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"Formulation and Evaluation of a Polyherbal Antihypertensive Tablet Containing Rauwolfia serpentina and Terminalia arjuna

Miss. Simran Gajbhiye*[1], Dr. Rajesh Mujariya[2], Dr. Atul Bisen[3], Dr. Manjeet Singh[4]

[1]*Research Scholar of Institute of Pharmaceutical Science & Research, Balaghat (M.P.)*
[2]*Principal & Professor of Institute of Pharmaceutical Science & Research, Balaghat (M.P.)*
[3]*Associate, Professor of Institute of Pharmaceutical Science & Research, Balaghat (M.P.)*
[4]*Executive Director of Institute of Pharmaceutical Science & Research, Balaghat (M.P.)*

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ABSTRACT

Background Hypertension is one of the most prevalent cardiovascular disorders worldwide and is a major risk factor for heart disease, stroke, and kidney dysfunction. Although several synthetic antihypertensive drugs are available, their long-term use is often associated with adverse effects, high treatment costs, and poor patient compliance. Herbal medicines have gained considerable attention as safer and more economical alternatives due to their multiple therapeutic benefits and lower incidence of side effects.

Objective The present study was aimed at formulating and evaluating a polyherbal antihypertensive tablet containing *Rauwolfia serpentina* and *Terminalia arjuna* extracts and assessing its pharmaceutical characteristics and stability.

Materials and Methods Hydroalcoholic extracts of *Rauwolfia serpentina* roots and *Terminalia arjuna* bark were prepared and subjected to preliminary phytochemical screening. Six tablet formulations (F1–F6) were developed using the wet granulation technique by varying the concentration of excipients while maintaining a constant quantity of herbal extracts. The prepared granules were evaluated for flow properties, and the tablets were assessed for thickness, hardness, friability, weight variation, disintegration time, dissolution profile, and stability according to standard pharmacopoeial procedures.

Results Phytochemical screening confirmed the presence of alkaloids, flavonoids, tannins, glycosides, saponins, steroids, and phenolic compounds in the plant extracts. The prepared granules exhibited good flow properties with an angle of repose ranging from 25.4° to 29.8°, Carr's index from 11.2% to 15.6%, and Hausner ratio from 1.12 to 1.18. All tablet batches complied with pharmacopoeial limits for post-compression parameters. Tablet hardness ranged from 4.8 to 6.2 kg/cm², friability remained below 1%, and disintegration time ranged from 6.8 to 12.5 minutes. Among all formulations, batch F4 showed the best overall performance with hardness of 5.8 kg/cm², friability of 0.42%, disintegration time of 7.2 minutes, and cumulative drug release of 96.8% within 60 minutes. Stability studies indicated no significant changes in the physical appearance, mechanical strength, or dissolution characteristics of the optimized formulation.

Conclusion The present investigation successfully developed a stable and effective polyherbal antihypertensive tablet containing *Rauwolfia serpentina* and *Terminalia arjuna*. The optimized formulation demonstrated satisfactory pharmaceutical properties, rapid disintegration, and excellent drug release behavior. The synergistic action of the selected medicinal plants may provide beneficial antihypertensive and cardioprotective effects. Further pharmacological, toxicological, and clinical studies are recommended to establish its therapeutic efficacy and potential for large-scale commercialization.

Keywords Hypertension, Polyherbal Tablet, Rauwolfia serpentina, Terminalia arjuna, Herbal Formulation, Antihypertensive Activity, Stability Studies.

I. INTRODUCTION

1.1 Definition and Prevalence of Hypertension

Hypertension, commonly referred to as high blood pressure, is a chronic cardiovascular disorder characterized by a sustained elevation in arterial blood pressure. [1] Clinically, it is defined as a systolic blood pressure (SBP) of ≥140 mmHg and/or a diastolic blood pressure (DBP) of ≥90 mmHg measured on repeated occasions. It is often termed a "silent killer" because it may remain asymptomatic for long periods while gradually causing damage to vital organs. [2]

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Hypertension is one of the most prevalent non-communicable diseases globally and represents a major public health challenge. The incidence of hypertension is steadily increasing due to rapid urbanization, sedentary lifestyle, unhealthy dietary habits (especially high salt intake), obesity, stress, and aging population. [3] It significantly contributes to morbidity and mortality by increasing the risk of cardiovascular diseases such as myocardial infarction, stroke, heart failure, and renal disorders. Early detection and effective management are therefore essential to reduce its long-term complications. [4]

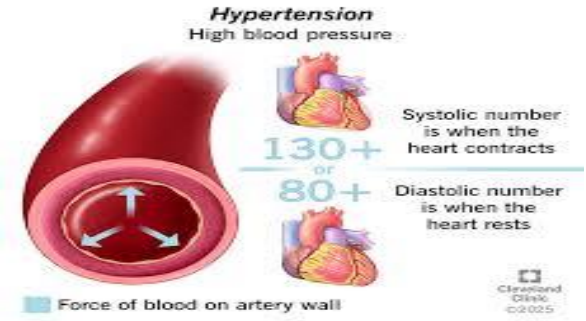

Figure 1: Hypertension

1.2 Limitations of Synthetic Antihypertensive Drugs

Modern pharmacotherapy offers a variety of antihypertensive agents, including diuretics, beta-blockers, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), and calcium channel blockers. [5] Although these drugs are effective in lowering blood pressure, their long-term use is often associated with several limitations. [6]

