Obtuse
5.	Odor	Odourless
6.	Size	Average Length: 4.9cm Average breadth: 2.1cm
7.	Petiole	Petiolated
8.	Composition	Simple leaf
9.	Shape	Obovate
11.	Lamina base	Symmetrical
12.	Venation	Reticulate
13.	Taste	Tasteless
14.	Texture	Glabrous

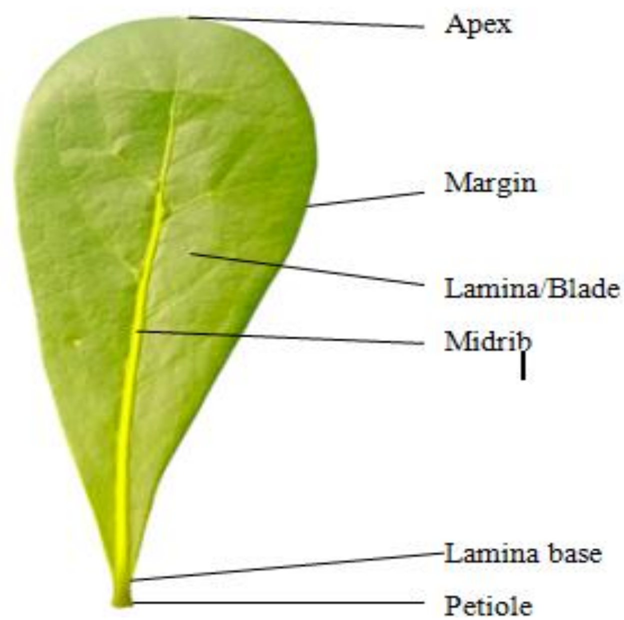

Figure 1a: Macroscopical features of the upper surface of *T. mantaly* leaf

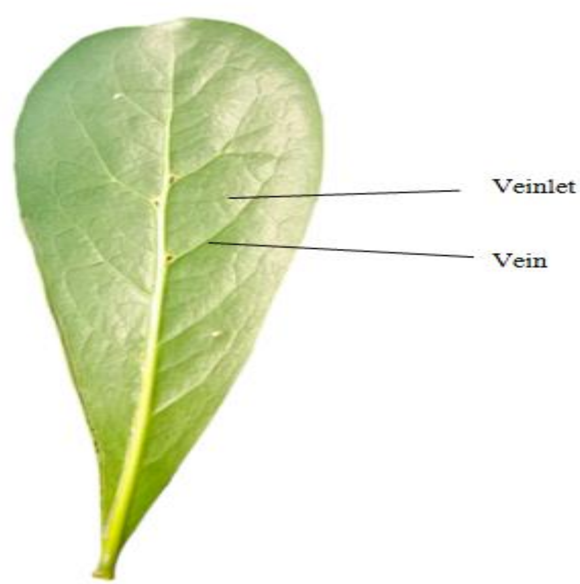

Figure 1b: Macroscopical features of the lower surface of *T. mantaly* leaf

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Microscopy

Microscopical examination of the leaf of *T. mantaly* revealed the presence of important diagnostic characters which include; Anisocytic type of stomata (Figure 2), calcium oxalate crystals (prismatic), straight-walled epidermal cell wall (more on the upper surface) and a slightly wavy epidermal cell wall (more on the lower surface) (Figure 3).

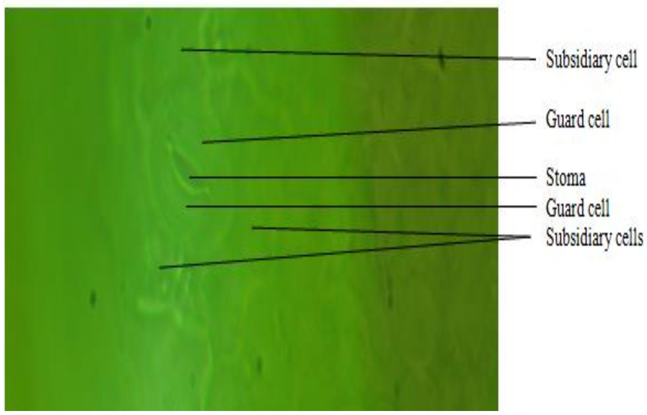

Figure 2: Anisocytic stomata with subsidiary cells, guard cells and stoma in *T. mantaly* leaf (Mag. x 400)

