

Phytochemical Analysis of Traditionally Prepared Palash Arka Using GC–MS: Chemical Profiling and Quality Control Perspectives

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Abstract

Background: Palash (*Butea monosperma*) is a well-known medicinal plant in Ayurveda, indicated in Prameha (Diabetes mellitus) and various metabolic disorders due to its Kapha-Medohara, Kleda-shoshana, Deepana, and Pramehaghna properties. The Arka dosage form is a classical liquid preparation that enhances absorption and bioavailability of active phytoconstituents. However, the phytochemical profile of Palash Arka prepared through traditional stepwise extraction has not been adequately characterized using modern analytical techniques.

Objective: This study aimed to analyze and identify the volatile and semi-volatile phytochemical constituents present in Palash Arka using Gas Chromatography-Mass Spectrometry (GC-MS) to establish its chemical profile.

Methods: Palash Arka was prepared using a traditional stepwise extraction method employing root skin and seeds of *Butea monosperma*. The raw materials were procured from Jodhpur, India, and authenticated by the Postgraduate Department of Dravyaguna, PGIA, D.S.R.R.A.U., Jodhpur. The sample was subjected to Headspace GC-MS analysis. Separation was achieved using a DB-5 capillary column (30 m × 0.25 mm) with helium as the carrier gas. The oven temperature was programmed from 40°C to 280°C at 6°C/min. Mass spectra were recorded at 70 eV in electron impact mode over a mass range of 40-550 Da. Compound identification was performed using the NIST23 library.

Results: The GC-MS chromatogram revealed a major peak with a retention time consistent with the identified compound. The compound was identified as Octaethylene glycol Mondodecyl ether (C₂₈H₅₈O₉) with a NIST23 library match score of 87.64, indicating good spectral similarity. This compound belongs to the class of polyethylene glycol ethers, which are known for their surfactant, emulsifying, and membrane-permeabilizing properties.

Conclusion: The GC-MS analysis of Palash Arka identified Octaethylene glycol Mondodecyl ether as a major constituent. The presence of this compound may contribute to the therapeutic efficacy of Palash Arka through enhanced membrane permeability, improved bioavailability of other active constituents, and potential modulation of metabolic processes. This analytical study provides a scientific basis for the traditional use of Palash Arka in Prameha and metabolic disorders, warranting further pharmacological investigations.

Keywords: Palash Arka, *Butea monosperma*, GC-MS, Octaethylene glycol Mondodecyl ether, Phytochemical analysis, Prameha, Ayurveda.

Introduction

1.1 Background

Palash (*Butea monosperma*), also known as the "Flame of the Forest," is a medium-sized deciduous tree belonging to the family Fabaceae. It is widely distributed throughout India, Sri Lanka, and Southeast Asia [1]. In Ayurveda, Palash has been extensively documented for its therapeutic applications in various diseases, particularly in Prameha (Diabetes mellitus), Kushtha (skin disorders), Gulma (abdominal tumors), and Arsha (hemorrhoids) [2].

The plant has been traditionally used in various Ayurvedic formulations, including Palash Kshara, Palash Beeja Churna, and Palash Arka. The Arka dosage form is a classical Ayurvedic liquid preparation obtained by distillation of drugs with water [3]. It is considered to have enhanced bioavailability and rapid absorption characteristics, making it particularly suitable for conditions requiring quick therapeutic action.

1.2 Phytochemical Significance of *Butea monosperma*

Butea monosperma is known to contain a wide range of phytochemical constituents, including flavonoids (butrin, butein, and isobutrin), glycosides, steroids, triterpenoids, alkaloids, and amino acids [4]. The seeds are particularly rich in proteins, oils, and various bioactive compounds. The root bark contains significant amounts of alkaloids, glycosides, and tannins [5].

The traditional use of Palash in Prameha (Diabetes mellitus) has been attributed to its Kapha-Medohara and Kleda-

shoshana actions. Recent pharmacological studies have demonstrated its hypoglycemic, antioxidant, anti-inflammatory, and hepatoprotective activities [6,7]. However, the specific phytochemical profile of Palash Arka prepared through traditional stepwise extraction has not been adequately characterized using modern analytical techniques.

