

# Evaluation of Modern Analytical Methods for Quality Control of Some Polyherbal Formulation

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**Abstract:** Polyherbal formulations are increasingly preferred in modern therapeutics due to their synergistic pharmacological effects and enhanced efficacy. However, the lack of rigorous standardization and quality control hinders their global acceptance.

The objective of these research work was to develop a simple, rapid and reliable HPTLC method for standardization for antidiabetic formulation. Development of method carried out by using Gymnemic acid and Berberine as bioactive marker reported to have an antidiabetic activity. Chromatographic analysis was performed using silica gel 60 F254 TLC plate, CAMAG Linomat 5 applicator and solvent system consisting of toluene: ethyl acetate: methanol: formic acid (6:2:1.5:0.5) and CCl<sub>4</sub>: methanol: acetic acid (4:1:0.5). Densitometry scanning performed under reflectance absorbance mode at 360 nm to identify the spot. The R<sub>f</sub> value of gymnemic acid and Berberine was found to be 0.03 and 0.11 respectively. No analytical method has been reported so far associated with polyherbal formulation associated with polyherbal formulation (Mahantak vati). Gymnemic acid and Berberine on antidiabetic activity.

Chromatography (TLC), High Performance Thin Layer Chromatography (HPTLC), Gas Chromatography (GC), and spectroscopic methods such as UV-Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), and Mass Spectrometry (MS) are discussed..

**Keywords:** Polyherbal formulation, marker compounds, HPTLC method development

## I. INTRODUCTION

India is known for its traditional medicinal system-Ayurveda, Siddha, and Unani. Medical systems are found mentioned even in the ancient Vedas and other scriptures. The Ayurvedic concept appeared and developed between 2500 and 500 BC in India. The literal meaning of Ayurveda is “science of life,” because ancient Indian system of health care focused on views of man and his illness. It has been pointed out that the positive health means metabolically well balanced human beings. Ayurveda is also called the “science of longevity” because it offers a complete system to live a long healthy life. It offers programs to rejuvenate the body through diet and nutrition. It offers treatment methods to cure many common diseases such as food allergies, which have few modern treatments. However, one should be aware that Ayurvedic nutrition is not a “magic bullet” system but requires the full participation of the patient to succeed. It is an interactive system that is user-friendly and educational. It teaches the patient to become responsible and self-empowered. Ayurveda is not a nutritional system for those seeking an escape or excuse to further abuse their body or mind. It is a system for empowerment, a system of freedom, and long life. Hence, the modern food habits are affecting the balanced nutrition.

The global demand for traditional and herbal medicines has surged significantly. Among these, polyherbal formulations (PHFs)—which combine two or more medicinal plants—are highly valued in traditional healthcare systems (such as Ayurveda, Unani, and Siddha). This combination is based on the principle of synergism, where the combined herbs enhance overall therapeutic efficacy while often mitigating potential toxicities.



However, ensuring the quality and consistency of these botanical mixtures presents a major scientific challenge. Unlike single-chemical drugs, polyherbal medicines consist of highly complex, variable mixtures of active phytochemicals. The chemical composition of these plants naturally fluctuates depending on geographical source, seasonal variations, harvesting practices, and processing methods. Because of these natural variations, traditional sensory evaluation methods (appearance, odor, and taste) are no longer sufficient to guarantee the authenticity, potency, and safety of a finished product.

To address these challenges, standardization and strict quality control (QC) are essential. The World Health Organization (WHO) Guidelines for Quality Control of Herbal Materials mandate the establishment of objective parameters to verify identity, purity, and active ingredient content.

This is where modern analytical methods play a transformative role. Advanced instrumental techniques allow researchers to move beyond basic pharmacognosy by utilizing chemical fingerprinting and phytomarker-based standardization. These methods provide precise, objective data on the active constituents of the formulation.