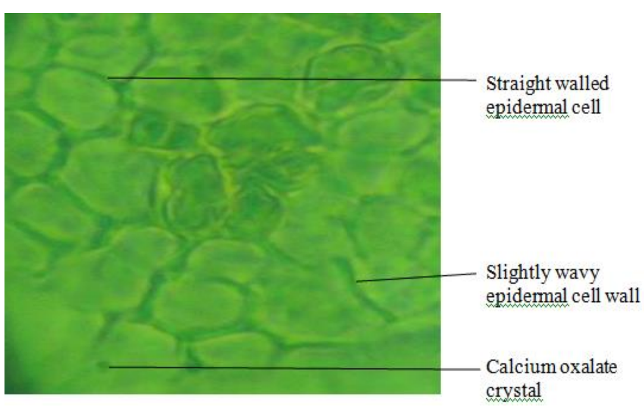

Figure 3: The cleared powdered leaf of *T. mantaly* showing the presence of prismatic calcium oxalate crystals, straight-walled and slightly wavy epidermal cell walls (Mag. x 400)

Transverse section of the leaf through the midrib and lamina revealed a dorsiventral type of tissue arrangement, where the upper palisade layer was interrupted by collenchyma cells at the midrib region. Upon staining with phloroglucinol and concentrated hydrochloric acid solution, the xylem and pericyclic layer were stained red (Figure 4).

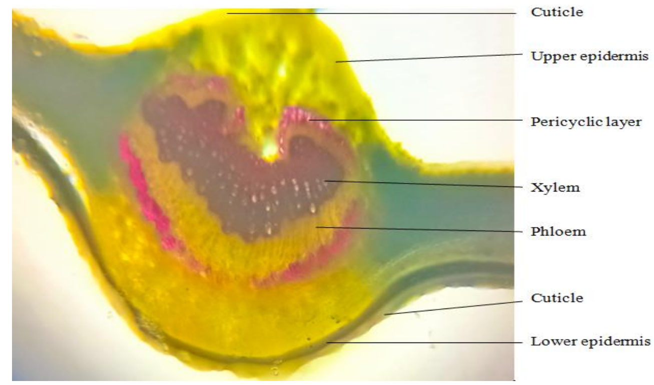

Figure 4: The transverse section of the midrib of *T. mantaly* leaf showing a dorsiventral cell arrangement (Mag. x 400).

Chemomicroscopy

Chemomicroscopical examination of the powdered leaf of *T. mantaly* showed the presence of various ergastic cell contents such as fixed oils, lignin, and phenolics, among others (Table 2).

Table 2: Chemomicroscopical results for *T. mantaly* leaf

Test	Status
Lignin	+
Phenolics	+
Starch	+
Fixed oils	+
Cellulose	+
Protein	+

Key: + = Present and - = Absent

The results obtained for the proximate composition or various nutritive parameters for the powdered leaf are shown in Table 3.

Table 3: Proximate composition of *T. mantaly* leaf

S/N	Parameter	Values (% w/w)
1.	Moisture content	8.98 ± 0.15
2.	Ash content	7.40 ± 0.19
3.	Crude fat	7.41 ± 0.29
4.	Crude fibre	4.86 ± 0.17
5.	Crude protein	31.07 ± 2.35
6.	Carbohydrate	40.28 ± 2.63

Key: n = 3. Values are expressed as Mean ± SEM.

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Elemental analysis

The results obtained using the X- ray fluorescence technique for the elements present in the leaf sample is shown in Table 4. Here, calcium was found to be the most dominant mineral.

Table 4: Elemental content for *T. mantaly* leaf

S/N	Elements	Mean values (mg/kg)
1.	Oxygen	30.54
2.	Aluminum	4.89
3.	Silicon	4.52
4.	Phosphorus	0.46
5.	Sulphur	1.86
6.	Chlorine	7.40
7.	Potassium	11.97
8.	Calcium	36.32
9.	Manganese	0.23
10.	Iron	0.73
11.	Nickel	0.01
12.	Copper	0.29
13.	Zinc	0.08
14.	Lead	0.06
15.	Chromium	0.02
16.	Vanadium	0.03
17.	Barium	0.00
18.	Strontium	0.21
19.	Tantalum	0.00
20.	Magnesium	0.00

Key: n = 3.

