

A review – On different evaluation methods of crude drugs

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Abstract

Evaluation is a systematic process utilized to ascertain quality, cleanliness in addition to authenticity of unrefined medications using defined standards. It is essential to ensuring that drugs used in herbal and traditional medicine are safe, effective, and of good quality. The main methods of evaluation include organoleptic, microscopic, physicochemical, and biological evaluations. Organoleptic evaluation involves assessing the drug by its color, odor, taste, and texture. Microscopic evaluation helps in identifying structural and cellular features. Physicochemical evaluation includes testing parameters like ash value, moisture content, and extractive value. Biological evaluation determines the pharmacological activity and therapeutic potential of the drug. The selection of evaluation methods depends on the nature of the crude drug, the type of information required, and the regulatory standards to be followed. The aim of crude drug evaluation is to guarantee the identity, purity, security and effectiveness of natural goods. Proper evaluation of crude drugs provides several benefits, such as prevention of adulteration, assurance of consistent quality, accurate identification, and improved therapeutic effectiveness. Overall, systematic evaluation helps in maintaining the reliability and standardization of herbal medicines used in healthcare.

Keywords: Crude drug evaluation, organoleptic evaluation, microscopic evaluation, physicochemical evaluation, biological evaluation, quality control, standardization, purity, authentication

Introduction

Historically, when it comes to the uneven makeup of herbal remedies and the blending from the same species and sharing similar physical traits, making its challenging as an recognize moreover classify organic medications. Different quality control tests are used to standardize herbal medicines or products in accordance with AYUSH guidelines ^[1].

Crude drugs definition

Natural substances obtained from plants, minerals, or creatures that have not undergone chemical modification are known as crude drugs. They usually stay in their natural or minimally processed state after being gathered, cleaned, and dried. Animal crude drugs can be glands, secretions, or tissues, whereas plant-derived crude drugs can be leaves, roots, bark, flowers, fruits, or seeds. This also includes minerals that are used in their natural state. These raw materials are the foundation for making pharmaceutical products, whose natural chemical components determine their therapeutic effects ^[2, 3].



Fig 1: crude drugs

Origin of crude drugs

Crude drugs are categorized according to their natural origin, which may be marine, mineral, plant, or animal. The

kind of active ingredients and how they are used in medicine are determined by these sources ^[4].

Plants Origin

The earliest source of natural medications is plants. Approximately 25% of the medications that are prescribed originated from plants, with the majority of these active compounds currently in use. The World Health Organization (WHO) considers many more crude drugs to be basic and necessary for primary health care. Additionally, natural precursors are used to make a significant number of synthetic drugs. As a result, plants offer a vast reservoir of phytochemical structures that are rich, intricate, and incredibly diverse and are unlikely to be produced solely in lab settings. For instance, vincristine, from *Cinchona* species, quinine and quinidine, and *Digitalis* species' digoxin and *Papaverum somniferum*'s morphine and codeine.

Animal Origin

One of the most intriguing sources of many medications is animals. Examples include the venom of snakes, cochineal carminic acid, sheep oil, the wax produced by bees, cod liver oil of sharks, bufalin from toads, insulin from animal pancreas, and musk.

Mineral Origin

A mineral is a naturally occurring material with an ordered atomic structure, a solid and stable state at room temperature, and a chemical formula that can be used to represent it. Minerals are typically biogenic. The majority of minerals that occur naturally are utilized in extremely pure form in medicine. For instance, calamine is used as an anti-itching agent, shilajit is used as a tonic, and sulfur is a crucial component of some bacteriostatic formulations.

Marine Origin

Both in their natural state and as models for synthetic modification, bioactive compounds derived from marine flora and fauna have been used extensively in the past. Currently being studied are several molecules that been split off from different marine organisms, including microorganisms, algae, fungi, invertebrates, and vertebrates. Thus far, over 10,000 compounds from marine organisms have been isolated. Out of over 25,000 plants, only 10% have had their biological activity examined. For instance, carrageenans, also known as Red seaweeds contain a family of linear sulfated polysaccharides called carrageenins and agar-agar is a gelatinous material made by boiling a polysaccharide fraction from red algae [5].

Evaluation of crude drugs

Drug evaluation is the approach to verifying and appraising a drug's identity, grade and integrity while also looking for signs of adulteration. The estimation of the pharmacologically active elements in the crude medicinal substance, morphological and microscopy analysis, physical and chemical analysis, and evaluation of the drug's pharmacological and biological behavior are also included [6].

Importance of crude drug evaluation

Standardization

Standardization of herbal remedies is made possible by the analysis of crude drugs. This makes dosing and treatment consistency more dependable by guaranteeing that the same quantity of active ingredients is present in every batch of a product.

Quality control

Crucial to the analysis of crude drugs is quality control. The Caliber of the product preserved and the possibility of negative Influences is decreased by detecting and managing contaminants, impurities, or substitutions.