### **Introduction of herbal medicines**

Herbal medicines have been used for centuries as an important component of traditional healthcare systems worldwide. In recent years, there has been a significant increase in the use of herbal and plant-based medicines due to their natural origin, perceived safety, affordability, and therapeutic effectiveness. Among these, polyherbal formulations have gained considerable attention because they combine two or more medicinal plants to achieve enhanced therapeutic action through synergistic effects. The concept of polyherbalism is based on the belief that combining multiple herbs can provide greater efficacy and reduced toxicity compared to single-herb formulations. Polyherbal formulations are widely used in various healthcare systems such as Ayurveda, Unani, Siddha, and traditional Chinese medicine for the treatment of numerous diseases including diabetes, liver disorders, inflammation, respiratory conditions, and gastrointestinal diseases. These formulations contain multiple bioactive compounds that act together to produce desired pharmacological effects. However, due to the complex composition of these preparations, maintaining their quality, safety, efficacy, and consistency remains a major challenge. Quality control of polyherbal formulations is a critical aspect in the pharmaceutical industry because variations in plant sources, cultivation practices, harvesting conditions, processing methods, and storage conditions can affect the quality of the final product. Unlike synthetic medicines that contain

a single active ingredient, herbal formulations possess a complex mixture of chemical constituents, making standardization difficult. Therefore, proper quality evaluation and analytical assessment become essential to ensure batch-to-batch consistency and therapeutic effectiveness. Traditional quality assessment methods such as organoleptic evaluation, microscopic examination, and basic physicochemical tests provide preliminary information regarding herbal products. Organoleptic evaluation includes characteristics such as color, odor, taste, and texture, while physicochemical parameters involve moisture content, ash value, extractive value, and pH determination. Though these methods are useful, they often fail to provide complete information regarding the chemical composition and purity of polyherbal products.

With advancements in pharmaceutical and analytical sciences, modern analytical methods have emerged as powerful tools for the quality evaluation and standardization of herbal formulations. These techniques provide accurate, reliable, and reproducible results for the identification and quantification of active constituents, impurities, contaminants, and adulterants present in herbal products. The application of advanced analytical techniques helps in ensuring the authenticity and safety of polyherbal formulations.

### **Challenges in polyherbal product**

Polyherbal formulations refer to medicinal preparations containing a combination of two or more herbs intended to provide synergistic therapeutic effects. The principle of polyherbalism is deeply rooted in traditional medicinal systems, particularly Ayurveda, where combinations of medicinal plants are used to improve efficacy and minimize



toxicity. These formulations may contain several plant extracts with different active constituents that work together to produce enhanced pharmacological activity.

The rationale behind polyherbal formulations is that individual herbs contribute unique therapeutic properties, and their combination creates a synergistic effect that improves treatment outcomes. Compared to single-herb formulations, polyherbal preparations often exhibit better therapeutic efficiency due to multiple mechanisms of action. They are commonly used in managing diseases such as diabetes mellitus, arthritis, liver disorders, hypertension, obesity, respiratory diseases, gastrointestinal disturbances, and various chronic conditions.

Despite their increasing popularity and therapeutic significance, quality control of polyherbal formulations remains a major challenge. Unlike conventional pharmaceutical products that usually contain one or two chemically defined active ingredients, polyherbal formulations consist of complex mixtures of phytoconstituents. Their chemical composition can vary depending on geographical location, climate, soil conditions, cultivation practices, harvesting time, processing methods, storage conditions, and extraction procedures.

Variability in herbal raw materials can significantly affect the quality, efficacy, and safety of the final product. The presence of adulterants, substitution of plant materials, microbial contamination, pesticide residues, heavy metals, and toxic compounds further complicates quality assurance processes. Therefore, standardization and quality control have become essential aspects in the development and manufacturing of herbal formulations.

### **Need for quality control**

Quality control refers to the process of ensuring the identity, purity, strength, and safety of pharmaceutical products. For polyherbal formulations, quality control aims to maintain consistency and ensure that every batch of product meets predetermined specifications. Effective quality control not only improves therapeutic efficacy but also ensures patient safety and regulatory compliance.

