REVIEW ARTICLE

An overview of the Importance of Quality Evaluation and Validation of Medicinal Plants

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Abstract

Phytoconstituents of medicinal plants and their derived formulations are evaluated for quality, safety, and efficacy. In recent years, most people are turning to the use of natural compounds or herbs or their formulations for the prevention or management of different disease conditions. Since phytotherapy is a common component of medical treatment, its efficacy and safety should be required, and the necessity of pharmacological, toxicological, and clinical trials is evident, as noted by Bauer and Tittel nearly 20 years ago. Different methods, such as physical, chemical, and biological, are used for the quality evaluation and standardization of herbal products and their formulations. For metabolomics profiling, a range of chromatographic and hyphenation with spectroscopic techniques, such as high-performance thin layer chromatography, high-performance liquid chromatography, liquid chromatography–mass spectrometry, gas chromatography–mass spectrometry, near infrareds, high-performance thin layer chromatography–mass spectrometry, and high-performance liquid chromatography–mass spectrometry, are the effective analytical approaches for quality measurement and standardization of medicinal plants and their extracts and herbal formulations. The processes of a quality evaluation and standardization paradigm are described in this article with the goal of ensuring and preserving the clinical efficacy, quality and safety, and consistent biologically active molecules of medicinal plants and their products.

Key words: Gas chromatography–mass spectrometry, high-performance thin layer chromatography, high-performance liquid chromatography, liquid chromatography–mass spectrometry, medicinal plants, near infrared, quality evaluation, standardization

INTRODUCTION

Medicinal products and their formulations have been used for centuries to prevent and manage different diseases worldwide, also providing nutritional benefits. Medicinal plants and their derived products offer a rich source of biologically active metabolites with effective therapeutic potential. According to the World Health Organization (WHO), 80% of the world population depends on medicinal plants and their formulations.[1] There is a great demand for herbs and medicinal plants worldwide, due to herbs and herbal products having great therapeutic potential in the world market.[2,3] Medicinal plants are used in various forms, i.e., leaves, flowers, fruits, woods, barks, roots, gums, resins, essential oils, etc., and formulations such as extracts, tinctures, etc., for the prevention and management of diseases.[4] In India, AYUSH systems of medicine are used for preventing and managing diseases.[5-7] Over the past few decades, less toxicity, interest of the public as well as acceptance of herbal compounds and their extracts has increased worldwide.[8] One or more extracts or herbs are recommended for synergistic action. No single herb is recommended for a particular health condition.[9] Phytomarkers and biologically active molecules in medicinal Plants responsible for their pharmacological properties.[10] These moieties depend on factors such as plant species, harvesting time, and nature of the soil.[11] In most

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cases, the active ingredients behind the biological activities of herbs are not certain, and their therapeutic activity is lower as comparatively to synthetic medicines. These drugs are used very effectively against chronic diseases with a low incidence of side effects.[12] Phytmolecules are used in a variety of field of studies, such as validation of original species, exploration for novel products and materials, extraction and purification process optimization, structural elucidation, and quality evaluation.[13] Phytomarkers through scientific investigation can contribute to the identification and discovery of novel medications.[14,15] The present study aims to provide an overview of the significance, methods, and factors involved in guaranteeing the efficacy, safety, and quality of medicinal plants and their products. A few important medicinal plants, their marker compounds, analytical methods, and pharmacological activities are shown in Table 1.

QUALITY CONTROL AND VALIDATION OF MEDICINAL PLANTS AND THEIR PRODUCTS

It is a systematic approach that involves surveillance, monitoring, and controlling different aspects of medicinal plants and their products development, manufacturing, and distribution to maintain product quality and importance to product safety, efficacy and acceptance. These are very essential process in the pharmaceutical industry.[16,17] Essentially, quality control depends on identity, purity, and content of active botanicals.[18]Extraction type, extraction solvent polarity, and component instability also affect herb quality.[19] Regulation of norms of the medicinal products is lenient when compared to the synthetic medicines. Because of this, quality of the herbal products is decreasing due to false medication.[20] It can lead to adverse effects on the health of the consumers. Hence, controlling the quality of the herbal products and their preparations is very much required for the betterment of humankind.[14]

Table 1: Important medicinal plants, major marker compounds, analytical method, and their pharmacological activity

