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Integrated Pharmacognostic and Phytochemical Profiling of Selected Medicinal Plants for the Development of a Polyherbal Formulation

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Abstract: *The present study aimed to systematically evaluate selected medicinal plants— (Piper nigrum), (Phyllanthus emblica), (Zingiber officinale), (Cinnamomum zeylanicum), and (Ocimum basilicum)through integrated pharmacognostic, phytochemical, and antioxidant analyses to support the development of an effective polyherbal formulation. Macroscopic examination confirmed the characteristic sensory and morphological attributes of each plant, ensuring proper identification for quality control. Microscopic evaluation further verified authentication by revealing diagnostic features such as stone cells and starch grains in Black pepper, rosette crystals in Amla, oleoresin cells in Ginger, sclerenchyma in Cinnamon bark, and peltate glandular trichomes in Basil. Pharmacognostic parameters including moisture content, ash values, and extractive values showed variations reflective of each plant's unique chemical nature, with methanol extractives generally higher, indicating the abundance of alcohol-soluble phytoconstituents.Preliminary phytochemical screening confirmed the presence of bioactive compounds such as alkaloids, flavonoids, glycosides, tannins, diterpenes, carbohydrates, proteins, essential oils, and phenols across the samples, supporting their traditional medicinal uses. Antioxidant assays (DPPH, ABTS, and Total Antioxidant Capacity) demonstrated that Amla possessed the highest free-radical scavenging activity, followed by Cinnamon and Basil. The polyherbal extract exhibited synergistic antioxidant activity, exceeding several individual extracts but remaining slightly lower than Amla alone. Compared with standard ascorbic acid, all extracts showed lower activity, validating the reliability of the methods used.Overall, this integrated assessment scientifically supports the suitability of these plants for polyherbal formulation development. Their diverse phytochemical profiles and antioxidant properties highlight their therapeutic relevance and potential application in natural health products*

Keywords: Pharmacognosy Phytochemical screening Antioxidant activity Polyherbal formulation Medicinal plants Amla Cinnamon Free radical scavenging

I. INTRODUCTION

Medicinal plants have been an integral part of traditional healing systems for centuries and continue to contribute significantly to modern pharmacotherapy.[1,2] In recent years, there has been a renewed global interest in plant-based medicines due to their broad therapeutic potential, cultural acceptance, lower incidence of side effects, and affordability compared to synthetic drugs.[3] The World Health Organization (WHO) estimates that more than 80% of the world's population relies on herbal remedies for primary healthcare, highlighting the importance of ensuring their safety, quality, and efficacy. To achieve this, systematic scientific evaluation through pharmacognostic, phytochemical, and bioactivity studies has become essential.[3]

Pharmacognosy plays a foundational role in the authentication and standardization of crude plant materials. Macroscopic and microscopic analyses provide reliable identification markers that prevent adulteration and ensure

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consistency in herbal formulations. Parameters such as moisture content, ash values, and extractive values help determine purity, stability, and the presence of essential phytoconstituents. These quality-control measures are crucial for maintaining therapeutic integrity, especially when multiple plants are combined in polyherbal formulations.

Phytochemical screening further enhances the understanding of medicinal plants by revealing the presence of bioactive compounds such as alkaloids, flavonoids, tannins, glycosides, phenolics, saponins, and essential oils. These compounds are responsible for various pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, and immunomodulatory effects. With increasing evidence linking oxidative stress to chronic diseases such as diabetes, cardiovascular disorders, neurodegeneration, and cancer, antioxidant-rich botanicals are gaining heightened research interest.[4,5]

Polyherbal formulations, which combine two or more medicinal plants, are believed to produce synergistic therapeutic effects by enhancing efficacy, reducing toxicity, and broadening the spectrum of action. However, the success of such formulations relies heavily on comprehensive evaluation of each plant's pharmacognostic and phytochemical characteristics. In this context, plants such as Black pepper (*Piper nigrum*), Amla (*Phyllanthus emblica*), Ginger (*Zingiber officinale*), Cinnamon (*Cinnamomum zeylanicum*), and Basil (*Ocimum basilicum*) have attracted significant attention due to their rich phytochemical composition and long-standing traditional use.