Traditional methods of evaluating herbal formulations include organoleptic, microscopic, and physicochemical examinations. Organoleptic evaluation involves assessing sensory properties such as color, odor, taste, shape, and texture. Microscopic analysis helps identify specific plant tissues and detect adulteration. Physicochemical parameters include ash values, extractive values, moisture content, pH, and foreign matter determination.

### **Modern analytical methods**

Modern analytical methods provide scientific and reliable tools for the identification, characterization, and quantification of phytochemical constituents present in herbal formulations. These methods offer high sensitivity, accuracy, specificity, and reproducibility compared to conventional techniques. They enable researchers and manufacturers to establish quality standards and ensure product consistency. Chromatographic techniques are among the most widely used analytical methods for herbal evaluation. Thin Layer Chromatography (TLC) is a simple and cost-effective technique used for the identification and separation of phytoconstituents. High Performance Thin Layer Chromatography (HPTLC) provides enhanced resolution and allows fingerprint profiling of herbal products. High Performance Liquid Chromatography (HPLC) is extensively employed for quantitative analysis and standardization of active compounds.

Chromatography (UPLC) offer greater speed, resolution, and sensitivity compared to traditional methods.

Spectroscopic techniques also contribute significantly to herbal quality assessment. Ultraviolet- visible spectroscopy (UV-Visible spectroscopy) is used for quantitative analysis of chemical compounds. Fourier Transform Infrared Spectroscopy (FTIR) helps identify functional groups and characterize molecular structures. Nuclear Magnetic Resonance (NMR) spectroscopy and Mass Spectrometry (MS) provide detailed information regarding structural elucidation of phytoconpounds. Furthermore, hyphenated analytical techniques such as LC-MS, GC-MS, and LC-NMR integrate multiple analytical approaches into a single system. These advanced techniques facilitate comprehensive analysis of complex herbal formulations by combining separation and structural identification capabilities.



Modern analytical techniques are also valuable for detecting impurities and contaminants in herbal products. Heavy metals like lead, mercury, arsenic, and cadmium can pose serious health risks. Pesticide residues, microbial contamination, aflatoxins, and adulterants may compromise safety and efficacy.

Analytical tools enable accurate detection and quantification of these harmful substances. Regulatory organizations and pharmacopoeias such as WHO guidelines, Ayurvedic Pharmacopoeia, Indian Pharmacopoeia, and international agencies increasingly emphasize standardization and quality evaluation of herbal medicines. Standard analytical methods are now considered essential for ensuring product quality and obtaining regulatory approval.

The rapid expansion of the herbal medicine market has highlighted the importance of scientific quality assurance systems. Implementation of modern analytical techniques supports authentication, standardization, and validation of herbal products while ensuring consumer safety and confidence. (5-6)

### **LITERATURE REVIEW**

1. Jadhav Santosh, Sawale Jyotiram et al.,(2016)

Herbal medicines are not a simple task since many factors influence the biological efficacy and reproducible therapeutic effect. Herbal products have gained increasing popularity in the last decade, and are now used by approximately 20% of the population or it is however a known fact that over 80% of the world population depends on herbal medicines and product for healthy living. WHO specific guidelines for the assessment of the safety, efficacy and quality of herbal medicines as a prerequisite for global harmonization are of utmost importance. WHO specific guidelines for the assessment of the safety, efficacy and quality of herbal medicines as a prerequisite for global harmonization are of utmost importance. This review seeks to enlighten stakeholders in herbal medicine on the need to establish quality parameters for collection, handling, processing and production of herbal medicine as well as employ such parameters in ensuring the safety of the global herbal market.