Safety

It is crucial to check crude medications for toxins and other impurities to ensure that they are safe to take. The risks to health that come with using herbal remedies are reduced thanks to toxicological research.

Efficacy

When evaluating the medicinal effectiveness of raw plant materials, it is necessary to know the active ingredients and their concentrations. By using this information, medical professionals can make well-informed treatment decisions [7].

Macroscopic / Organoleptic evaluation

The unique characteristics of any drug as experienced by the senses are known as the organoleptic property. It describes judging a medication by its look, color, taste, texture, and odor. These characteristics were ascertained using the techniques Wallis described [8].

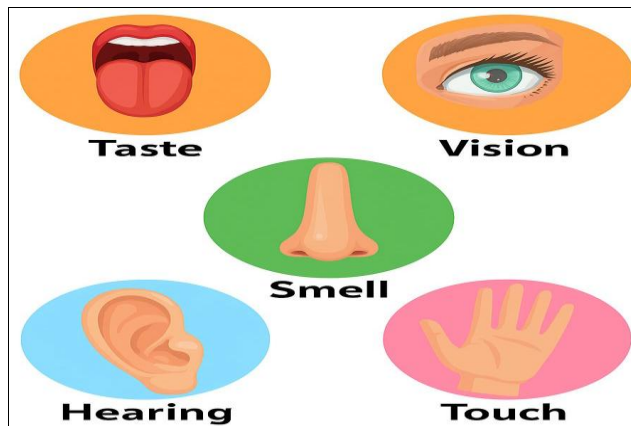


Fig 2: Organoleptic evaluation of crude drugs by sensory organs

Colour

Colour of a crude drug provides a visual clue about its identity, purity, and age. It can be natural or due to pigments, volatile oils, or chemical constituents.

Examples

Cinchona bark – brownish-grey
 Mature leaves – green
 Clove buds – dark brown
 Turmeric rhizome – yellow-orange

Odour

Odour is a distinct smell perceived by the olfactory senses, caused by volatile oils or other aromatic constituents.

Types of odour

Aromatic (clove, cinnamon)
 Fruity (orange peel)
 Nauseating (castor oil)
 Characteristic (garlic, asafoetida)

Examples

Clove – strong aromatic odour
 Garlic – pungent odour due to sulfur compounds

Taste

Taste is perceived through the taste buds of the tongue and helps to differentiate crude drugs.

Types of taste

Bitter (quinine, neem)
 Sweet (liquorice)
 Sour (tamarind)
 Pungent (ginger)
 Astringent (clove, myrobalan)
 Tasteless (tragacanth gum)

Examples

Quinine bark – intensely bitter
 Liquorice root – sweet
 Ginger rhizome – pungent

Texture

Texture refers to the surface characteristics of a crude drug such as smoothness, roughness, hardness, or brittleness — perceived by touch or breaking.

Examples

- Senna leaves – brittle
- Cinnamon bark – rough
- Clove – hard

Shape and shape

The size and shape of a crude drug are important macroscopic characteristics used to help in identification, standardization, and detection of adulteration. These features depend on the part of the plant used (root, leaf, bark, fruit, seed, etc.) and its maturity or method of collection [9].

Microscopic evaluation

Another method is to examine crude drugs under a microscope. Help from pharmacology, which can be very beneficial when it comes to standardizing medicinal plants. A cross-cut view, lengthwise slice, radial longitudinal plane, tangential longitudinal plane, along with microscopic examination of powdered material, can all be employed in such investigations to recognize genuine plant drugs. These anatomical preparations, when treated with specific coloring agents, help reveal different structural components and allow identification based on their characteristic tissue features. Depending on the sample’s hardness, specimens were soaked in water or another solvent before being cut into transverse sections with sharp razor blades. Microtome sectioning was used to cut a small number of microscopic sections. The specimen’s microscopical sections were mounted in a variety of permanent and temporary forms and subjected to microscopical examination. To distinguish between various cell wall components, transverse sections were stained with various reagents [10].

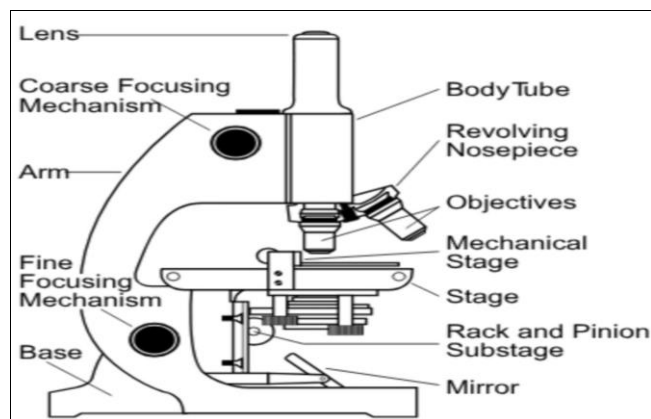


Fig 3: Microscope

Stomata

A key component of photosynthesis, transpiration, and plant adaptation, stomata are microscopic pores found primarily on the epidermis of leaves and stems. They are surrounded by specialized guard cells that control gas exchange and water loss. Stomata are categorized into several types. Stomatal types can be distinguished according to the number and pattern of supportive epidermal units positioned around the pore-forming cells. These include: Actinocytic, where the stoma is encircled by radiating accessory units; Paracytic, in which a pair of flanking epidermal partners aligned lengthwise with the opening elements is present; Diacytic, characterized by two adjoining epidermal helpers whose shared wall is set at a right angle to the pore cells;