Amla is widely recognized for its exceptional antioxidant potential, attributed to its high vitamin C and polyphenol content. Ginger and Cinnamon are valued for their anti-inflammatory, antioxidant, and digestive properties, while Black pepper acts as a bioavailability enhancer. Basil offers additional antioxidant and antimicrobial benefits. Together, these plants have the potential to form a highly effective polyherbal formulation with promising health-promoting properties.

Therefore, the present study aims to conduct a comprehensive pharmacognostic evaluation, phytochemical screening, and antioxidant analysis of these selected medicinal plants. By integrating morphological, microscopic, chemical, and functional assessments, the research establishes a scientific foundation for developing a standardized, efficacious, and synergistic polyherbal formulation.[6]

II. MATERIALS AND METHODS

Collection and Authentication of Plant Materials

Fresh and dried plant materials of *Piper nigrum* (Black pepper), *Phyllanthus emblica* (Amla), *Zingiber officinale*(Ginger), *Cinnamomum zeylanicum* (Cinnamon bark), and *Ocimum basilicum* (Basil leaves) were procured from a certified herbal raw-material supplier. Each plant specimen was authenticated by a qualified botanist from the Department of Botany, and voucher specimens were deposited for reference. The collected samples were cleaned thoroughly to remove dust and foreign particles, shade-dried for 7–10 days, and then pulverized into coarse powder using a mechanical grinder. The powdered samples were stored in airtight containers until further analysis.

Preparation of Extracts

For extraction, 10 g of each powdered plant sample was macerated with 100 mL of methanol for 48 hours with occasional shaking. The mixtures were filtered using Whatman No. 1 filter paper, and the filtrates were concentrated under reduced pressure using a rotary evaporator. The dried extracts were stored at 4°C in amber-colored vials. A polyherbal extract was prepared by mixing equal proportions of the individual plant extracts before analysis.

Pharmacognostic Evaluation: Macroscopic and Microscopic Studies

Macroscopic examination involved observing sensory and physical characteristics such as shape, size, color, odor, and texture as per standard WHO guidelines. Microscopic analysis was carried out using transverse sections and powder microscopy. Thin sections of each plant part were prepared, stained with phloroglucinol–HCl and iodine, and examined under a compound microscope. Diagnostic structures such as stone cells, trichomes, fibers, oleoresin cells, calcium oxalate crystals, stomata, and vascular arrangement were identified and photographed.

Physicochemical Parameters

Physicochemical evaluation included determination of **moisture content**, **total ash**, **acid-insoluble ash**, **water-soluble ash**, and **extractive values** (water and methanol). Standard procedures outlined in the WHO and Indian Pharmacopoeia were followed. All experiments were performed in triplicate, and values were expressed as mean ± standard deviation.

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Preliminary Phytochemical Screening

Qualitative phytochemical screening of individual and polyherbal extracts was performed using standard reagents to detect the presence of alkaloids, flavonoids, glycosides, tannins, saponins, phenolics, proteins, carbohydrates, terpenoids, and essential oils. Tests such as Mayer's and Dragendorff's (alkaloids), Shinoda (flavonoids), Salkowski (terpenoids), Ferric chloride (phenolics), and Keller-Killiani (glycosides) were performed.

Antioxidant Assays

The antioxidant potential of all extracts was evaluated using **DPPH radical scavenging assay**, **ABTS radical cation decolorization assay**, and **Total Antioxidant Capacity (phosphomolybdenum method)**. Ascorbic acid was used as the standard reference. Extract solutions of varying concentrations (0.1–1.0 mg/mL) were prepared, and absorbance was recorded using a UV-Visible spectrophotometer. Radical scavenging activity (%) was calculated using standard equations, and results were expressed as mean ± SD.[7-12]

III. RESULT AND DISCUSSION

The macroscopic evaluation of the selected medicinal plants provided essential initial data regarding their identity and physical quality, serving as a crucial first step in quality control. This examination confirmed the plants' characteristic features, which are directly related to their established uses and commercial standards. Black Pepper was identified by its small, round, wrinkled black berries, possessing a characteristic strong, pungent odor and taste due to volatile oils like piperine. Amla showed the typical transition from its greenish-yellow fresh color to a brownish, shriveled dried form, with a defining sour and astringent taste indicative of its high tannin and vitamin C content. Ginger exhibited the expected irregular, branched rhizome structure with a strong, aromatic odor and pungent, slightly sweet taste, confirming the presence of gingerols and shogaols. Cinnamon was recognized by its distinct thin, brittle bark quills and characteristic sweet, warm, and highly aromatic properties due to cinnamaldehyde. Finally, Basil presented with oval leaves and a strong, clove-like odor and aromatic, slightly pungent taste, reflecting the presence of eugenol and other essential oils.