2. Pulok K Mukherjee Elsevier et al.,(2019)

Advances in analytical methods and bioassay development have helped to push forward the research in natural products. Their high chemical diversity and the effects of evolutionary pressure to create biologically active molecules could be attributed to success in drug discovery. Despite the availability of modern analytical instrumentation techniques, metabolic profiling covers the identification of a selected group of metabolites. The phytochemical analysis is commonly performed using standard techniques such as thin-layer chromatography, high- gas chromatography and more recently mass spectrometry and nuclear magnetic resonance spectrometry. Two- dimensional J-resolved Nuclear Magnetic Resonance (NMR) spectra and multivariate data analysis techniques were applied to avoid low resolution and overlapping signals hampering the identification of the individual components of botanicals. On-targeted metabolomic analysis via the ultra-high performance liquid chromatography-quadrupole time-of-flight mass spectrometry (UHPLC/Q-TOF-MS) was utilised to localise compounds belonging to various chemical classes (ie. oxygenated fatty acids, flavonols, phenolic acids, and sinapoyl choline derivatives). Rotation planar chromatography over-pressured layer chromatography and electro planar chromatography are the other innovations.

serially coupled layers open up new avenues for the analysis of a large number of samples for high-throughput screening and very complex matrices in a natural product. Analytical strategies with applications to natural extracts and novel methods that have strong potential, regardless of how often they are used are discussed with respect to their potential applications challenges and future trends. (7-8)

3. Amber Vyas, Vishal Jain, Umakant Sahu, Narendra Kumar, Neelu Joshi et al.,( 2023)

High Performance Thin Layer Chromatography (HPTLC) is the most potent and sophisticated type of Thin Layer Chromatography (TLC). It uses chromatographic layers with the highest levels of separation, efficiency and employs high-tech equipment for every step of the process, including accurate sample application, standardised reproducible chromatogram development, and software-controlled evaluation. HPTLC is a concept that incorporates both the use of established methodologies for qualitative



and quantitative analysis and a widely standardised methodology founded on scientific facts. The resolution can be increased and more exact quantitative measurements, which satisfies all quality standards for today's analytical needs. Development of an analytical technique based on HPTLC and parameter validation in line with practical assessment. It complies with standards while reducing mistakes and inquiries. Quality Control and Quality Assurance of raw materials of Plant Origin can easily and effectively be done qualitative characterization and quantitative determination of mixtures of substances, Chemical Fingerprinting by High Performance Liquid Chromatography. This review article provides fundamental principles, guidance for proper validation practise, aids in selecting the best mobile phase, and clarifies the processes couf rrethnet aadnvaalnyctiecmalentpsr,ocheassn.g, esprmotaoedceolt,o TseLpCartahtiaot nl,edretosoHluPtiToLnC, , voapltiidmatizoantiopnr, opreoscse, ss control, automation, and hyphenation.

4. Pulok K Mukherjee, Ranjit K Harwansh, Shiv Bahadur, Sayan Biswas et al.,(2016)

Secondary metabolites from plants provide lead molecules for drug development. Metabolomics is a modern omic-technique for comprehensive analysis of phytochemicals. Advances in mass spectrometry (MS) based platforms like GC-MS and LC-MS, helped in separation and identification of several metabolites. Such analysis can be a valuable tool for identifying potential biomolecules from medicinal plants. Despite the potential use, metabolomics data of Indian medicinal plants and spices are extremely limited. Similarly, metabolomic studies on Ayurvedic formulations, e.g. Triphala/Trikatu, are lacking. Our review emphasizes the importance of metabolomics of Indian medicinal plants, crucial for quality evaluation and scientific validation of herbal products. (13-14)