Anomocytic, identified by the absence of clearly differentiated surrounding partners; and Anisocytic, where a trio of unevenly sized accessory units occurs near the stoma [11].

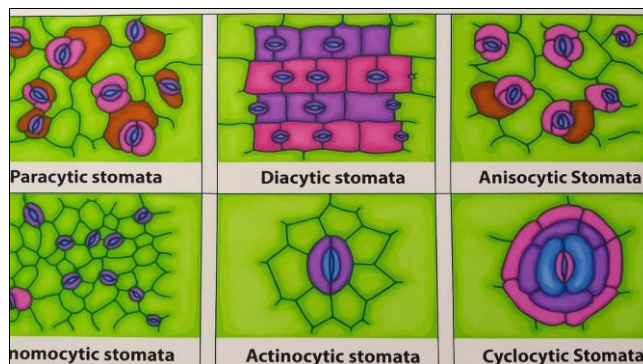


Fig 4: Types of stomata

Trichomes

Trichomes come in a wide variety of morphologies and are found on the surface of various organs and tissues in different plants. Trichomes can be classified as either unbranched or branched, single-celled or multicellular and, depending on various traits and roles, glandular or non-glandular. Additionally, trichomes come in a variety of shapes, including scale, hook, star, and head. Theobald and Based on the leaf distributions, Barthlott further classified trichomes into three groups: glandular, tiny, and large trichomes. Small trichomes are found in the stomatal membranes, while large trichomes are primarily found in the vascular bundles, abaxial surface, and margins paracellular, and glandular trichomes are typically uniformly dispersed throughout the leaf surface’s sub epidermal tissue [12].

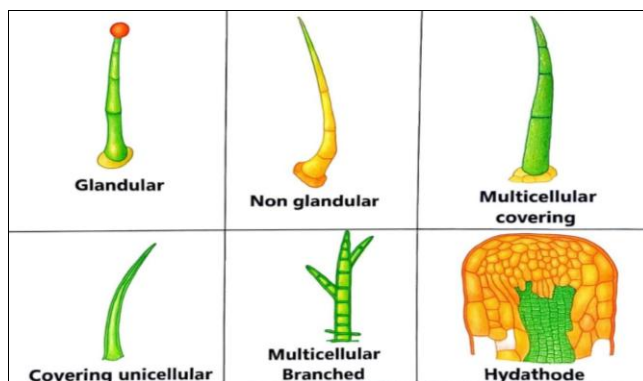


Fig 5: Types of trichomes

Calcium oxalate crystal

Many plant organs contain calcium oxalate formations, which may occur as aggregated spheres (druses), elongated facets (prisms), pointed rod-like bodies, bundles of sharp needles, or fine crystalline grains. More than 215 families of advanced plants are known to possess these calcium oxalate structures. Their presence in plant tissues is associated with several physiological and protective roles, such as detoxifying excess minerals, strengthening internal tissues, regulating light distribution, maintaining calcium balance, serving as a reserve of calcium, eliminating surplus oxalate, and offering protection against insects and grazing animals. Because these formations are often associated with irritating substances or proteolytic compounds, they help the plant

deter herbivores. Additionally, the piercing action of their slender, spear-like mineral bodies can discourage animals that attempt to feed on the plant [13].