Medicinal plant	Marker compounds	Analytical method	Pharmacological activity	References
Andrographis paniculata	Andrographolide, Neoandrographolide, Isoandrographolide, Apigenin	HPLC, HPTLC, HPTLC-MS, NIRs	Treatment in fever, inflammation, upper respiratory tract infection	[38,39]
Allium sativum	Ajoenes, allicin, and alliin	HPLC, HPTLC/ UPLC-MS	Hypoglycemic, hypolipidemic, antihypertensive	[40]
Aloe vera	Emodin, P-coumaric, gallic, vanilic, ferulic, cinamic and ellagic acids.	HPLC, UV-Vis, HPTLC	Wound healing, anti-inflammatory, hypoglycemic	[41,42]
Azadirachta indica	Nimbanene, nimbidin, and nimbin,	HPTLC, GC-MS	Antibacterial, antimalarial	[43]
Berberis vulgaris	Berlambine, hydroxycanthine, tejedine	LC MS/MS	Used to treat skin infections	[44]
Bacopa monnieri	Bacoside, apigenin, brahmine	HPLC	Memory improver, anti-influenzal	[45,46]
Boswellia serrate	Boswellic acid, lupeolic acid, and acetyl lupeolic acid	UPLC-Q-Tof-MS	Used to treat inflammatory bowel disease, rheumatoid arthritis	[47]
Capsicum annum	Capsaicin, caffeic acid, luteolin, and vitexin	GC-MS, FT-IR	Hypocholesterolemic, antiviral, and antibacterial	[48]
Centella asiatica	Asiaticoside, asiatic acid, and centellicin	HPLC	Antimicrobial and antiinfluezal	[49]
Calendula officinalis	α-cadinol, cadinenes, and copane	HPTLC	Used in treatment of wounds	[50]
Curcuma longa	Curcumin, cyclocurmin, coumaric, and sinapic acid	HPTLC, NIRs	Anti-tumor, antioxidant, anti-arthritic	[51,52]
Citrus limon	Sabinene, 3-carene, limonene	LC-MS/MS	Used for coughs and sore	[53]
Digitalis lanata	Digitoxin, digitoxigenin, and lanatoside C	RP-TLC	Digoxin is used as an antiarrhythmic and inotrope	[54]
Emblica officinalis	Gallic acid, methyl gallate, ellagic acid	HPLC	Antioxidant, anti-inflammatory, adaptogenic	[55]
Ephedra sinica	Ephedrine, pseudoephedrine, N-methylephedrine	LC–MS/MS	Bronchodilators and decongestants	[56]

(*Contd...*)

Table 1: (*Continued*)