5. Siddheshwar Kisan Chauthe, Soham Rajyaguru et al.,(2025)

Plants have played an essential role in human healthcare since ancient times. Various herbal formulations are used to treat different ailments, but over time, as the popularity of herbal medicines is growing, the challenges related to their formulation, authentication, safety profiling, and standardization have increased. Quality challenges and regulatory approval of herbal medicines present a complex and dynamic landscape in the world of healthcare. Herbal medicines, often derived from plant sources, face unique quality control challenges due to variations in plant composition, growing conditions, and extraction processes. Ensuring consistent potency and purity is essential to guarantee their safety and efficacy. There are many regulatory authorities that provide guidelines to overcome these challenges including WHO, US- FDA, EMA, CDSCO, and others. Due to the complexity and interactions of the chemical constituents, especially in formulations containing a combination of herbs, it becomes difficult to test them analytically and therapeutically. Improved guidelines are expected from the agencies to alleviate these problems. This chapter discusses the polyherbal formulations, the challenges in their preparation and analysis, existing regulatory guidelines, and existing challenges in the regulatory approval of herbal medicines.

6. Swarna Hapuarachchi, Dinithi Silva, Chamali Madhushika et al.,( 2025)

Trijata is a polyherbal Ayurveda preparation containing Twak (Cinnamomum verum syn. Cinnamomum zeylanicum), Ela (Elettaria cardamomum), and Patra (Cinnamomum tamala) mentioned in an Ayurveda textbook. This study aimed to develop a novel preparation of Trijata incorporating C. zeylanicum leave substituting Cinnamomum tamala, due to the unavailability of C. tamala in Sri Lanka. Furthermore, quality control and standardization parameters were developed for this Novel Trijata (NT). The hot and cold aqueous extractions were subjected to qualitative phytochemical screening. Total phenolic, flavonoid contents and in-vitro antioxidant activity were determined using DPPH and ABTS assays. Microbiological limits, heavy metal content, and physicochemical parameters including; the ash content, and extractable matter were determined for quality control and standardization. Preliminary phytochemical



analysis revealed the presence of phenols, flavonoids, tannins, alkaloids, saponins, terpenoids, reducing sugars, and cardiac glycosides in NT aqueous extract.

The physicochemical parameters including;  $4.6 \pm 0.2\%$  of total ash,  $3.1 \pm 0.1\%$  of water-soluble ash, and  $0.6 \pm 0.2\%$  of acid-insoluble ash on a dry weight basis were determined. In-vitro antioxidant activity as per DPPH and ABTS assays was dose-dependent and the highest activity was obtained with IC 50 of hot water extract. (15-16)

## **MATERIAL AND METHODS**

### **Introduction**

The materials and methods section describes the procedures, instruments, chemicals, and analytical techniques used for the evaluation of modern analytical methods in quality control of polyherbal formulations. The purpose of this section is to explain the methodology adopted for standardization and quality assessment of selected polyherbal products using conventional and advanced analytical techniques.

Quality control evaluation includes examination of organoleptic properties, physicochemical characteristics, chromatographic analysis, spectroscopic studies, and advanced analytical techniques to ensure identity, purity, safety, and consistency of the formulation

The Materials and Methods section is an important part of any research project because it provides a detailed description of the materials used, experimental procedures followed, instruments employed, and analytical techniques adopted during the study. This section ensures that the research work can be accurately understood, repeated, and validated by other researchers. It serves as the foundation of the project by explaining how the study was conducted systematically and scientifically.

In the present project entitled “Evaluation of Modern Analytical Methods for Quality Control of Some Polyherbal Formulation,” various materials, chemicals, reagents, laboratory instruments, and analytical procedures are used for evaluating the quality, purity, identity, and consistency of selected polyherbal formulations. Quality control of herbal formulations is an essential process because herbal medicines contain complex mixtures of phytochemical constituents obtained from different medicinal plants. Due to the presence of multiple active ingredients and natural variability in plant sources, maintaining consistency in herbal products becomes difficult.

Polyherbal formulations are widely used in traditional systems of medicine such as Ayurveda, Siddha, and Unani because they offer synergistic therapeutic effects and enhanced efficacy compared to single-herb preparations. These formulations contain several medicinal herbs in fixed combinations that act together to produce desired pharmacological actions. Although polyherbal products provide many therapeutic advantages, variations in plant species, geographical origin, harvesting conditions, environmental factors, processing techniques, and storage conditions can affect their quality and efficacy.