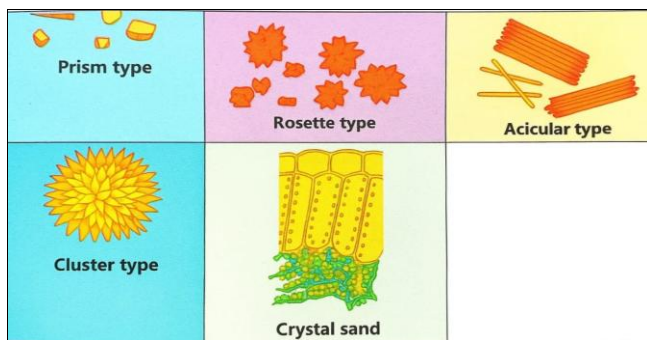


Fig 6: Types of calcium oxalate crystal

Leaf constant

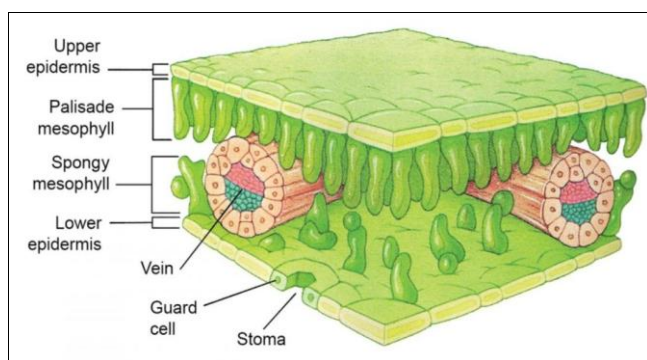


Fig 7: Transverse section of leaf

Stomatal number

The average number of stomata in a leaf's upper and lower epidermis measured in a 1 mm square is known as the stomatal number (SN) [14].

Stomatal index

The proportion of a leaf's epidermis' final divisions that can develop into stomata is measured by the stomatal index. The stomatal index can be found using the formula below:

$I = S / E + S \times 100$, where I is the stomatal index, S is the number of stomata per millimeter, and E is the number of normal epidermal cells per millimeter [15].

Palisade Ratio

The average number of palisade cells under a single epidermal cell is known as the palisade ratio. Four continuous epidermal cells are taken out for analysis. The following formula was used to calculate the Palisade Ratio: [Number of Palisade Cells / Number of Epidermal Cells] [16]

Vein islet Number

An essential microscopic constant for identifying and evaluating the quality of leaf-based crude medications is the vein-islet number. The tiny, polygonal section of leaf tissue bounded by the delicate vein branches is known as a vein islet. The average number of these enclosed mesh-like areas within one square millimeter of the leaf surface is counted in order to calculate this parameter. The vein-islet number stays comparatively constant due to the genetic regulation of each plant species' vein pattern, making it a dependable diagnostic characteristic for differentiating closely related

species, identifying adulteration, and promoting the standardization of herbal materials. When macroscopic features are inadequate or when visual identification is challenging due to powdered leaves, this measurement is especially helpful [17].

Vein termination number

It has been shown that each plant species has a fixed number of veinlet's or vein-islets per unit area of leaf surface, which can be used as a trait to identify the species. Vein terminations are found halfway between the midrib and the margin, per square millimeter of the leaf surface. The last free veinlet termination is known as a vein termination [18].

Quantitative microscopy

Lycopodium spore method

This numerical constant allows one to calculate the equivalent mass corresponding to any counted quantity of these units viewed through a microscope, regardless of the magnification settings used. Regardless of the magnification settings, this numerical constant enables one to determine the equivalent mass corresponding to any counted quantity of these units viewed through a microscope [19].

Physical evaluation

The process of evaluating a drug based on important physical characteristics or physical attributes of the active ingredient is known as physical evaluation. Examined are the following: solubility, ash value, volatile oil content, refractive index, melting point, moisture content, and foreign organic matter [20].

Moisture content

As excessive moisture can promote microbial growth, fermentation, and enzymatic degradation, ultimately reducing the stability and therapeutic quality of herbal materials. The moisture level of a drug indicates the amount of water retained within its tissues, and controlling this parameter helps prevent contamination, spoilage, and loss of active constituents. Common methods used for assessing moisture include loss on drying, toluene distillation, and Karl Fischer titration, each chosen based on the nature of the plant material and the sensitivity required. This evaluation ensures that crude drugs are stored safely, remain chemically stable, and meet quality standards for further processing or formulation [21].

Melting point

A solid transition into a liquid once it reaches its characteristic fusion temperature, and many plant-derived constituents display stable and well-defined thermal softening characteristics. Because natural drug materials contain a mixture of compounds, they are often described by a temperature interval of fusion rather than a single value. This thermal property is valuable for assessing the identity and purity of various natural substances. For instance, natural wax from honeycombs liquefies around 62–65°C, lanolin softens and flows at approximately 34–44°C, and agar begins to liquefy near 85°C [22, 23].

Solubility

When it comes to determining the purity of crude drugs and spotting adulteration, their solubility properties are crucial. The evaluation of oils and oleoresins is aided by their

unique solvent-dependent behaviors. For instance, Peruvian balsam dissolves in chloral hydrate solution and produces turbidity when combined with higher concentrations of the solvent, whereas Colombo resin is soluble in light petroleum. Castor oil helps verify its authenticity because it dissolves in half the volume of light petroleum and creates turbidity with twice as much. Similarly, three volumes of 90% alcohol can dissolve pure castor oil; however, adulteration frequently makes it more soluble. While their salt forms easily dissolve in polar solvents, alkaloidal bases are typically soluble in organic solvents. When it comes to fraud detection and crude drug standardization, these solubility patterns serve as diagnostic tools [24, 25].