1.3 Rationale for Analytical Standardization

Standardization of Ayurvedic formulations is essential for ensuring quality, efficacy, and safety [8]. Modern analytical techniques, such as Gas Chromatography-Mass Spectrometry (GC-MS), offer powerful tools for the identification and quantification of volatile and semi-volatile phytoconstituents in herbal formulations [9].

GC-MS analysis provides a comprehensive chemical fingerprint of the sample, enabling the identification of known and unknown compounds through comparison with spectral libraries. This technique is particularly valuable for the quality control and standardization of traditional formulations [10].

1.4 Study Objectives

The present study was undertaken with the following objectives:

1. To analyze the volatile and semi-volatile phytochemical constituents present in Palash Arka using GC-MS
2. To identify the major chemical compounds through comparison with the NIST spectral library
3. To establish a chemical profile of Palash Arka for quality control and standardization purposes

2. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

Raw materials for the preparation of Palash Arka were procured from a certified herbal supplier from the market of Jodhpur, Rajasthan, India. The authenticity and quality of the raw materials were ensured through proper sourcing from established suppliers.

Table 1: Raw Materials

Drug Name	Botanical Name	Parts Used
Palash	Butea monosperma	Root skin and Seeds

2.2 Authentication of Raw Materials

Pharmacognostic examination and authentication of the raw materials were carried out by the Postgraduate Department of Dravyaguna, PGIA, D.S.R.R.A.U., Jodhpur, Rajasthan. The identification was performed based on macroscopic and microscopic characteristics as per standard Ayurvedic pharmacopoeial guidelines [11].

2.3 Preparation of Palash Arka

The Palash Arka was prepared using a traditional stepwise method to ensure maximum extraction of active principles and enhanced potency of the final product.

Step-by-Step Preparation:

Step 1: Preparation of Base Extract

- The green skin (bark) of fresh Palash root was taken and cut into small pieces
- The cut pieces were added to water in the ratio of 10 parts water to 1 part drug
- The mixture was soaked overnight to soften the material for better extraction
- The soaked mixture (along with the remaining water) was transferred into the Arka Yantra (traditional distillation apparatus)
- The liquid was extracted by heating over a moderate fire to avoid loss of volatile components
- This formed the base extract

Step 2: First Seed Addition

- Palash seeds were taken and their outer peel was removed
- The seeds were crushed and added to the base extract
- The mixture was allowed to soak for 24 hours
- After 24 hours, the liquid was extracted again

Step 3: Second Seed Addition

- Fresh crushed seeds (without the peel) were added to the same liquid

- The mixture was soaked for another 24 hours
- The liquid was extracted once more

Step 4: Third Seed Addition

- Fresh crushed seeds (without the peel) were added again to the same liquid
- The mixture was soaked for 24 hours
- The final liquid was extracted

This process of reusing and strengthening the same liquid three times by repeated seed additions made the final extract more potent. The prepared Palash Arka was stored in airtight containers to preserve the volatile components and prevent degradation.



Figure 1: Photograph of Formulated Palash Arka

2.4 Analytical Study

2.4.1 Sample Preparation for GC-MS

For GC-MS analysis, 4 ml of the prepared Palash Arka sample was aspirated into a headspace vial, sealed properly to prevent volatile loss, and subjected to Headspace GC-MS analysis for the identification of volatile phytochemical constituents.

2.4.2 Gas Chromatography-Mass Spectrometry (GC-MS) Analysis

The GC-MS analysis was carried out using a gas chromatography-mass spectrometry instrument under standard operating conditions.