The microscopic evaluation of the selected medicinal plants revealed distinct structural characteristics that are crucial for their authentication and quality assessment. Black pepper showed polygonal epidermal cells with a thick cuticle, abundant parenchyma, starch grains, and stone cells, which are typical diagnostic markers of *Piper nigrum*. Amla exhibited polygonal epidermal cells, mucilage-containing parenchyma, and rosette-shaped calcium oxalate crystals, confirming the identity of *Phyllanthus emblica* as a tannin- and mucilage-rich fruit. Ginger displayed suberized cork cells along with abundant starch granules and oleoresin cells, consistent with the microscopic features of a rhizome. Cinnamon bark showed characteristic tangentially elongated cork cells, mucilage cells, and sclerenchymatousfibers in the secondary phloem. Basil differed from all other samples by exhibiting peltate and capitate glandular trichomes and numerous oil glands—structures commonly associated with essential oil–rich leaves. These diagnostic features collectively ensure the proper identification of each plant and help detect adulteration.

The pharmacognostic analysis further supported the quality and purity of the plant materials. Moisture content was within acceptable limits for all samples, ranging from 5.60% in Amla to 8.90% in Ginger, indicating reduced microbial susceptibility. Ash value variations suggested differences in mineral composition among the plants, with Basil showing the highest ash content and Amla the lowest. Acid-insoluble ash was highest in Cinnamon, likely due to natural siliceous matter in bark tissues. Extractive values indicated that methanol generally extracted more phytochemicals than water, demonstrating the presence of alcohol-soluble constituents such as flavonoids, phenols, resins, and essential oils. Basil displayed the highest water extractive value, suggesting that it contains more hydrophilic compounds than the other plants. These parameters collectively serve as important tools for standardizing raw herbal materials.

Phytochemical screening revealed a diverse range of secondary metabolites across the selected plants. Alkaloids were strongly present in Amla and Cinnamon, while Black pepper showed a moderate presence. Flavonoids, phenols, glycosides, diterpenes, carbohydrates, and proteins were detected in all samples, confirming their broad medicinal potential. The strong presence of tannins in Amla and Ginger supports their known antioxidant and astringent roles. Essential oils and fats were found in significant amounts across all samples, especially in plants like Basil and

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Cinnamon, which are recognized for their aromatic properties. These findings indicate that each plant possesses a unique yet complementary phytochemical profile that contributes to its traditional therapeutic uses.

The antioxidant evaluation provided insight into the free radical–scavenging potential of the extracts. Amla demonstrated the highest antioxidant activity in all three assays (DPPH, ABTS, and Total Antioxidant Capacity), which can be attributed to its high vitamin C, tannin, and phenolic content. Cinnamon and Basil exhibited moderate antioxidant activity, reflecting the influence of phenolic compounds, essential oils, and flavonoids. Black pepper showed a lower activity compared to Amla and Cinnamon, but its antioxidant effects increased dose-dependently due to the presence of piperine and other alkaloids. Ginger displayed the lowest antioxidant activity among the individual samples, although its gingerols and shogaols contributed to noticeable scavenging effects.

The polyherbal extract displayed a synergistic antioxidant activity, producing higher scavenging effects than several individual plants but lower than Amla alone. This intermediate performance suggests that combining different plant materials enhances the overall antioxidant profile by contributing multiple classes of phytochemicals. When compared with the standard antioxidant (ascorbic acid), all plant extracts showed lower activity, which validates the experimental procedures and confirms ascorbic acid as a strong reference compound. The overall ranking of antioxidant potency was: Ascorbic acid > Amla > Polyherbal extract > Cinnamon ≈ Basil > Black pepper > Ginger. This pattern closely corresponds with the phytochemical distribution observed in earlier analyses