Optical rotation

By changing its orientation, some crystallized substances and specimens that have too much among a chiral molecule's enantiomers is capable of blocking the polarized light plane. This is known as optical rotation, and any material that possesses this characteristic is considered optically active. The compounds known as enantiomers are distinguished by their capacity to rotate the polarized light plane in directions Dextrorotatory (d) is another name for this movement, which is clockwise or right-hand. or (+). Another equivalent is the enantiomer levorotatory, which is known as such because it propagates the plane of polarized light counterclockwise. There is a correlation between the quality and the degree of orientation, which can vary [26].

Refractive index

Studying the refractive index of medicinal oils is essential for a variety of applications. The conventional technique for calculating the refractive index, Abbe's refractometer, has limitations of its own, including being heavy and bulky, only being effective with transparent liquids, and having a lower degree of accuracy. calculations of the refractive index by. Various techniques have been documented in the literature. A different refractive index sensor based on optical fibers has reportedly been developed in light of the aforementioned [27].

Ash value

The remnants remaining after burning are referred to as crude drugs' ash content. It typically identifies and adheres to the drug's naturally occurring inorganic salts, but it may also include inorganic substances added for adulteration purposes. The amount of ash in different medications varies significantly, although there are fine limits to this variation.

Determination of total ash value

Before being weighed, two grams of the finely ground material were placed in a crucible and allowed to air dry after being ignited and cooled to 450°C. It separated the spark until the weight remained constant. By comparing the air-dried sample to the reference, the ash percentage was determined.

Determination of water-soluble ash

The percentage of total ash that dissolves in water is known as water-soluble ash, and it is determined by boiling the entire amount of ash with distilled water, filtering it, and then burning the insoluble material that remains. The amount of water-soluble ash, which indicates the presence

of naturally occurring soluble minerals and aids in detecting the addition of water-insoluble adulterants, is indicated by the difference between the total ash and the residue left over after filtration.

Sulphated residue

A pair of grams of the rough, air-dried Powder samples were meticulously collected. The mixture was then heated to 450 degrees Celsius in a hot air oven for at least three hours before being cooled, and four to five drops of concentrated sulfuric acid were added. Again, concentrated H₂SO₄ was added in drops of four to five, activated, cooled, and weighed [28, 29].

Calculating acid-insoluble ash

The amount of ash that is still insoluble in diluted hydrochloric acid is measured. The total ash is treated with diluted HCl for this test, then it is filtered, cleaned, and the residue is ignited to a constant weight. The acid-insoluble residue that results is primarily silica, particularly from sand, soil, or earthy contaminants. As such, it is a sensitive indicator of crude drug adulteration, inadequate cleaning, or poor handling [30].

Extractives value

The approximate weights of the chemical components of the crude drug that can be extracted under different solvent environments are represented by these [31]. Value extraction is helpful in figuring out of illicit substances and provides details regarding the characteristics of the current chemical constituents. It should be possible for the extraction solvent to dissolve the necessary amounts of the materials [32].

Volatile oil content

The odorous principal of aromatic drugs, which are volatile oils, gives them pharmaceutical significance. These crude drugs are standardized based on the volatiles they contain [33].

Foreign organic matter

The parts of the crude drug's organs that are not mentioned in the definition and description are referred to as foreign organic matter. The maximum amount of foreign organic matter is specified in the crude drug monograph. The quality of the medication declines if it exceeds the limits. Recognizing foreign issues, A thin layer of the drug sample (100–500 g) or the bare minimum recommended by the monograph should be spread out. The foreign object should be identified by inspection using the unaided eye or a 6x lens. Once it has been separated and weighed, determine the percentage present [34].

Chemical Evaluation

Analyzing the chemical components found in the raw plant material is part of the chemical evaluation of crude drugs. This procedure is essential for evaluating the potential, quality, and authenticity of medicinal plants' therapeutic value. The chemical compounds found in crude drugs are identified and quantified using a variety of analytical techniques. These are the main techniques for assessing crude drugs chemically [35].

Detection of alkaloids

The identification of alkaloids in crude drugs requires precipitation reactions between alkaloidal bases and specific

complexing reagents. After the plant extract is acidified with diluted hydrochloric acid to convert the alkaloids into their soluble salt form, different reagents specific to alkaloids are applied in general screening.

Mayer's Test

yields a cream-white precipitate that indicates the presence of alkaloids when potassium mercuric iodide reagent is used.

Wagner's Test

Uses potassium iodide solution with iodine, which gives rise to a reddish-brown or brown precipitate in the presence of alkaloids.

Hanger's Test

A yellow crystalline precipitate containing alkaloidal compounds is produced by Hager's Test using a saturated picric acid solution.

Dragendroff's Test

Bismuth potassium iodide is present in one of the most sensitive tests, which confirms even trace amounts of alkaloids by producing an orange or reddish-brown precipitate [36, 37].