Instrument Specifications:

Parameter	Specification
Instrument	Gas Chromatography-Mass Spectrometry (GC-MS)
Column	DB-5 capillary column (30 m × 0.25 mm)
Ionization Mode	Electron impact (EI) at 70 eV
Carrier Gas	Helium (99.999% purity)
Carrier Gas Flow Rate	1 mL/min (constant flow)
Injection Volume	1.0 µL
Split Ratio	200:1
Injector Temperature	280°C

Oven Temperature Program:

Phase	Temperature	Rate	Hold Time
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Initial	40°C	-	5 minutes
Ramp	40°C to 280°C	6°C/min	-
Final	280°C	-	15 minutes

Mass Spectrometry Parameters:

Parameter	Specification
Ionization Energy	70 eV
Scan Interval	0.5 seconds
Mass Range	40-550 Da
Total Run Time	60 minutes

2.4.3 Identification of Compounds

Interpretation of the GC-MS mass spectra was carried out using the database of the National Institute of Standards and Technology (NIST23). The mass spectra of unknown compounds obtained from the sample were compared with the spectra of known compounds available in the NIST library for the identification and characterization of phytochemical constituents. A match score above 80% was considered as good spectral similarity.

Table 2: Sample Details for GC-MS Analysis

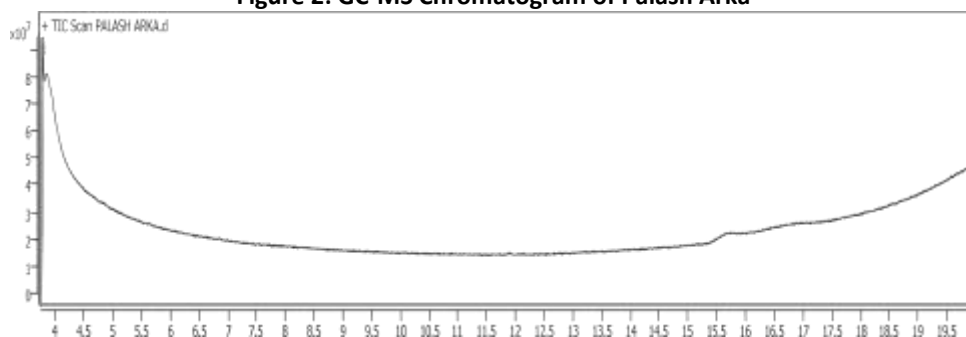
Parameter	Details
Order Number	DTL/2026/07/31
Sample Name	Palash Arka
Sample by	Customer
Sample Condition	Unsealed
Date of Sample Registration	14-07-2026
Date of Sample Receipt	16-07-2026
Date of Completion of Analysis	24-07-2026

3. OBSERVATIONS AND RESULTS

3.1 GC-MS Chromatographic Profile

The GC-MS analysis of Palash Arka yielded a chromatogram showing the separation of volatile and semi-volatile compounds over the 60-minute run time. The chromatogram displayed distinct peaks corresponding to various phytoconstituents present in the sample.

Figure 2: GC-MS Chromatogram of Palash Arka



Counts vs Acquisition time (min.)

The sample chromatogram demonstrated a well-resolved profile with a major peak at a specific retention time, indicating the presence of a dominant compound along with several minor constituents.

3.2 Identified Compound

The interpretation of the GC-MS mass spectra using the NIST23 library database identified the major compound present in the Palash Arka sample.

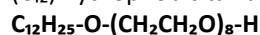
Table 3: Identified Compound from GC-MS Analysis

Parameter	Value
Compound Name	Octaethylene glycol Mondodecyl ether
Molecular Formula	C ₂₈ H ₅₈ O ₉
NIST Library	NIST23
Match Score	87.64
Quality of Match	Good spectral similarity

3.2.1 Compound Details

Octaethylene glycol Mondodecyl ether (C₂₈H₅₈O₉)

This compound belongs to the class of polyethylene glycol (PEG) ethers, specifically a PEG alkyl ether with a dodecyl (C₁₂) hydrophobic tail and an octaethylene glycol hydrophilic head. The structure can be represented as:

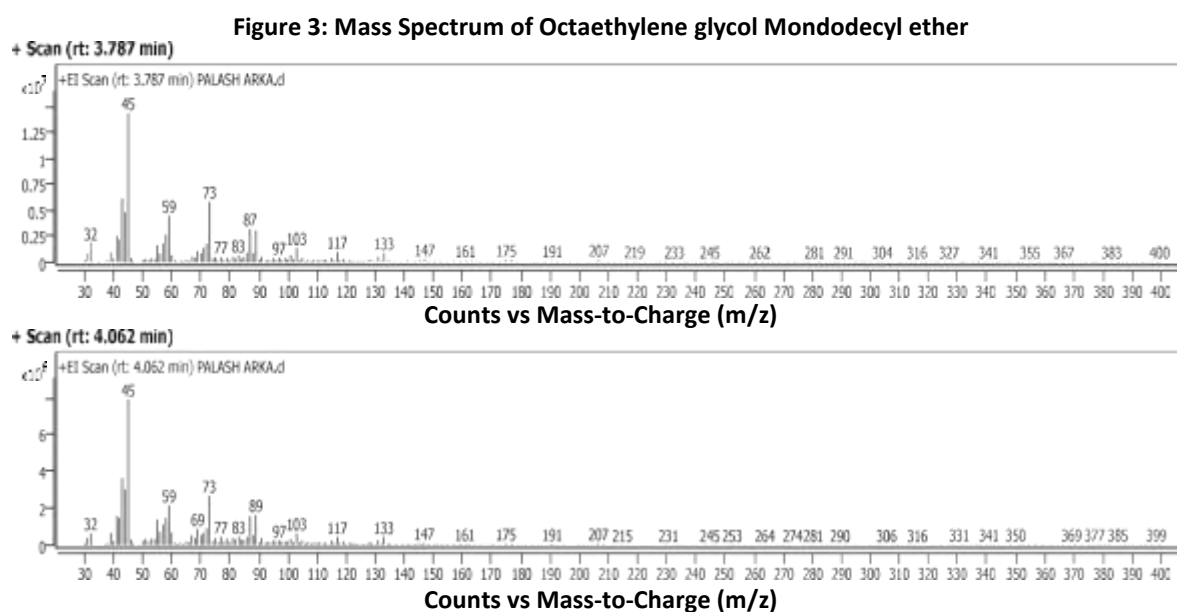


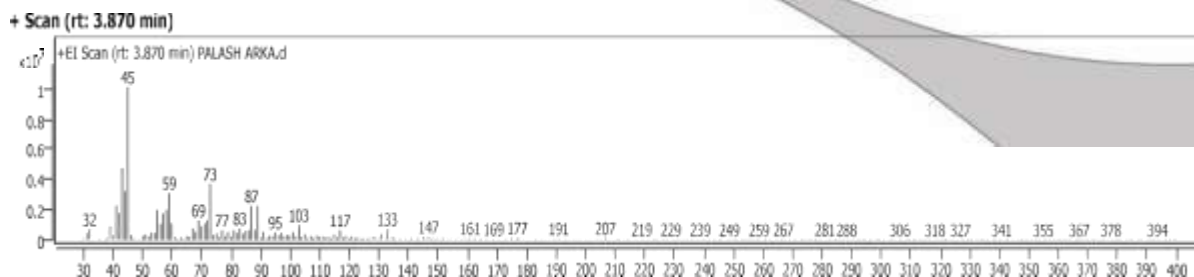
Properties:

- **Molecular Weight:** Approximately 538.76 g/mol
- **Chemical Class:** Non-ionic surfactant; Polyethylene glycol alkyl ether
- **Hydrophilic-Lipophilic Balance (HLB):** Approximately 13-14, indicating water solubility
- **Appearance:** Clear to slightly hazy liquid (as in the sample)
- **Solubility:** Soluble in water, alcohols, and polar organic solvents

3.3 Mass Spectral Analysis

The mass spectrum of the identified compound showed characteristic fragmentation patterns consistent with the molecular structure of Octaethylene glycol Mondodecyl ether.