Medicinal plant	Marker compounds	Analytical method	Pharmacological activity	References
Erythroxylum coca	Cocaine	GC-MS	Anesthetic	[57]
Ferula assa-foetida	Carvacrol, α-bisabolol, β-ocimene	GC-MS	Hypocholesterolemic and antiasthmatic	[58,59]
Fumaria officinalis	Chelidonine, protopine, and stylopine	MS and MS/MS	Used in skin infections and conjunctivitis	[60]
Gingko biloba	Ginkgolide A, ginkgolide B, and ginkgoside B	LC-HRMS	Antioxidant, anti-Alzheimer	[61]
Glycyrrhiza glabra	Glycyrrhizin, glabridin, glycyrrhizin, glabridin licochalcone A	RP-HPTLC	Anti-inflammatory, antiulcer, antioxidant, hepatoprotective, antibacterial, and antiviral	[62,63]
Geranium robertianum	Ellagitannin, hexahydroxydiphenylglucose	HPLC	Used in wound healing, tooth decay	[64]
Hypericum perforatum	Hypericin, chlorogenic acid	HPLC-ESI-Q-TOF MS	Antidepressant	[65]
Lavandula angustifolia	Camphene, sabinene	SPME-GC-MS	Antiseptic and antipsychotic	[66]
Lawsonia inermis	Eugenol, hexadecanoic acid, phytol, and α-terpineol	TLC	Antibacterial, analgesic and anti-inflammatory	[67]
Momordica charantia	Momordicine I, momordicine II,	PYR-GC/MS	Hypoglycemic and adaptogenic	[68]
Morinda citrifolia	Americanin A, asperuloside, citrifolinin B	HPLC	Used for arthritis, joint pain, and skin infections	[69]
Nelumbo nucifera	Betulinic acid, nelumnucifoside A and nelumnucifoside B	LC-MS/MS	Anti-influenzal, anti-inflammation, anticancer	[71]
Ocimum sanctum	Carvacrol	LC-MS	Oxidative stress, microbial infections, and hypertension	[72]
Piper nigrum	Piperine	HPTLC, Raman spectroscopy	Antiageing, adaptogenic, and immunomodulator, antidiabetic	[72-74]
Piper methysticum	Kavain, methysticin, yangonin	UPLC-MS/MS	Antiasthamatic	[75]
Silybum marianum	Silibinin, silychristin, isosilybin a, taxifolin, Silandrin	UHPLC-MS/MS	Hepatoprotective	[76]
Terminalia belerica	Gallic acid	LC-MS	Anti-atherosclerotic, hepatoprotective, cardioprotective	[77]
Terminalia chebula	Punicalagin, terflavin A, terchebulin, terchebin, and neo-chebulic acid	LC, UPLC-MS/MS	Liver protective, cardiotonic, anticancer and antimicrobial	[78]
Withania somnifera	Withanolide A, withanolide B, withanone, withasomnine, withanoside iv	HPLC	Anti-tumor, antituberculosis, and antiulcer	[79]
Youngia japonica	Chlorogenic acid, chicoric acid, caftaric acid	Light and scanning electron microscopy	Antitussive, used in the treatment of boils and snakebites	[80]
Zingiber officinale	Gingerol, β-bisabolene	HPTLC	Antiviral, antimicrobial	[81]

HPTLC: High-performance thin-layer chromatography, HPLC: High-performance liquid chromatography, LC-MS: Liquid chromatography–mass spectrometry, GC-MS: Gas chromatography–mass spectrometry, NIRs: Near infrareds, HPTLC-MS: High-performance thin-layer chromatography–mass spectrometry, HPLC-MS: High-performance liquid chromatography–mass spectrometry, UPLC-MS: Ultra-performance liquid chromatography–mass spectrometry, UV-Vis: Ultraviolet visible, UPLC-Q-Tof-MS: Ultra-performance liquid chromatography-quadrupole time-of-flight–mass spectrometry, FT-IR: Fourier-transform infrared, RP-HPTLC-MS: Reversed-phase high-performance thin-layer chromatography, LC-HRMS: Liquid chromatography-high-resolution mass spectrometry, SPME-GC-MS: Solid-phase microextraction-gas chromatography–mass spectrometry, PRY-GC-MS: Pyrolysis-gas chromatography–mass spectrometry, HPLC-ESI-Q-TOF: High-performance liquid chromatography-electrospray ionization-quadrupole-time-of-flight, RP-TLC: Reverse phase thin-layer chromatography, UPLC-MS/MS: Ultra-performance liquid chromatography–tandem mass spectrometry, UHPLC-MS/MS: Ultra-high-performance liquid chromatography–tandem mass spectrometry