Detection of carbohydrates

Color-based qualitative tests that determine both the general presence and particular reducing properties of carbohydrates in crude drugs are used to detect them.

Molisch's Test

The Molisch Test, a universal test for carbohydrates, involves adding a few drops of Molisch reagent (α -naphthol) to the sample followed by concentrated sulfuric acid; the formation of a purple-violet ring at the interface confirms carbohydrates due to dehydration to furfural derivatives

Benedict's test

Reducing sugars are further identified using Benedict's Test, in which the sample is heated with Benedict's reagent, producing a green, yellow, or brick-red precipitate depending on the amount of reducing sugar present, reflecting the reduction of cupric ions to cuprous oxide.

Fehling's Test

The Fehling's Test distinguishes reducing sugars by boiling the sample with Fehling's A and B solutions; a brick-red cuprous oxide precipitate indicates the presence of reducing carbohydrates [38].

Identifying glycosides

Adapted Bornträger's Exam

The Modified Bornträger's Test is an essential qualitative method for assessing and validating crude medications that contain anthraquinone C-glycosides, which normally do not react to the standard Bornträger's reaction due to the resistance of their glycosidic linkage to straightforward alkaline hydrolysis. This modified method helps to oxidize and hydrolyze the C-glycosidic bond, releasing free anthraquinone aglycones, by first boiling the powdered medication with diluted hydrochloric acid and ferric chloride. After cooling, an organic solvent such as benzene

or chloroform is used to extract the mixture, and potassium hydroxide or ammonia is used to shake the organic phase that has been separated. When the alkaline layer becomes pink, red, or rose-violet in color, anthraquinone derivatives are present [39].

Identifying saponins

Froth Test

Using a similar principle but a more precise serial dilution method to grade froth height, the extract is shaken in ten test tubes with progressively smaller volumes of the sample. The highest dilution that still yields at least 1 cm of stable froth is noted as the froth index, which aids in comparing the saponin content of various crude medications.

Foam Test

Half a gram of water was shaken with two milliliters of the extract. If the resulting foam persists for ten minutes, saponins are present [40].

Biological evaluation

The assessment of a medication is based on its distinct pharmacological and biological properties. The specific type of constituents found in the plant extract are actually what cause this activity. Both intact and isolated organs from living animals were used for testing. One way to assess the potency of drug preparation is through bioassays [41]. Biological evaluation of crude drugs involves assessing their pharmacological actions, potency, and safety using biological systems such as cultured cells, isolated tissues, or whole animals, providing essential evidence that complements botanical and chemical analyses. It is conducted to confirm therapeutic claims, identify toxic effects, ensure quality control, and guide standardization by linking biological activity with phytochemical markers. *In vitro* assays (such as antimicrobial, antioxidant, enzyme inhibition, cytotoxicity and receptor-based assays) offer rapid screening and mechanistic insights, while *ex vivo* tissue preparations help determine direct organ-level effects, and *in vivo* studies measure integrated responses—including analgesic, anti-inflammatory, antidiabetic, or toxicity outcomes—to determine effective and safe dose ranges. Proper evaluation requires authenticated plant material, standardized extraction, use of positive and negative controls, dose-response testing, and appropriate statistical analysis, while recognizing that crude extracts are complex, may show batch variation, and that *in vitro* activity does not always translate into clinical efficacy; ethical guidelines and regulatory frameworks (including WHO standards) also guide animal use and safety assessment [42].

Conclusion

A fundamental component of pharmacognosy and herbal quality assurance, the thorough evaluation of crude drugs serves as the foundation for guaranteeing the authenticity, purity, safety, and therapeutic dependability of natural medicines. The scientific validation of crude drugs has grown in importance as traditional and herbal remedies continue to gain popularity worldwide. This review highlights that in order to achieve dependable standardization, an efficient evaluation system needs to be multifaceted, combining traditional knowledge with contemporary analytical tools. The first step in determining the identity and therapeutic significance of crude drugs is to