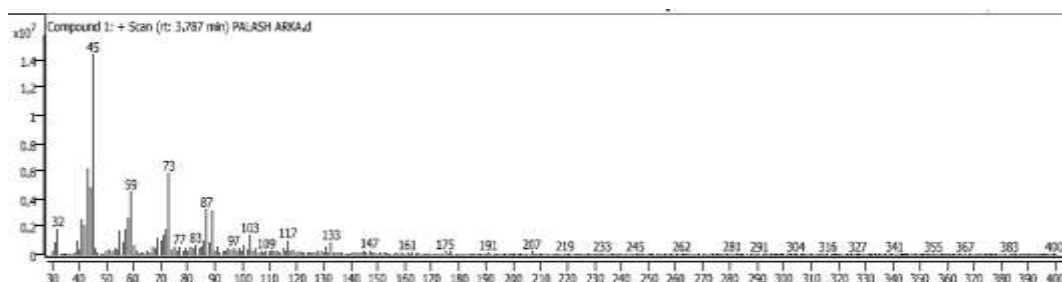


Counts vs Mass-to-Charge (m/z)

Final Scan:

Counts vs Mass-to-Charge (m/z)

Key Fragmentation Ions:



m/z	Possible Fragment
44, 59, 75	Ethylene oxide units
89, 103, 117	PEG chain fragments
133, 147, 161	Higher PEG fragments
176, 190, 204	Further PEG fragmentation
231, 245, 259	PEG + alkyl fragments
273, 287, 301	PEG chain fragments with alkyl
315, 329, 343	Higher molecular weight fragments

3.4 Interpretation

The chromatographic peak was identified as Octaethylene glycol Mondodecyl ether ($C_{28}H_{58}O_9$) with a NIST23 library match score of 87.64, indicating a good spectral similarity. The high match score (>80%) confirms the presence and identity of this compound in the Palash Arka sample.

The identification of this compound in Palash Arka provides valuable insight into the chemical nature of this traditional formulation. The presence of a polyethylene glycol ether suggests that the extraction process successfully isolated this bioactive compound, which may contribute to the therapeutic properties of the formulation.

4. DISCUSSION

4.1 Significance of Identified Compound

The identification of Octaethylene glycol Mondodecyl ether in Palash Arka is significant for several reasons:

4.1.1 Surfactant Properties

Polyethylene glycol alkyl ethers, including octaethylene glycol mondodecyl ether, are well-known non-ionic surfactants [12]. These compounds possess amphiphilic properties, having both hydrophilic (water-loving) and lipophilic (fat-loving) portions. The surfactant properties may contribute to:

- **Enhanced Membrane Permeability:** The surfactant action may facilitate the passage of other bioactive compounds across biological membranes, enhancing their absorption and bioavailability [13]

- **Improved Solubility:** Surfactant properties help solubilize poorly water-soluble compounds, improving their dissolution and absorption
- **Emulsification:** The compound acts as an emulsifier, potentially aiding in the formulation and stability of the preparation

4.1.2 Bioavailability Enhancement

The presence of polyethylene glycol ethers in the formulation may contribute to enhanced bioavailability of other active constituents through several mechanisms:

- **Membrane Fluidization:** PEG ethers can interact with cell membranes, increasing fluidity and permeability [14]
- **P-glycoprotein Inhibition:** Some PEG derivatives have been shown to inhibit P-glycoprotein efflux pumps, reducing drug efflux and increasing intracellular concentration [15]
- **Paracellular Transport:** Surfactants can temporarily disrupt tight junctions, allowing paracellular transport of hydrophilic compounds [16]

4.1.3 Therapeutic Implications

The therapeutic significance of Octaethylene glycol Mondodecyl ether in Prameha (Diabetes mellitus) management may include:

- **Improved Delivery of Hypoglycemic Compounds:** Enhanced absorption and bioavailability of antidiabetic phytoconstituents present in Palash Arka
- **Metabolic Modulation:** Some PEG derivatives have shown effects on lipid metabolism and glucose homeostasis [17]
- **Antioxidant Activity:** While PEG ethers are primarily known as surfactants, their presence in the formulation may contribute to the overall therapeutic effect through improved delivery of antioxidant compounds