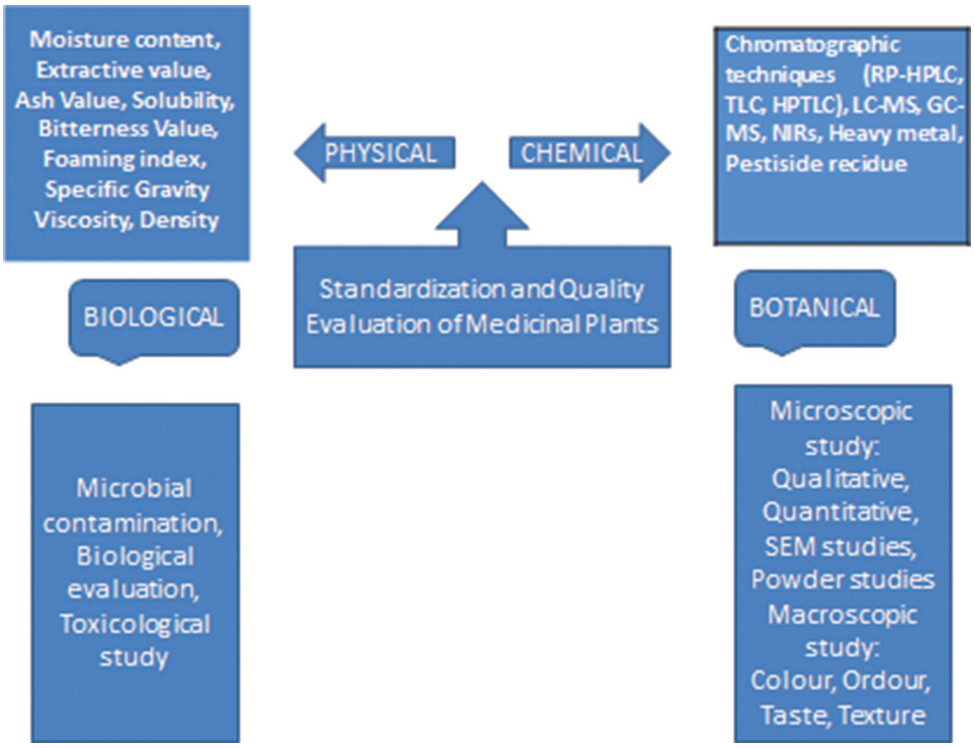

Figure 1: Flowchart of standardization and quality evaluation techniques of medicinal plants

Table 2: Quality evaluation of some Indian medicinal plants using HPTLC

Medicinal plant	Mobile phase	Spraying reagent	Visible region	Marker Compound	References
Clitoria ternatea L	Hexane: Ethyl acetate (4:1 v/v).	Anisaldehyde reagent	420 nm	Taraxerol	[82]
Vitex trifolia	Chloroform: Acetone (98:2, v/v)	Vanillin/sulfuric acid reagent	610 nm	Diterpenoids	[83]
Ruellia tuberosa	Chloroform: Toluene: Ethyl acetate (6: 3: 1, v/v)	Anisaldehyde sulfuric acid reagent	366 nm	Retension factor (Rf) Value 0.56 was selected as marker compound	[84]
Terminalia sericea	Dichloromethane: ethyl acetate: Methanol: Formic acid (90:10:30:1)	10% Sulfuric acid in methanol	White light	Resveratrol-3-O-β-rutinoside	[85]
Myrica esculenta	Toluene: Ethyl acetate: Formic acid: Methanol (3:3: 0.6: 0.4)	5% Sulfuric acid in methanol	366 nm	Myricetin	[86]
Holostemma ada-kodien	Toluene: Ethyl acetate: Formic acid (5: 3: 0.1)	Vanillin-sulfuric acid reagent,	Visible light	The methanol extract under visible light in track I showed a maximum area of 46.87%, spanning from Rf 0.73 to 0.98, and in track II, it displayed a maximum area of 36.59%	[87]
Fumaria parviflora	Chloroform: Ethylacetate: Formic acid (5:4:1).		254 nm and 366 nm	At 254 nm, it represents 11 and 10 peaks for track 1 and track 2, respectively, whereas at 366 nm, 9 and 12 peaks for track 1 and track 2, respectively.	[88]

HPTLC: High-performance thin-layer chromatography

Table 3: Quality control of some important medicinal plants using LC-MS studies

Medicinal plant	Phyto-marker	Biological activity	References
Valeriana jatamansi	Valerenic acid	antitumour	[89]
Michelia champaca	Phlorizin and astilbin	Hypoglycemic	[90]
Zingiber officinale	Pyrogallol, p-hydroxybenzoic acid, ferulic acid and p-coumaric acid	Antioxidant	[91]
Mangifera indica	Neomangiferin, mangiferin, kaempferol-3-O-rutinoside, isoquercetin and quercetin	Antioxidant, hypoglycemic	[92]
Salvia miltiorrhiza	Cryptotanshinone, trijuganone B, and 15,16-dihydrotanshinone I	Used for the treatment of cardio-cerebrovascular diseases, cirrhosis, cancer, and osteoporosis	[93]
Hedyotis aspera	14,19-Dihydroaspi dospermatine, coumeroic acid, lycocernuine and muzanzagenin	Nephroprotective	[94]
Andrographis paniculata	Neoandrographolide, andrographolactone, 14-dehydroxy-11,12-didehydroandrographolide, skullcapflavone I, and 5-Hydroxy-2′,7,8-tri methoxy flavone	Anti-malarial	[95]
Euphorbia hirta	Neochlorogenic acid, quercetin-3β-D-glucoside, syringic acid, caffeic acid, ellagic acid, astragalin, afzelin, quercetin, corchorifatty acid F, 2-undecanone 2,4-dinitrophenylhydrazone, and demexiptiline.	Anti-gout	[96]