Phytochemical analysis

Phytochemical screening of the extract of the powdered leaf showed the presence of useful phytochemical constituents as seen in Table 5.

Table 5: Phytochemical results for the leaf extract of *T. mantaly*

S/N	Constituents	Status
1.	Glycosides	+
2.	Saponins	+
3.	Phenolics	
a.	Tannins	+
b.	Flavonoid	+
4.	Terpenoids	+
5.	Alkaloids	-
6.	Cyanogenetic glycoside	-
7.	Anthracene derivatives	-

Key: + = Present and - = Absent

GC - MS analysis

The result of the gas chromatography – mass spectrometry analysis of the methanol extract of the leaf of *T. mantaly* confirmed the presence of twenty (20) compounds in the extract. The constituents identified are shown in Table 6, with 9-octadecanamide, undecane, tetradecanamide, 1-undecene – 11- nitro, and oxiraneundecanoic acid-3-pentyl; being the most abundant.

Table 6: Constituents, retention times, and % contents of the various components present in the methanol extract of *T. mantaly* leaf

S/N	Constituent	Retention Time (min)	Area	% Content
1.	1,6-Dimethyl[1,2,4] triazolo[3,4-c][1,2,4] triazin5(1H)-one	3.733	35887	0.63
2.	1-Pentanol, 5-(methylenecyclopropyl)-	5.587	6595	0.12
3.	Tetradecane	6.045	12715	0.22
4.	Isobutyl nonyl carbonate	6.228	55079	0.96
5.	Trans-2-Dodecen-1-ol, pentafluoropropionate	6.451	10772	0.19
6.	Undecane	6.663	448384	7.85
7.	Pentane, 3-methylene-	8.094	15550	0.27
8.	4,7,7-Trimethylbicyclo[2.2.1]heptan-2-one O-allyloxime	10.892	12023	0.21
9.	Tridecanoic acid, 4,8,12-trimethyl-, methyl ester	12.385	41622	0.73
10.	2-Propionyl-3,4,5,6-tetrahydropyridine	13.221	7018	0.12

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11.	5,6-Dihydro-2-iso-propenyl-4,4,6-trimethyl-(4H)-1,3-oxazine	14.577	8188	0.14
12.	Heptadecanoic acid, 16-methyl-, methyl ester	14.657	32395	0.57
13.	Cyclopentanethiol, 2-methyl-, trans-	15.006	6836	0.12
14	Decanenitrile	16.453	20783	0.36
15	Hexadecanoic acid, methyl ester	16.711	63594	1.11
16.	1-Undecene, 11-nitro-	18.17	206042	3.61
17.	2,11-Dodecadiene, 4-chloro-	18.296	26995	0.47
18.	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis-	18.359	110632	1.94
19.	Tetradecanamide	19.045	352279	6.17
20.	9-Octadecenamide	20.596	4236126	74.19

HPLC analysis

The result of the high performance liquid chromatography analysis of the leaf extract of *T. mantaly* confirmed the presence of twenty-three (23) compounds in the extract. The compounds include quercetin, caryophyllene, gallic acid, corilagin and casuarin were dominant. The constituents identified are shown in Table 7.

Table 7: Constituents, retention times, peak areas and % contents of the various components present in the leaf

S/N	Constituent	Retention Time (min)	Peak Area	% Content
1.	Quinic Acid	1.366	46.1660	0.77
2.	Adipic Acid	2.633	71.7595	1.20
3.	Caryophyllene	3.700	1596.9775	26.62
4.	Casuarin	5.883	424.0030	7.07
5.	Casuarinin	6.966	41.1550	0.69
6.	Gallic Acid	7.966	688.7430	11.48
7.	Ellagic Acid	9.116	63.5220	1.06
8.	Tellimagrandin	10.150	41.6010	0.69
9.	Beta-Sitosterol	10.500	73.4330	1.22
10.	Stigmasterol	11.116	41.1710	0.69
11.	Shikimic Acid	11.850	94.0960	1.57
12.	Betulinic Acid	12.816	46.0425	0.77
13.	Scopoletin	13.833	54.8770	0.91
14.	Corilagin	15.500	473.6850	7.90
15.	Quercetin	17.233	1808.8700	30.16
16.	Arjungenin	19.166	49.8770	0.83
17.	Penicalagin	20.183	61.8925	1.03
18.	Ursolic Acid	21.066	60.2820	1.00
19.	Lupeol	21.983	53.8210	0.90
20.	Humulene	23.083	43.4140	0.72
21.	Squalene	23.866	46.5670	0.78
22.	Friedelin	24.616	58.1630	0.97
23.	Nerolidol	25.450	57.9660	0.97