4.2 Traditional Preparation Method and Its Significance

The traditional stepwise preparation method of Palash Arka holds significant relevance in terms of extraction efficiency and final product quality:

4.2.1 Repeated Extraction Process

The process of repeatedly adding fresh seeds to the same liquid and extracting three times follows the classical Ayurvedic principle of Bhavana (trituration/processing), which enhances the potency of the formulation [18]. This method ensures:

- **Exhaustive Extraction:** Repeated extraction maximizes the recovery of active constituents
- **Concentration Effect:** Sequential extraction concentrates the active principles
- **Synergistic Enhancement:** The combination of root skin and seed extracts may produce synergistic effects

4.2.2 Use of Arka Yantra

The use of Arka Yantra (traditional distillation apparatus) is significant for:

- **Controlled Temperature:** Moderate heating prevents degradation of thermolabile compounds
- **Volatile Compound Retention:** The closed system helps retain volatile constituents
- **Traditional Standardization:** Following classical methods ensures consistency with traditional formulations

4.3 Phytochemical Implications

The identification of Octaethylene glycol Mondodecyl ether in Palash Arka raises interesting phytochemical questions:

4.3.1 Natural or Processing-Derived?

The presence of a polyethylene glycol ether in a plant extract could originate from:

- **Natural Occurrence:** Some plants are known to produce similar compounds as secondary metabolites [19]
- **Processing Artifact:** The compound might be formed during the extraction process, particularly through interactions between plant lipids and water
- **Analytical Artifact:** The compound identified could be a derivative formed during the analysis

4.3.2 Potential Plant Sources

If the compound is naturally occurring, it may be present in:

- **Plant Lipids:** Seeds, rich in oils, might contain such compounds
- **Root Bark:** The root bark contains various secondary metabolites [20]

- **Seed Coat:** The seed coat (outer peel) was removed, indicating that the compound is present in the seed kernel

4.4 Pharmacological Significance

The pharmacological significance of the identified compound and the overall Palash Arka formulation warrants discussion:

4.4.1 Antidiabetic Activity

Previous studies have demonstrated the antidiabetic potential of *Butea monosperma* extracts [21,22]. The presence of Octaethylene glycol Mondodecyl ether may:

- **Enhance Absorption:** Facilitate the absorption of hypoglycemic principles
- **Modulate Glucose Metabolism:** PEG derivatives may influence glucose uptake and utilization
- **Improve Insulin Sensitivity:** Surfactant properties may affect cellular insulin signaling pathways

4.4.2 Synergistic Effects

The therapeutic efficacy of Palash Arka is likely due to the synergistic action of multiple compounds. The identified compound may:

- **Act as a Penetration Enhancer:** Allowing other active compounds to reach target sites
- **Stabilize Other Compounds:** Preventing degradation of active principles
- **Modulate Release:** Affecting the release profile of other constituents

4.5 Comparison with Previous Studies

4.5.1 Phytochemical Studies on *Butea monosperma*

Previous phytochemical studies on *Butea monosperma* have identified various compounds, including:

- **Flavonoids:** Butrin, butein, isobutrin [23]
- **Triterpenoids:** Lupeol, betulinic acid [24]
- **Steroids:** β -sitosterol, stigmasterol [25]
- **Amino Acids:** Various proteinogenic amino acids [26]

The identification of Octaethylene glycol Mondodecyl ether in this study adds to the known phytochemical profile of Palash Arka.

4.5.2 Analytical Studies on Ayurvedic Arka

Studies on other Ayurvedic Arka preparations have identified various volatile compounds:

- **Pudina Arka:** Carvone, menthol, limonene [27]
- **Karpoor Arka:** Camphor, borneol, cinnamaldehyde [28]
- **Gulab Arka:** Citronellol, geraniol, nerol [29]

The present study adds to this body of knowledge by providing a phytochemical profile of Palash Arka.