LC-MS: Liquid chromatography–mass spectrometry

Table 4: Quality evaluation of some Indian medicinal plants using FT-IR method

Medicinal plant	FT-IR analysis	References
Polyherbal formulation: *a. Dillenia indica* b. *Trigonella foenum graecum* c. *Cuminum cyminum*	FT-IR analysis of chloroform, water, and ethyl acetate extracts revealed several functional groups. Alkenes (C=C bending at 721 cm^{-1}) were present in all extracts. Amines/Fluoro compounds/Tertiary alcohols/Alkyl aryl ethers (C-N stretching at 1161 cm^{-1} and C-F stretching at 1231 cm^{-1}) were also found in all extracts. C=O stretching (1686 and 1746 cm^{-1}) was observed in chloroform and ethyl acetate extracts. The chloroform extract also showed O-H bending and C-F stretching at 1377 cm^{-1}. Importantly, 11 bands across all extracts indicated the presence of alcohols (O-H stretching)	[97]
Momordica balsamina	FT-IR analysis revealed six major peaks, confirming the presence of alkaloids, flavonoids, terpenes, anthraquinones, and phenolic compounds. A peak at 3384.84 cm^{-1} suggested O-H (phenols, alcohols) or N-H (amines, amides) stretching, likely indicating phenolic compounds and possibly alkaloids. A peak at 2938.72 cm^{-1} (C-H stretching) pointed to terpenes. A peak at 2039.40 cm^{-1} (C≡C stretching) suggested alkynes. A peak at 1637.18 cm^{-1} was in a complex region, potentially indicating aromatic rings, amino acids, flavonoids, or C=C stretching (alkenes). Finally, peaks at 1084.85 and 1029.61 cm^{-1} (C-O stretching) suggested esters or secondary alcohols.	[98]
Operculina terpathum	Peaks at 3893.01 and 3860.20 cm^{-1} suggested organic acids (-COOH). Hydroxyl and phenolic compounds were indicated by peaks at 3522.6 and 3421.74 cm^{-1}. Aliphatic compounds (C–H bend) and esters were identified by peaks at 3138 and 1632.63 cm^{-1}, respectively. Peaks at 1343.42, 1148.16, and 1074.91 cm^{-1} suggested amides, ketones, aldehydes, aromatics (C–C and C-O stretch), and aliphatic amines (C–N stretch). Finally, peaks from 988.74 to 608.56 cm^{-1} indicated halogen compounds (C-Cl, C-F, C-Br).	[99]
Combretum album	FT-IR analysis of an ethanolic leaf extract showed major bands at 2923.56, 1608.34, 1282.43, 1175.4, and 1014.37 cm^{-1}. These bands suggest the presence of alcohols (3400–3200 and 1075–1000 cm^{-1}), aromatics (1040–995 and 730–680 cm^{-1}), amines (1146–1132 and 3500–3300 cm^{-1}).	[100]