### **Herbal Ingredients Present in Formulation**

Depending upon the selected product, common herbal ingredients may include:

*Curcuma longa* (Turmeric)

Contains curcuminoids with anti-inflammatory and antioxidant activity. Uses:

Anti-inflammatory activity Wound healing Antioxidant effect

*Withania somnifera* (Ashwagandha) Used as an adaptogenic herb.

Uses:

Stress management Immunity enhancement General tonic

*Tinospora cordifolia* (Guduchi) Possesses immunomodulatory activity. Uses:

Fever management Immune support

Anti-inflammatory action

*Emblica officinalis* (Amla)

Rich source of vitamin C and antioxidants. Uses:



Immunity enhancement Digestive support Antioxidant effect

Azadirachta indica (Neem)

Known for antimicrobial properties. Uses:

Skin disorders

Antibacterial activity Blood purification

Ocimum sanctum (Tulsi)

Traditionally used in respiratory disorders. Uses:

Cough and cold

Stress relief Antioxidant action (38)

### **Chemicals and Reagents**

Various analytical-grade chemicals and reagents are used for extraction, chromatographic analysis, physicochemical evaluation, and spectroscopic studies.

### **Organic Solvents**

Methanol Uses:

Extraction of phytoconstituents

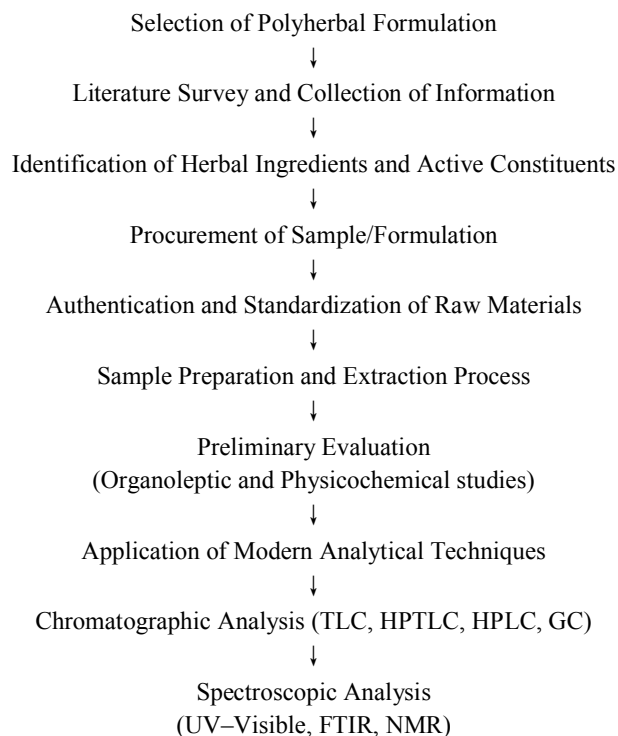
Sample preparation

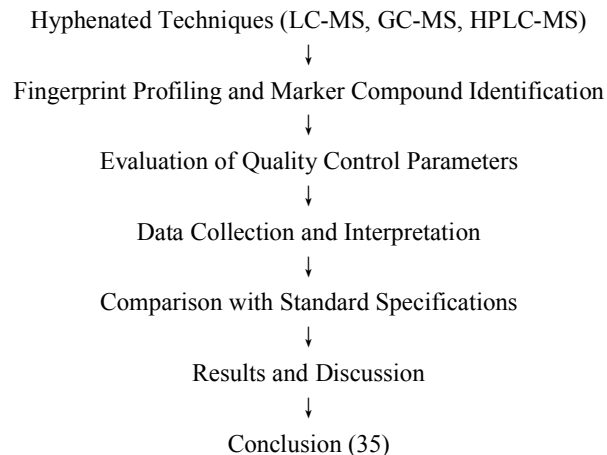
Chromatographic studies

### **Ethanol Uses:**

Herbal extraction Preparation of test solutions

### **Methodology FlowChart**





### **MODERN ANALYTICAL METHODS**

Modern analytical methods play a significant role in the quality control and standardization of polyherbal formulations. Polyherbal products contain multiple herbs and numerous phytoconstituents, making their analysis complex. Conventional methods alone are often insufficient for evaluating quality, purity, safety, and consistency. Therefore, advanced active analytical techniques are used to identify, separate, quantify, and characterize compounds and ensure batch-to-batch uniformity.

The main objectives of modern analytical methods are:

Quantification of active marker compounds  
Detection of adulterants and contaminants  
Fingerprint profiling  
Standardization of formulations  
Assessment of purity and safety  
Classification of Modern Analytical Methods

Modern analytical techniques used in quality control of polyherbal formulations are broadly classified into:

1. Chromatographic
  2. Spectroscopic
  3. Hyphenated
  4. Fingerprinting
- techniques techniques techniques methods

#### **5. Miscellaneous advanced methods**

1. Chromatographic Techniques

Chromatography is a separation technique in which compounds are separated based on differences in their movement between stationary and mobile phases.

##### **A. Thin Layer Chromatography (TLC) Principle**

TLC separates compounds based on differences in adsorption and partition properties between stationary and mobile phases.