Table 1: Macroscopic Evaluation of Selected Medicinal Plants

Plant Material	Color	Odor	Taste	Macroscopic Characters
Black Pepper	Black to dark brown	Strong, pungent	Pungent, spicy	Small, round, wrinkled berries
Amla	Greenish-yellow (fresh); brownish (dried)	Slight, astringent	Sour, astringent	Round berry; shriveled when dried
Ginger	Yellowish-brown outer; pale inner	Strong, aromatic	Pungent, slightly sweet	Irregular, branched rhizome
Cinnamon	Light to reddish brown	Sweet, aromatic	Sweet, warm, spicy	Thin, brittle bark quills
Basil	Green (fresh); brownish-green (dried)	Strong, clove-like	Aromatic, slightly pungent	Oval leaves, smooth surface

Table 2: Microscopic Evaluation of Selected Medicinal Plants

Parameter	Black Pepper	Amla	Ginger	Cinnamon	Basil
Epidermis	Polygonal cells with cuticle	Single-layered polygonal cells	Suberized cork cells	Tangential elongated cork cells	Polygonal cells with cuticle
Cortex / Mesocarp	Parenchyma + stone cells	Parenchyma + mucilage + stone cells	Parenchyma rich in starch	Parenchyma + mucilage + crystals	Dorsiventral mesophyll
Crystals	–	Ca-oxalate rosettes	–	Ca-oxalate in cortex	–
Storage Structures	Starch (simple & compound), oil cells	Starch, oil globules, tannins	Abundant starch, oil & oleoresin cells	Oil cells, mucilage	Numerous oil glands
Trichomes	Absent	Absent	Absent	Absent	Covering & glandular (peltate,

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					capitate)
Vascular Tissue	Perisperm vascular strands	Scattered bundles	Collateral bundles with sclerenchyma	Secondary phloem, sclerenchyma, rays	Bicollateral bundles
Diagnostic Features	Stone cells, starch	Rosette crystals, tannin, mucilage	Ovoid starch, oleoresin	Oil cells, sclerenchyma, mucilage	Peltate trichomes, oil glands

Table 3: Pharmacognostic Parameters of Selected Medicinal Plants

Parameter	Black Pepper	Amla	Ginger	Cinnamon	Basil
Moisture Content	7.40	5.60	8.90	7.50	8.50
Ash Content	6.25	5.62	8.60	5.70	9.15
Acid-Insoluble Ash	8.60	7.90	8.75	5.50	8.60
Water-Soluble Ash	4.20	5.05	6.25	4.25	3.90
Water Extractive Value	16.30	14.30	21.20	17.55	22.65
Methanol Extractive Value	24.20	25.70	20.50	21.40	23.30