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Discussion

Standardization is essential in ensuring the efficacy and safety of medicinal plants, as their compositions often vary and may not always conform to strict pharmacopoeial standards (Evans, 2009). Such variations can significantly affect the potency and consistency of herbal preparations. Establishing standardization protocols therefore enhances both the therapeutic reliability and the commercial value of herbal medicines (Kunle *et al.*, 2012).

This present study has helped to establish some quality control parameters that are useful for accurate identification, standardization, and the development of a monograph. Pharmacognostic evaluation was successfully done using standard methods of analyses; while chromatographic profiling was done using Gas Chromatography–Mass Spectrometry (GC–MS) and High Performance Liquid Chromatography (HPLC) methods.

The identification, purity, and quality of herbal drugs are guided by the reference standards outlined in pharmacopoeias, which specify the analytical, physical, and structural parameters required for quality assurance (Wang *et al*., 2023). Standardization thus represents a systematic process designed to maintain the quantity, quality, and therapeutic efficacy of the bioactive components present in each formulation (Evans, 2009).

According to the World Health Organization (WHO)**,** macroscopic and microscopic evaluation forms a crucial initial step in confirming the identity and purity of medicinal plants (Kunle *et al.*, 2012). Consequently, macroscopic and microscopic studies of both the fresh and powdered leaves of *T. mantaly* were conducted.

These macroscopic and microscopic examinations provided diagnostic features of taxonomic and pharmacognostic importance that are useful in ensuring the genuineness of the plant material and thus, help in preventing adulteration of the plant material. In chemomicroscopic analysis**,** cellular structures, specific chemical reactions, and observable colour changes are of great diagnostic value in identifying powdered plant materials (Evans, 2009). The identification of such materials depends largely on the morphology of tissues, the presence or absence of distinctive cell wall types, and various cell inclusions. The presence of ergastic cell contents such as lignin, fixed oils, and proteins among others, will serve as useful diagnostic parameters in the identification of *T. mantaly.*

The evaluation of physicochemical parameters is essential for determining the purity, quality, and stability of herbal materials (Das *et al*., 2020). These parameters serve as critical quality control indicators in standardizing crude drugs in accordance with pharmacopoeial specifications**.**

Moisture content plays a pivotal role in the processing, storage, and shelf life of plant materials. A low moisture level helps prevent microbial proliferation and enzymatic degradation, thereby enhancing product stability (Otunola and Afolayan, 2018); while high moisture level results in microbial proliferation, enzymatic degradation, and reduction in product stability (Kashyap *et al*., 2022). A moisture content of 8.98% obtained in this study revealed that the plant material could be stored for a long time as the moisture content falls within the specified limit of 8 – 14% for vegetable drugs, specified in the Pharmacopoeia. Ash content represents the total inorganic residue remaining after the complete combustion of organic matter. This reflects the mineral composition of the plant (Das *et al*., 2020). It serves as a quality indicator and a measure of the plant's functional and nutritional properties. The medicinal, nutritional and toxic properties in humans of these various minerals/elements, are well reported (Institute of Medicine (US) Panel on Micronutrients, 2001).

In this study, the X - ray fluorescence (XRF) method used is an analytical technique that is non-destructive, fast, identifies (qualitative) and quantifies (quantitative) the elemental contents of medicinal plant materials. The absence of barium in this plant is beneficial as soluble barium salts are toxic. Only the insoluble barium sulphate ($BaSO_4$) is used for X-ray or CT scans as barium meals. Magnesium, which is an essential element needed for several enzymes and important functions in the body was found to be absent. Lead, a heavy metal and non essential element, was found to be present. This probably maybe due to the close proximity of the cultivated tree to the road, where exhaust fumes from vehicles must have contributed to the 0.06 mg/kg of lead present in the powdered leaf.