##### **Procedure**

Silica gel-coated plates are used as stationary phase. Sample extract is applied as spots.

Plate is developed in a solvent chamber.

Separated spots are visualized under UV light or by spraying reagents.



### **Applications**

Preliminary phytochemical analysis Detection of adulteration Identification of herbal constituents Quality assessment

B. High Performance Thin Layer Chromatography (HPTLC) Principle

Advanced form of TLC with improved separation and quantitative analysis.

Instrumentation Sample applicator HPTLC plates

Development chamber Scanner

Software system

Applications

Herbal fingerprinting Quantification of markers Authentication of herbal drugs Detection of impurities

### **C. High Performance Liquid Chromatography (HPLC)**

#### **Principle**

Compounds are separated based on differences in interaction with stationary and mobile phases under high pressure.

Instrumentation Solvent reservoir Pump

Injector Column Detector

Data processor

#### **Applications**

Quantification of phytoconstituents Estimation of active markers Stability studies

Purity testing

#### **Advantages**

High precision High sensitivity

Suitable for complex mixtures

### **D. Gas Chromatography (GC) Principle**

Volatile compounds are separated based on boiling point and distribution Procedure.

#### **Applications**

Analysis of volatile oils Essential oil profiling

Detection of pesticides and contaminants

#### **Advantages**

High sensitivity

Fast analysis (38-40)

### **Evaluation and Quality Control Parameters**

#### **Introduction**

Evaluation and quality control are essential aspects in the standardization of polyherbal formulations. Since polyherbal products contain multiple herbal ingredients with diverse phytochemical constituents, maintaining consistency, safety, purity, and therapeutic efficacy is challenging. Quality control parameters help ensure that formulations meet pharmacopoeial standards and are free from adulteration, contamination, and variations between batches.

The major objectives of quality control are: To ensure product identity

To maintain purity and safety

To establish consistency between batches To detect contaminants and adulterants

To ensure efficacy and stability of formulations

The evaluation of polyherbal formulations generally includes:

1. Organoleptic evaluation
2. Physical evaluation



3. Physicochemical evaluation
4. Chemical evaluation
5. Microbiological evaluation
6. Toxicological evaluation
7. Stability studies

### 1. Organoleptic Evaluation

Organoleptic evaluation refers to the assessment of characteristics using sensory organs. Parameters assessed:

Color

Odor Taste

Texture

Appearance

Surface characteristics

### 2. Physical Evaluation

Physical parameters provide information regarding formulation characteristics and uniformity.