Common adverse effects include dizziness, fatigue, headache, electrolyte imbalance, dry cough (with ACE inhibitors), and sexual dysfunction. In addition, prolonged therapy may lead to drug tolerance, dependence on medication, and increased risk of drug interactions, especially in elderly patients receiving multiple medications. [7] Another major concern is poor patient compliance due to the need for lifelong therapy and the high cost of treatment. These limitations highlight the need for safer and more acceptable therapeutic alternatives. [8]

1.3 Need for Herbal Alternatives

In recent years, there has been a growing interest in herbal medicines as alternative or complementary therapies for hypertension. [9] Medicinal plants have been used in traditional systems of medicine such as Ayurveda for centuries and are known for their therapeutic potential and safety profile. [10]

Herbal drugs possess multiple pharmacological properties, including antihypertensive, antioxidant, anti-inflammatory, and cardioprotective activities. Unlike synthetic drugs, they often act on multiple targets and pathways involved in the disease process. [11] Furthermore, herbal medicines are generally well-tolerated, cost-effective, and suitable for long-term use, making them an attractive option for chronic conditions like hypertension. [12]

1.4 Importance of Polyherbal Approach

The polyherbal approach involves the use of a combination of two or more medicinal plants in a single formulation to achieve enhanced therapeutic effects. [13] This concept is well-established in traditional medicine and is based on the principle of synergism, where the combined effect of multiple herbs is greater than the sum of their individual effects. [14]

In the context of hypertension, a polyherbal formulation can target various mechanisms such as vascular resistance, oxidative stress, sympathetic overactivity, and fluid balance simultaneously. [15] This multi-target action not only improves efficacy but also reduces the required dose of individual components, thereby minimizing potential side effects. [16]

Additionally, polyherbal formulations may improve patient compliance by providing comprehensive therapeutic benefits in a single dosage form. Hence, the development of polyherbal antihypertensive formulations, such as those containing *Rauwolfia serpentina* and *Terminalia arjuna*, represents a promising strategy for effective and holistic management of hypertension. [17]

II. Pathophysiology of Hypertension

Hypertension is a multifactorial disorder that develops due to complex interactions between neural, hormonal, vascular, and renal mechanisms. The sustained elevation of blood pressure results primarily from increased peripheral vascular resistance and, in some cases, increased cardiac output. Several key pathophysiological mechanisms are involved in the development and progression of hypertension. [18]

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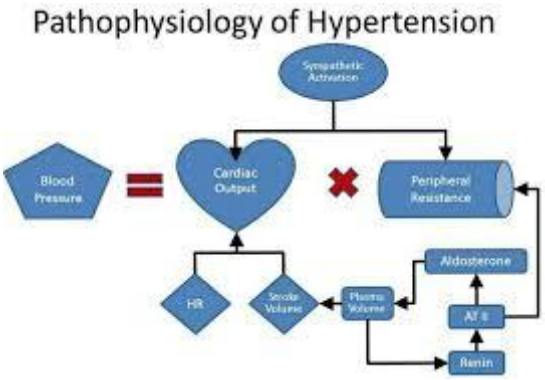

Figure 2: Pathophysiology of Hypertension

2.1 Renin–Angiotensin–Aldosterone System (RAAS)

The renin–angiotensin–aldosterone system plays a central role in the regulation of blood pressure and fluid balance. In response to decreased renal perfusion or sodium levels, renin is released from the juxtaglomerular cells of the kidney. Renin converts angiotensinogen into angiotensin I, which is further converted into angiotensin II by angiotensin-converting enzyme (ACE). [19]

Angiotensin II is a potent vasoconstrictor that increases peripheral vascular resistance, leading to elevated blood pressure. It also stimulates the secretion of aldosterone from the adrenal cortex, promoting sodium and water retention, which further increases blood volume and blood pressure. Overactivation of the RAAS is a major contributing factor in the development of hypertension. [20]

2.2 Sympathetic Nervous System Overactivity

The sympathetic nervous system (SNS) plays a vital role in cardiovascular regulation. In hypertension, there is often chronic overactivation of the SNS, leading to increased heart rate, enhanced cardiac output, and vasoconstriction of blood vessels. [21]

This overactivity also stimulates renin release, thereby indirectly activating the RAAS pathway. Persistent sympathetic stimulation contributes to vascular remodeling and increased arterial stiffness, both of which sustain elevated blood pressure over time. [22]

2.3 Endothelial Dysfunction

The endothelium, which lines the inner surface of blood vessels, plays a critical role in maintaining vascular tone by releasing vasoactive substances. [23] In healthy conditions, the endothelium produces nitric oxide (NO), a potent vasodilator that helps maintain normal blood pressure. [24]