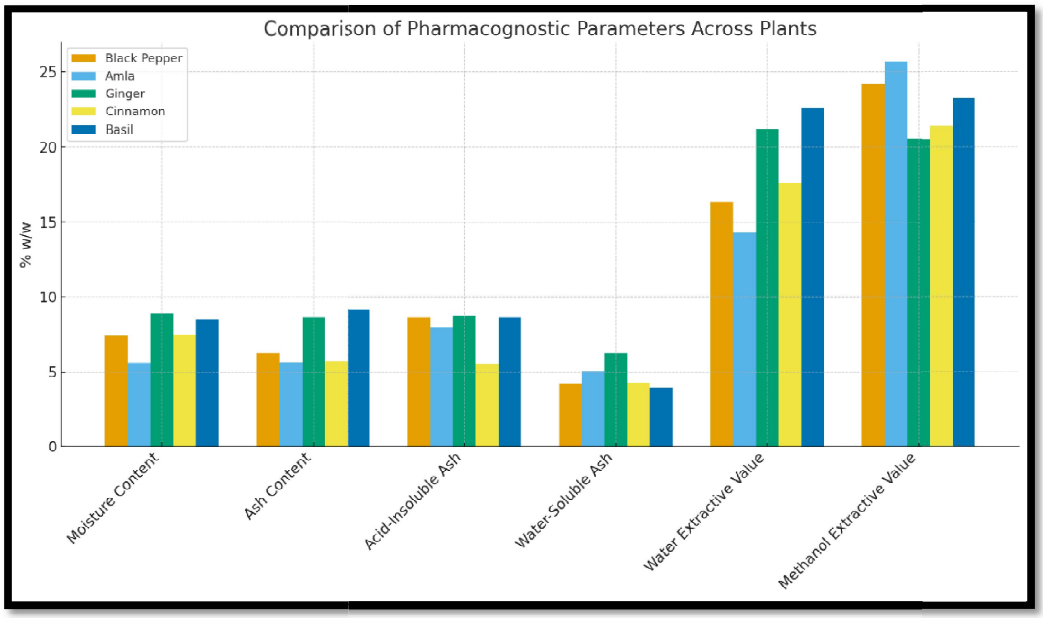

Table 4: Preliminary Phytochemical Evaluation of herbal Extract

S. No	Phytoconstituents	Black Pepper	Amla	Ginger	Cinnamon	Basil
1	**Alkaloids**	++	++	+	–	–
2	**Glycosides**	++	+	++	+	+
3	**Tannins**	–	+	+	–	+
4	**Resins**	+	–	–	–	+
5	**Flavonoids**	+	++	+	+	+
6	**Steroids**	–	+	–	+	+
7	**Amino acids**	–	–	–	–	+
8	**Proteins**	+	+	+	+	+
9	**Carbohydrates**	+	+++	++	++	++

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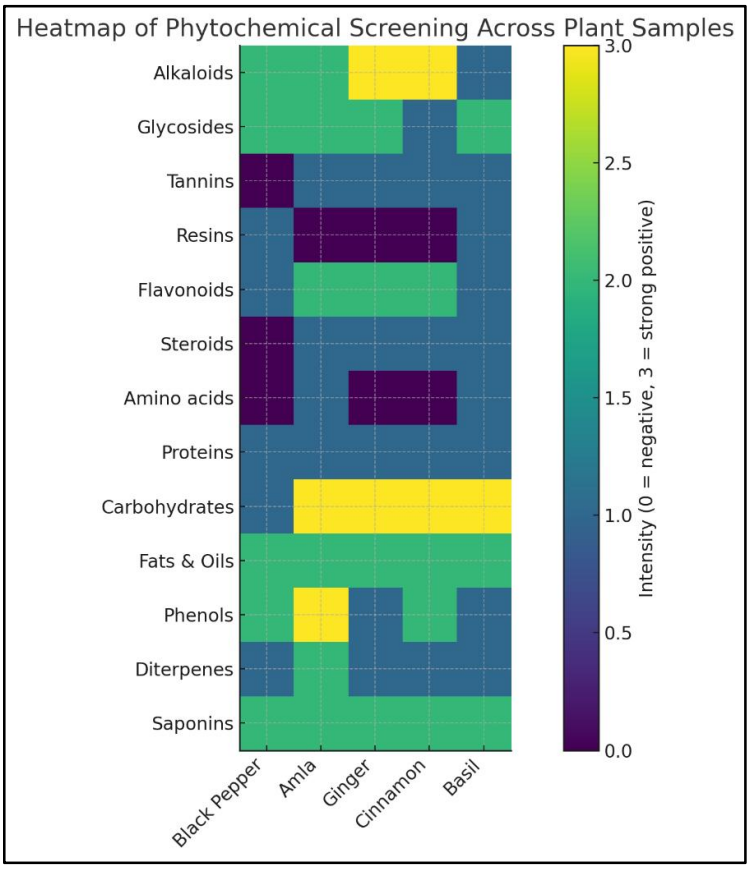
10	**Fats & Oils**	++	++	++	++	++
11	**Phenols**	++	+++	+	++	+
12	**Diterpenes**	+	++	+	+	+
13	**Saponins**	++	++	++	++	++

+ve (Positive), ++ve (Moderately Positive), +++ve (Strongly Positive), -ve (Negative-absent).



In Vitro Antioxidant Activity

Table 5: In Vitro Antioxidant Activity

Sample	Concentration (mg/mL)	DPPH Radical Scavenging (%)	ABTS Radical Scavenging (%)	Total Antioxidant Capacity (mg AAE/g)
Black pepper	0.1	22 ± 1.80	32 ± 2.20	16 ± 1.10
	0.5	32 ± 2.20	42 ± 2.70	20 ± 1.40
	1.0	42 ± 2.70	52 ± 3.20	24 ± 1.80
Amla	0.1	40 ± 2.50	52 ± 3.00	30 ± 1.50
	0.5	58 ± 2.80	72 ± 3.50	48 ± 2.00
	1.0	72 ± 3.20	85 ± 3.80	60 ± 2.30
Basil	0.1	25 ± 2.00	35 ± 2.50	18 ± 1.20
	0.5	35 ± 2.50	45 ± 3.00	22 ± 1.50
	1.0	45 ± 3.00	55 ± 3.50	25 ± 2.00
Cinnamon	0.1	30 ± 2.50	40 ± 3.00	20 ± 1.50