FT-IR: Fourier-transform infrared

Table 5: Quality evaluation of some Indian medicinal plants using GC-MS method

Medicinal plant	Biological activity	Phyto-marker	References
Rhazya stricta	Used in the treatment female reproduction diseases, cardiovascular diseases, obesity, inflammatory conditions, and liver disorders	methyl stearate, Methyl palmitate, methyl tetradecanoate	[101]
Amomum nilgiricum	Antibacterial and antifungal	Serverogenin acetate	[102]
Citrullus colocynthis	Strong antimicrobial	Isooctylphthalate	[103]
Hibiscus asper	Antioxidant, anti-inflammatory, anti-diarrhea, anti-ulcer, and anticancer	9,12,15-octadecatrien-1-ol, n-Hexadecanoic acid, octadecatrienol acid, methyl palmitate, and phytol.	[104]
Amomum tsaoko	Gastrointestinal regulation, blood sugar reduction properties and antibacterial	Copaene, 2-octylfuran, 2,3-dihydro-1H-indene-4-carbaldehyde	[105]
Tylophora pauciflora	n-Hexadecanoic acid has the highest peak area and it Its properties include anti-oxidant, 5-alpha-reductase-inhibitor, anti-fibrinolytic, hemolytic, antibacterial activity, hypocholestemic nematicide, pesticide	The n-hexadecanoic acid, Octadecadienoic acid, Nonenoic acid, methyl ester	[106]
Papaver decaisnei	Antiradical, and antitumor	Decarbomethoxy- tabersonine, hexadecanoic acid, and anthocyanin. In the leaves, the major alkaloids identified in the methanol extract were 9,12,15-octadecatrien-1-ol, hexadecanoic acid, and γ-sitosterol.	[107]

GC-MS: Gas chromatography–mass spectrometry

HIGH PERFORMANCE THIN LAYER CHROMATOGRAPHY (HPTLC) METHOD FOR THE QUALITY EVALUATION AND VALIDATION OF MEDICINAL PLANTS

It is an excellent and convenient approach for the standardization and validation of herbs and herbal compounds. Applications of HPTLC include phytochemical screening, quantification, fingerprinting, and estimation of adulterants.[21] One important quality control method for determining the pharmacopeial standards of different herbal, Siddha, and ayurvedic medications is the HPTLC fingerprinting instrument. The HPTLC method can be used as a quality control method for identification and is employed concurrently to compare the chemicals in the samples and the reference. The HPTLC fingerprint images provide both qualitative and quantitative data when compared to reference standards. This technique can be applied to determine the minimum content, purity percentage, and marker compound identification. Some important medicinal plants, and their quality evaluation using HPTLC method have been shown in Table 2.

HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC) ANALYTICAL METHOD FOR THE QUALITY CONTROL OF BOTANICALS

HPLC is a versatile separation method for qualitative as well as quantitative evaluation of targeted phytomolecules in medicinal plants and herbal extracts. The HPLC technique is generally used in authentication, validation, standardization, and quality evaluation based on the marker compounds, which ensure its quality, safety, and efficacy of medicinal products. HPLC is hyphenated with various detection techniques, such as ultraviolet visible, photodiode array detector, mass spectrometry (MS), and nuclear magnetic resonance, to obtain higher sensitivity and detection capabilities of the phytoconstituents for quality control of herbal medicines.[22] The hyphenated chromatographic techniques, along with chemometric analysis, often offer an excellent approach for the evaluation of the quality as well as efficacy of medicinal plants. In the reverse-phase HPLC (RP-HPLC) technique, the chemical nature of the stationary phase, i.e., the column, is relatively non-polar in comparison

to the mobile phase. The column most widely used is the C18 column, which is better known as the octadecylsilane column. The mobile phase is a mixture of two solvents.[23] One of the solvents is an aqueous phase, consisting of water (HPLC grade), whose Potential of hydrogen (pH) has been adjusted with an orthophosphoric acid or glacial acetic acid to a desired PH and another organic solvent, such as methanol or acetonitrile.

LIQUID CHROMATOGRAPHY–MASS SPECTROMETRY (LC-MS) ANALYTICAL METHOD FOR THE QUALITY CONTROL AND VALIDATION OF MEDICINAL PLANTS AND THEIR FORMULATIONS

In complicated matrix analysis, where prior treatment for the concentration and purification of the API is required to simplify the procedure and produce better results, the HPLC method has several limitations when used alone without the combination of other methods. Liquid chromatography–mass spectroscopy, a mass spectroscopy-coupled HPLC technology, overcomes this limitation by significantly increasing detection sensitivity.[24] Ion trap LC-MS, quadrupole time-of-flight high-resolution MS, and triple-quadrupole MS are various techniques that can be integrated with HPLC analytical methods for method simplification. The LC-MS technique can be used to identify, quantify, and control the quality of raw plant material extracts and marketed products. Its capabilities include structure elucidation, molecular mass, fragmentation information, retention time, and a wide range of detection and separation of analytical compounds.[25] A few important medicinal plants, quality control using LC-MS studies are shown in Table 3.