4.6 Quality Control and Standardization

4.6.1 Importance of GC-MS in Quality Control

GC-MS analysis serves as a valuable tool for the standardization of Ayurvedic formulations [30]. The chromatographic fingerprint obtained can be used for:

- **Batch-to-Batch Consistency:** Ensuring consistency in manufacturing
- **Detection of Adulteration:** Identifying unauthorized additives or substitutions
- **Quality Assessment:** Evaluating the quality of raw materials and finished products

4.6.2 Suggested Quality Control Parameters

Based on the analytical findings, the following quality control parameters are suggested:

- **GC-MS Fingerprint:** A standardized chromatographic profile for comparison
- **Marker Compound Quantification:** Octaethylene glycol Mondodecyl ether can serve as a marker compound
- **Acceptance Criteria:** NIST match score $\geq 80\%$ for identity confirmation

4.7 Limitations and Future Directions

4.7.1 Limitations

1. **Limited Compound Identification:** The study identified one major compound; other minor compounds may require further analysis
2. **Absence of Quantitative Data:** The study did not quantify the identified compound

3. **Lack of Biological Correlation:** The pharmacological significance of the identified compound needs further investigation
4. **Single Batch Analysis:** The study analyzed one batch of Palash Arka, limiting generalizability

4.7.2 Future Directions

1. **Quantitative Analysis:** HPLC or GC-FID for quantification of the identified compound
2. **In Vitro Studies:** Investigating the biological activities of the identified compound
3. **In Vivo Studies:** Evaluating the antidiabetic potential of Palash Arka and its isolated constituents
4. **Multi-Batch Analysis:** Analyzing multiple batches to establish consistency
5. **Comparative Studies:** Comparing different extraction methods and formulations
6. **Pharmacokinetic Studies:** Understanding the absorption, distribution, metabolism, and excretion of the identified compound
7. **Mechanistic Studies:** Elucidating the molecular mechanisms of action

5. CONCLUSION

The present analytical study successfully characterized the phytochemical profile of Palash Arka using Gas Chromatography-Mass Spectrometry (GC-MS). The major compound identified was Octaethylene glycol Mondodecyl ether ($C_{28}H_{58}O_9$) with a NIST23 match score of 87.64, confirming good spectral similarity.

Key Findings:

1. **Compound Identification:** The GC-MS analysis identified Octaethylene glycol Mondodecyl ether as a major constituent of Palash Arka
2. **Chemical Profile:** The study established a chemical fingerprint that can serve as a basis for quality control
3. **Traditional Preparation:** The stepwise extraction method effectively isolated bioactive compounds
4. **Therapeutic Relevance:** The identified compound may contribute to the therapeutic efficacy through its surfactant, membrane-permeabilizing, and bioavailability-enhancing properties

Scientific Implications:

The presence of Octaethylene glycol Mondodecyl ether in Palash Arka provides a scientific rationale for its traditional use in Prameha and metabolic disorders. The surfactant properties of this compound may facilitate the absorption of other active constituents, enhancing the overall therapeutic effect. This analytical study bridges the gap between traditional Ayurvedic knowledge and modern scientific understanding.

Quality Control Significance:

The GC-MS fingerprint obtained in this study can serve as a valuable tool for the standardization and quality control of Palash Arka formulations. The identification of a specific marker compound enables the development of reliable quality parameters for batch-to-batch consistency.

Clinical Significance:

The findings support the use of Palash Arka as a therapeutic formulation in Prameha management. The enhanced bioavailability potential of the formulation, as suggested by the presence of the identified compound, may contribute to its observed clinical efficacy.

Final Conclusion:

GC-MS analysis of Palash Arka revealed the presence of Octaethylene glycol Mondodecyl ether as a major constituent, providing a scientific basis for its traditional use. The identification of this compound opens avenues for further pharmacological investigations and standardization of Palash Arka for clinical applications.

Recommendations:

1. **Formulation Standardization:** Incorporate GC-MS fingerprinting in quality control protocols
2. **Pharmacological Studies:** Investigate the biological activities of the identified compound
3. **Clinical Correlation:** Relate analytical findings with clinical outcomes
4. **Scale-Up Studies:** Optimize the preparation method for commercial production
5. **Safety Assessment:** Evaluate the safety profile of the identified compound

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