A. Particle Size Analysis Purpose:

Determines uniformity and influences dissolution and absorption. Methods:

Microscopy

Sieve analysis

B. Bulk Density Definition:

Mass of powder divided by bulk volume. Importance:

Used for packaging and flow property assessment.

C. Tapped Density

Determined after mechanically tapping the powder. Importance:

Used to evaluate compressibility.

D. Flow Properties

Flow properties influence manufacturing processes. Parameters include:

Angle of Repose

Determines powder flowability.

E. Viscosity

Important for liquid and semisolid formulations. Determined using:

Viscometer

F. pH Measurement Measured using pH meter. Importance:

Product stability Compatibility

### RESULT

The polyherbal formulation was successfully evaluated using various modern analytical methods to assess its quality, safety, and consistency. Organoleptic examination revealed acceptable color, odor, taste, and appearance, indicating good physical quality. Physicochemical parameters such as moisture content, ash values, extractive values, and pH were found to be within acceptable limits, demonstrating the formulation's stability and purity.

Preliminary phytochemical screening confirmed the presence of important bioactive constituents, including alkaloids, flavonoids, tannins, saponins, glycosides, and phenolic compounds, which are responsible for the therapeutic activity of



the formulation. Thin Layer Chromatography (TLC) analysis produced characteristic spots with reproducible R<sub>f</sub> values, confirming the identity of herbal ingredients. High-Performance Thin Layer Chromatography (HPTLC) generated distinct fingerprint profiles, which can be used for authentication and batch-to-batch consistency evaluation. High-Performance Liquid Chromatography (HPLC) analysis successfully identified and quantified selected marker compounds with high accuracy and precision. UV-Visible spectrophotometric analysis demonstrated satisfactory levels of total phenolic and flavonoid contents, indicating the antioxidant potential of the formulation. Microbial limit testing showed that total bacterial and fungal counts were within permissible limits and that no pathogenic microorganisms were detected. Heavy metal analysis confirmed that the levels of lead, cadmium, arsenic, and mercury were below the prescribed safety limits.

Overall, the results demonstrated that the selected modern analytical techniques are reliable, sensitive, and effective for the quality control and standardization of polyherbal formulations. The formulation complied with established quality standards and exhibited acceptable safety, purity, and consistency, supporting its suitability for therapeutic use and routine quality assessment.

## II. CONCLUSION

The present project entitled “Evaluation of Modern Analytical Methods for Quality Control of Some Polyherbal Formulation” highlights the importance of advanced analytical techniques in ensuring the quality, safety, efficacy, and standardization of polyherbal formulations.

Polyherbal products contain multiple herbal ingredients with diverse phytoconstituents, making their quality assessment more complex than synthetic formulations. Therefore, the use of reliable and sensitive analytical methods is essential for maintaining consistency and therapeutic effectiveness.

In this study, different modern analytical approaches including chromatographic techniques such as TLC, HPTLC, HPLC, and GC; spectroscopic techniques such as UV-Visible spectroscopy, FTIR, and NMR; and hyphenated techniques like LC-MS and GC-MS were reviewed and evaluated. These methods provide efficient identification, separation, polyherbal formulations. and quantification of active phytoconstituents present in Tprhoep erteiveas, luaantdio n qualityontrol parameters including organoleptic physicochemical analysis, phytochemical screening, microbial evaluation, heavy metal analysis, and stability studies were found to be important in assessing the overall quality profile of herbal formulations. Fingerprinting and marker-based analysis also played a major role in authentication and batch-to-batch consistency.

The findings suggest that modern analytical methods provide accurate, reproducible, and comprehensive results for quality assurance of polyherbal products. These techniques help detect adulteration, contamination, and variations in herbal preparations while supporting regulatory compliance and standardization requirements.

Thus, modern analytical methods can be considered essential tools for improving the reliability and global acceptance of polyherbal formulations and ensuring the delivery of safe and effective herbal medicines to patients.

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