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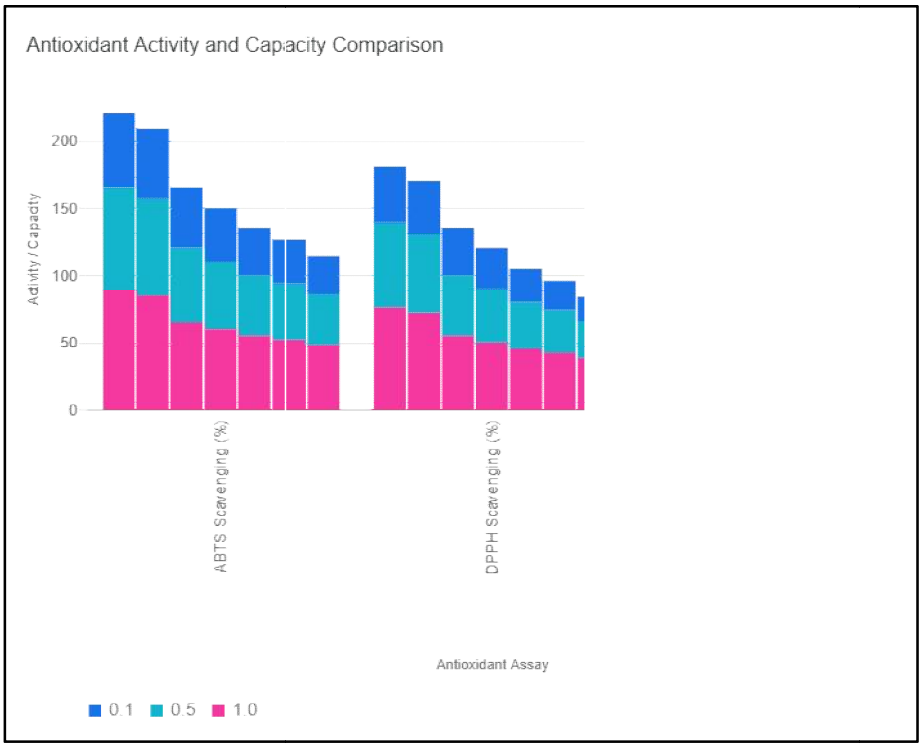
	0.5	40 ± 3.00	50 ± 3.50	24 ± 1.80
	1.0	50 ± 3.50	60 ± 4.00	28 ± 2.00
Ginger	0.1	18 ± 1.20	28 ± 1.80	14 ± 0.90
	0.5	28 ± 1.80	38 ± 2.30	18 ± 1.10
	1.0	38 ± 2.30	48 ± 2.80	22 ± 1.30
Polyherbal extract	0.1	35 ± 3.00	45 ± 3.50	25 ± 2.00
	0.5	45 ± 3.50	55 ± 4.00	30 ± 2.20
	1.0	55 ± 4.00	65 ± 4.50	35 ± 2.50
Ascorbic acid	0.1	42 ± 2.93	56 ± 3.14	32.5 ± 1.18
	0.5	63 ± 1.76	76 ± 1.02	52.6 ± 2.07
	1.0	76 ± 1.86	89 ± 2.83	64.4 ± 1.06



IV. CONCLUSION

The comprehensive pharmacognostic, phytochemical, and antioxidant profiling of Black pepper, Amla, Ginger, Cinnamon, and Basil confirms their quality, identity, and therapeutic potential. Distinct macroscopic and microscopic features validated authenticity, while extractive values and ash parameters established purity and suitability for formulation. The rich presence of flavonoids, phenols, glycosides, alkaloids, and essential oils across the plants highlights their broad medicinal relevance. Antioxidant analyses demonstrated that Amla showed the strongest radical-scavenging activity, followed by Cinnamon and Basil, while the polyherbal extract exhibited synergistic and enhanced antioxidant potential compared with most individual extracts. These findings collectively support the use of these botanicals in developing an effective polyherbal formulation and provide a strong scientific basis for their traditional applications and future therapeutic development.

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