comprehend their natural origins, whether they come from plants, animals, minerals, or marine organisms. The material's chemical profile and pharmacological potential are determined by these origins. Despite their simplicity, organoleptic and macroscopic evaluations provide crucial initial data by analyzing sensory and physical attributes like color, taste, odor, size, shape, and texture. During initial handling, these characteristics serve as quick markers of authenticity and aid in preventing egregious adulteration. By identifying structural details that are not discernible through external observation, microscopic evaluation offers a deeper level of confirmation. For the identification of crude drugs, characteristics like stomatal patterns, trichome structures, calcium oxalate crystal formations, cell arrangements, and vascular elements are definitive diagnostic markers. Stomatal index, palisade ratio, vein-islet number, and specialized techniques like the Lycopodium spore technique are examples of quantitative microscopic constants that provide quantifiable, species-specific information that improves identification accuracy and reduces substitution risk. The physical characteristics and chemical consistency of crude drugs are determined by physicochemical analysis, which is equally important. Important information about purity, quality, and stability can be found in parameters like ash values, extractive values, solubility behavior, moisture content, refractive index, melting point, volatile oil content, and foreign organic matter. By identifying contamination, incorrect processing, and adulteration, these assessments help guarantee that crude medications meet pharmacopeial requirements. By locating and verifying the presence of biologically active components that are responsible for therapeutic activity, chemical evaluation makes a further contribution. Alkaloids, glycosides, saponins, carbohydrates, and other phytochemical tests support the standardization of herbal materials and confirm their chemical composition. These tests guarantee that crude drugs are free of hazardous or superfluous additives and contain sufficient amounts of active compounds. The last and most important stage is biological evaluation, which uses the pharmacological effects of crude drugs to show their functional significance. By evaluating activities like antimicrobial, anti-inflammatory, antioxidant, analgesic, and cytotoxic responses, *in vitro*, *ex vivo*, and *in vivo* studies aid in the verification of therapeutic claims. These assessments support the creation of standardized herbal formulations by confirming efficacy and assisting in the determination of dose, potency, and safety parameters. A comprehensive and scientifically sound system for assessing crude drugs is produced by combining organoleptic, microscopic, physicochemical, chemical, and biological techniques. Such an integrated approach ensures accuracy in identification, consistency in quality, and reliability in therapeutic performance. The importance of thorough evaluation and standardization increases with the growth of the worldwide market for herbal medicines.

References

1. Kumar S, Jaiswal AK, Aggarwal M, Ekbal R, Gaurav. A review on quality control aspects of Indian medicinal plants. *Pharmacognosy Reviews*,2023;17(34):276–286.
2. Heinrich M, Barnes J, Prieto-García J, Gibbons S, Williamson E M. *Fundamentals of pharmacognosy and phytotherapy* (3rd ed., p. 3), 2018.
3. Orhan İE. Pharmacognosy: Science of natural products in drug discovery. *BioImpacts*,2014;4(3):109–110.
4. Paradkar SR. Identification and standardization of crude drugs according to Ayurvedic and modern parameters. *Research, Reviews: A Journal of Pharmacognosy*,2017;4(1):11–16.
5. Deore SL. Sources of crude drugs. In: *Pharmacognosy and Phytochemistry*. BSP Publications, 2022, 1–10.
6. Kokate CK, Purohit AP, Gokhale SB. *Pharmacognosy*. 49th ed. Nirali Prakashan, Pune, 2014, 7–9.
7. Dobson R. Analysis methods and importance of crude drugs in modern medicine. *Pharmaceutical Analytical Chemistry*,2023;8(5):212.
8. Gupta M, Sumaiya S, Ali S, Naved T, Sharma A, Ahmad A, *et al.* Pharmacognostical and phytochemical evaluation of an Unani polyherbal formulation Dawa ul Kurkum by HPTLC. *Separations*,2023;10(2):89.
9. Wallis TE. *Textbook of Pharmacognosy*. 5th ed. CBS Publishers Distributors, New Delhi, 2005, 82–85.
10. Singh RJ, Nautiyal P, Kumar A, Malik JK. Microscopic study of crude drugs. *Saudi Journal of Medical and Pharmaceutical Sciences*,2020;6(3):297–305.
11. Prabhakar M. Structure delimitation nomenclature and classification of stomata. *Journal of Integrative Plant Biology*,2004;46(2):242–252.
12. Wang X, Shen C, Meng P, Tan G, Lv L. Analysis and review of trichomes in plants. *BMC Plant Biology*,2021;21(1):70.
13. Konyar ST, Tumer M. Occurrence types and distribution of calcium oxalate crystals in plants. *Plant Ecology and Evolution*,2014;147(1):59–68.
14. Khan SA, Khan MA. Pharmacognostic evaluation of *Rhus succedanea* var. *himalaica* leaves for quality control. *Pharmacognosy Journal*,2016;8(6):482–487.
15. Kumar D, Kumar K, Kumar S, Kumar T, others. Pharmacognostic evaluation of leaf and root bark of *Holoptelea integrifolia* Roxb. *Asian Pacific Journal of Tropical Biomedicine*,2012;2(3):169–175.
16. Sarkar RD, Pradhan R, Samanta A. Micro-qualification by estimation of leaf constants of the ethnobotanical plant *Costus igneus* by optical microscopical analysis. *World Journal of Biology and Pharmaceutical Health Sciences*,2023;12(1):1–8.
17. Kharat R, Kazi S, Bais S. Review on assessing the quality of herbal drugs and formulations. *Research and Reviews Journal of Pharmacognosy and Phytochemistry*,2023;11(1):9–15.
18. Babu CR, Sanyal S. An automated or semi-automated identification system using venation pattern to delimit Indian leaf drugs. *Journal of Biosciences*,2011;36(4):817–826.
19. Wanjari AS, Bhutada S, Desai P, Chouragade NB, Wanjari DS. Standardization of herbal products in relation to Indian market Lycopodium spore method and other quantitative microscopy techniques. *Research Journal of Pharmacognosy and Phytochemistry*,2016;8(4):245–251.
20. Kazi S, Bais S, Kharat R. An updated review on quality aspects of herbal drug and its formulations. *International Journal of Pharmacognosy and Life Science*,2023;4(1):32–36.
21. Mukherjee PK, Nema NK, Maity N, Sarkar BK. Phytochemical and therapeutic potential of medicinal plants a review of standardization and quality control