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In confirming the genuineness of a plant, any plant claimed to be *T. mantaly*, collected within same axis as that used in this study, must have values not significantly different from that obtained in this study. Crude fat, fiber, protein and carbohydrate contents also help in determining a plant's functional and nutritional properties. Crude fat (lipid) content reflects the concentration of energy-dense compounds that form part of cellular membranes, providing structural integrity and regulating molecular transport (Kashyap *et al*., 2022). Lipids also function as barriers **a**gainst water loss and oxidative damage. Crude fiber is a structural carbohydrate component found in plant cell walls, composed mainly of cellulose, hemicellulose, lignin, and pectin**.** Fiber provides mechanical strength to plant tissues and has nutritional importance due to its role in digestion and metabolic regulation. Crude protein is a fundamental nutritional component, a major energy-yielding and body building macronutrient, in both plant and animal diets (Otunola and Afolayan, 2018). Carbohydrates are well known for their energy yielding capabilities (Uwumarongie and Oyiana, 2017).

Preliminary phytochemical screening revealed a number of secondary metabolites/phytoconstituents. The presence of phytoconstituents such as glycosides, saponins, flavonoids**,** tannins and steroids; as well as their usefulness in the treatment of various ailments, can't be overemphasized and are well documented (Evans, 2009; Uwumarongie and Oyiana, 2017, Wang *et al*., 2023). Alkaloids and cyanogenetic glycosides were absent.

GC-MS is an important technique useful in evaluating the different thermostable phytoconstituents present in various plant extracts. It is a useful analytical research tool for authentication of herbal materials and for quality control of herbal medicines. It provides qualitative and quantitative data. The GC-MS analysis revealed the presence of twenty bioactive compounds, of which the most dominant compounds were 9-Octadecanamide, Undecane,1-Undecene,11-nitro, Tetradecanamide and Oxirane. 9-Octadecanamide which is also called Oleamide, regulates feeding and sexual behaviour; modulates memory function; exerts hypnotic, analgesic, anxiolytic and antioxidant activities; relieves inflammatory pain and improve arthritis (Shin and Kim, 2024).

Undecane, a natural hydrocarbon, has shown promise as an anti-allergic and anti-inflammatory agent for the treatment of various skin ailments (Choi *et al*., 2020).

Tetradecanamide which is a fatty acyl may be involved in the maintenance of the complex tear film and ocular signaling (Nichols *et al*., 2007; Rambaran *et al*., 2022). It also possess antimicrobial (against bacteria and fungi), antibiofilm properties, and has shown promise in improving cognitive and neurological health. The constituent, 1-Undecene, 11-nitro- is also known as 11-nitroundec-1-ene. It is usually used as a reagent in research (organic and pharmaceutical). Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis- which is frequently detected in plant extracts using GC-MS, has anti-arthritis, anticancer, anti-inflammatory and antioxidant activities (Cheng, 2016; Youssef *et al*., 2023; Ikezu and Ikpa, 2024). These and other constituents detected in this study, may act individually or synergistically to account for the various ethnomedicinal uses of the plant.

HPLC like GC-MS, is useful for authentication and quality control of herbal medicines. It also provides qualitative and quantitative data. Unlike GC-MS, it is suitable for thermolabile phytoconstituents. HPLC analysis of this study revealed the presence of twenty-three (23) bioactive compounds belonging to various classes such as coumarins (scopoletin); cyclohexanecarboxylic acid and cyclitol (quinic and shikimic acids); dicarboxylic acid (adipic acid); flavonoids (quercetin); phenolic acid (gallic acid); polyphenol hydrolysable tannins (casuarin, casuarinin, ellagic acid, tellimagrandin, corilagin and penicalagin); phytosterol (β-sitosterol and stigmasterol); triterpenoids (betulinic and ursolic acids, arjungenin, lupeol, squalene and friedelin); and sesquiterpenes (caryophyllene, humulene and nerolidol). The usefulness of these various classes of compounds in the treatment of ailments are well reported in literature.

Conclusion

The various qualitative and quantitative analyses conducted have established some useful pharmacognostic standards that are essential for the accurate identification of the plant. These standards enhance the plant's authenticity, thereby minimizing risks of adulteration and substitution.

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Furthermore, the findings provide valuable data and reference values that can contribute to the development of a herbal monograph, for the plant.

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