GAS CHROMATOGRAPHY–MASS SPECTROMETRY (GC-MS) METHOD FOR THE QUALITY CONTROL AND VALIDATION OF MEDICINAL PLANTS

The analytical method known as gas chromatography–mass spectroscopy combines the use of gas chromatography to separate the various components of chemical compound mixtures with the use of mass spectroscopy to analyze the components that the GC is separating. GC-MS can also be used in the pharmaceutical, cosmetic, and food sectors, as well as environmental and forensic applications, to analyze the components of a substance, primarily active medicinal compounds. Qualitative component identification, component separation, and quantification of various volatile and non-volatile substances are all included in a single analysis. It is feasible to analyze many substances at the same time.[26]

NEAR INFRAREDS (NIRS) TECHNIQUE FOR THE QUALITY CONTROL AND VALIDATION OF MEDICINAL PLANTS AND THEIR PRODUCTS

NIR spectroscopy is an attractive analytical tool in medicinal research at the current time, which has been mentioned in the European Pharmacopoeia since 1997.[27] The principles of the NIR method differ from the conventional analytical techniques, such as GC, mass spectroscopy, HPLC, or HPTLC, which are conventionally used in quality evaluation and validation purposes of medicinal plants.[28] This approach is used to estimate quality-related parameters such as starch, amylose, protein, moisture, glycosides, and polyphenolic compounds in medicinal plants. This technique can provide specific, simultaneous, rapid, non-destructive, and accurate estimation of phytochemically active molecules of different medicinal plants and their products. In near-infrared spectroscopy, molecules are excited in the wavelength range of 750–2500 nm. Harmonics and combinations can be found in the NIR range.[29]

STANDARDIZATION OF MEDICINAL PLANTS

Pre-defining the quantity, quality, and therapeutic efficacy of each dose molecule, standardization, and identification of herbs and medicinal plants during the production process and quality control lead to reproducible quality of a specific product.[30] Standardized plant extracts containing specific compounds and quality controlled during the growing, harvesting, and production process. Phyto-marker compound selection basically depends on different factors such as stability, ease of analysis, time and cost of analysis, and therapeutic effect. Controversial identity and adulteration of plant material are very challenging for the standardization of botanicals. Other issues are also related to the standardization of herbal products. The majority of the time, the active components in herbal products are unknown, and reference compounds and specific analytical techniques may not be commercially accessible. Herbal medicines are typically blends of numerous botanicals.[31,32]

MARKER PROFILING

Biolgically active compounds of a medicinal plant or extract that having biologically active properties which are subjected for quality control purposes.[33] Herbal medications must take into account a variety of botanicals for effective quality control, rather than considering one or two individual marker compounds to assess product quality. However, all medicinal plant products and their extracts contain hundreds of unknown ingredients, many in very small amounts.[34,35] It is crucial to get chromatographic fingerprints shown in

Figure 1. Marker profiling by FT-IR) spectroscopy is a rapid, non-destructive analytical method used to produce molecular fingerprint of a phytochemically active molecules. A few important medicinal plants, and their quality evaluation using FT-IR method are shown in Table 4. GC-MS study is used to qualitative component identification, component separation, and quantification of various volatile and non-volatile substances are all included in a single analysis. Some important medicinal plants and their quality evaluation using GC-MS method have been shown in Table 5. Assuring quality control of medicinal plants begins with the identification of the purported plant. In botany, unequivocal nomenclature plays a key role for the precise definition of the vegetal material used in botanical medicines and food supplements, or plants studied by phytochemists. Thus, quality evaluation, validation, chemoprofiling, characterization and standardization are essential tech for determining and quantifying of the active phytomolecule(s) and linking the chemical properties to the pharmacological activities.[36,37]

CONCLUSION

There are numerous factors such as pesticides residue, toxins content, the heavy metals contamination, good agricultural practice, good manufacturing practice, etc. which are affect the quality, safety, and efficacy of medicinal plant materials and its products. Different chromatographic and spectroscopic evaluation leads to increase in the quality and safety of medicinal plants. Standardization is the analytical approach for maintaining the quality, safety, potency and consistency of phytomarkers of herbal products and its formulations. This quality control and standardization techniques will provide required potency, safer and effective use and treatment of herbs and herbal products which will provide a method of well-being for mankind and society.

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