- practices. *Journal of Ethnopharmacology*,2012:140(3):483–495.
22. Sharma A, Shukla A. Evaluation parameters for standardization of herbal drugs an overview. *Journal of Pharmaceutical Sciences and Research*,2015:7(4):200–204.
 23. Dixit VK, Yadav NP. Recent approaches in herbal drug standardization. *Indian Journal of Pharmaceutical Sciences*,2008:70(3):304–315.
 24. Physical evaluation. *Pharmacy180*, n.d. <https://www.pharmacy180.com/article/physical-evaluation-73/>
 25. Kaneria M, Chanda S. Phytochemical and pharmacognostic evaluation of leaves of *Psidium guajava* L. *Journal of Pharmacognosy and Phytochemistry*,2011:3(1):15–23.
 26. Chakole CM, Bodhankar SS, Borkar AA, Badwaik CB. Standardisation and evaluation methods for traditional medicinal plants. In: *Futuristic Trends in Herbal Medicines and Food Products*. IIP Series, 2024, 93–103.
 27. Rao SV, Srinivasulu S. Determination of refractive index of certain medicinal oils. *International Journal of Research*,2018:7(10):1352–1356.
 28. Jain S, Yadav JS, Shukla K. Evaluation of antimicrobial and wound healing activity of lab purpose. *World Journal of Pharmaceutical and Life Sciences*,2020:6(6):183–195.
 29. Ndamitso MM, Jimoh TO, Abubakar MB. Comparative assessment of physico-chemical and heavy metals content of selected herbal plants. *International Research Journal of Pharmacy*,2013:4(3):123–127.
 30. Adebayo AH, Tan NH, Akindahunsi AA, Zeng GZ. Anticancer and antiradical scavenging activity of *Ageratum conyzoides* extract. *African Journal of Biomedical Research*,2010:13(3):213–219.
 31. Shinde M, Bais SK, Devmare D. Review on standardization of herbal drug and formulation. *International Journal of Pharmacognosy and Life Science*,2023:4(1):20–24.
 32. Ahmad T, Singh SB, Pandey S. Phytochemical screening and physicochemical parameters of crude drugs a brief review. *International Journal of Pharma Research and Review*,2013:2(12):53–60.
 33. Ahmed S, Hasan MM. Standardization of crude drugs a precise review. *World Journal of Pharmaceutical Research*,2015:4(10):155–174.
 34. Shah D, Patel J, Parikh K. Evaluation of crude drugs mono or polyherbal formulation. *PharmaTutor*, 2012. <https://www.pharmatutor.org/articles/evaluation-crude-drugs-mono-polyherbal-formulation>
 35. Sonawane SD, Bais SK, Dhumal DD. A review different evaluation method of crude drugs. *International Journal of Pharmacy and Herbal Technology*,2024:2(1):1295–1322.
 36. Abubakar AR, Haque M. Preparation of medicinal plants basic extraction and fractionation procedures for experimental purposes. *Journal of Pharmacy and Bioallied Sciences*,2020:12(1):1–10.
 37. Sasidharan S, Chen Y, Saravanan D, Sundram KM, Yoga Latha L. Extraction isolation and characterization of bioactive compounds from plants' extracts. *African Journal of Traditional Complementary and Alternative Medicines*,2011:8(1):1–10.
 38. Sharma A, Gupta R. Phytochemical screening of medicinal plants for primary and secondary metabolites. *Asian Journal of Pharmaceutical and Clinical Research*,2015:8(5):68–72.
 39. Pandey A, Tripathi S. Concept of standardization extraction and pre-phytochemical screening strategies for herbal drug. *Journal of Pharmacognosy and Phytochemistry*,2014:2(5):115–119.
 40. Parekh J, Chanda S. *In vitro* antibacterial activity of the crude methanol extract of *Woodfordia fruticosa* Kurz. *Indian Journal of Pharmacology*,2007:39(4):203–207.
 41. Kulkarni K, Jagtap G, Magdum S. A comprehensive review on herbal drug standardization. *American Journal of PharmTech Research*,2019:9(3):98–122.
 42. Fabricant DS, Farnsworth NR. The value of plants used in traditional medicine for drug discovery. *Environmental Health Perspectives*,2001:109(1):69–75.