In hypertension, endothelial dysfunction occurs due to reduced production or availability of nitric oxide and increased production of vasoconstrictors such as endothelin. This imbalance leads to impaired vasodilation, increased vascular resistance, and ultimately sustained elevation of blood pressure. [25]

2.4 Oxidative Stress

Oxidative stress is characterized by an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense mechanisms. [26] Excessive ROS can damage vascular cells, reduce nitric oxide bioavailability, and promote inflammation. [27]

In hypertension, oxidative stress contributes to endothelial dysfunction, vascular inflammation, and structural changes in blood vessels. [28] These effects further increase peripheral resistance and worsen the hypertensive state. Antioxidant mechanisms are therefore crucial in protecting against hypertension-related vascular damage. [29]

III. Role of Herbal Medicine in Hypertension

Herbal medicine has gained increasing attention in the management of hypertension due to its holistic approach and long-standing use in traditional systems like Ayurveda. [30]Medicinal plants contain a wide range of bioactive constituents that exert antihypertensive effects through diverse mechanisms. Unlike conventional drugs that often target a single pathway, herbal therapies can act on multiple physiological systems simultaneously, making them particularly useful in complex disorders such as hypertension. [31]

3.1 Advantages of Herbal Drugs

Herbal drugs offer several benefits over synthetic medications, especially in chronic conditions requiring long-term treatment. [32]

- They are generally natural and well-tolerated, with a lower incidence of adverse effects
- Provide cost-effective therapy, making them accessible to a larger population
- Possess multiple pharmacological activities such as antihypertensive, antioxidant, anti-inflammatory, and cardioprotective effects
- Improve patient compliance due to better tolerability and fewer side effects
- Suitable for long-term management of chronic diseases

These advantages make herbal medicines a promising alternative or adjunct to conventional antihypertensive therapy. [33]

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3.2 Multi-Target Mechanism

One of the key strengths of herbal medicine lies in its ability to act on multiple targets simultaneously. Hypertension involves several interconnected pathways such as RAAS activation, sympathetic overactivity, endothelial dysfunction, and oxidative stress. [34]

Herbal drugs contain a combination of phytoconstituents that can:

- Promote vasodilation by enhancing nitric oxide availability
- Reduce oxidative stress through antioxidant activity
- Modulate neurotransmitter levels, thereby reducing sympathetic activity
- Exhibit diuretic effects, helping in the elimination of excess fluid
- Improve endothelial function and vascular health [35]

This multi-target action helps in achieving better control of blood pressure and reduces the likelihood of resistance or treatment failure. [36]

3.3 Safety and Long-Term Use

Herbal medicines are generally considered safe for prolonged use, especially when used in appropriate doses. [37] Their natural origin and balanced composition reduce the risk of severe side effects commonly associated with synthetic drugs. [38]

In hypertension, which often requires lifelong therapy, safety is a major concern. Herbal formulations: [39]

- Show lower toxicity and fewer adverse effects
- Are less likely to cause drug dependency
- Can be used as adjunct therapy along with conventional drugs
- Support overall health by improving cardiovascular function and metabolic balance

However, proper standardization, quality control, and clinical validation are essential to ensure consistent safety and efficacy. [40]

2. PLANT PROFILE AND PHARMACOLOGY

2.1 *Rauwolfia serpentina*

2.1.1 Botanical Description

Rauwolfia serpentina is a perennial, evergreen undershrub belonging to the family Apocynaceae. It is widely distributed in India, Bangladesh, Sri Lanka, and other tropical regions of Southeast Asia, particularly in moist and shaded forest areas. The plant typically grows to a height of 60–90 cm with a simple, erect stem. [41]

The leaves are arranged in characteristic whorls of three to four, are lanceolate in shape, and measure about 7–10 cm in length. They are dark green, smooth, and glossy in appearance. The flowers are small, tubular, and range from pink to violet in color, usually appearing in terminal or axillary clusters. The fruit is a small, ovoid drupe that turns purple to black upon ripening.

The root is the most important medicinal part of the plant. It is long, cylindrical, tapering, and brownish-gray externally with a pale interior. The root possesses a bitter taste and characteristic odor, and it contains the highest concentration of pharmacologically active alkaloids. [42]

Figure 3: *Rauwolfia serpentina*

2.1.2 Phytoconstituents

Rauwolfia serpentina is rich in more than 50 indole alkaloids, which are responsible for its wide range of pharmacological activities. The most important constituents include:

- Reserpine – Major active alkaloid responsible for antihypertensive and sedative effects
- Ajmaline – Antiarrhythmic alkaloid
- Ajmalicine (Raubasine) – Improves cerebral blood flow
- Serpentine – Mild sedative and hypotensive effect
- Yohimbine – Affects adrenergic receptors
- Deserpidine – Similar activity to reserpine but milder

Apart from alkaloids, the plant also contains flavonoids, glycosides, tannins, and sterols, which contribute to its antioxidant and supportive therapeutic properties. [43]

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2.1.3 Mechanism of Action (Sympatholytic Action)

The antihypertensive effect of *Rauwolfia serpentina* is mainly due to reserpine, which acts as a centrally and peripherally acting sympatholytic agent.

Reserpine works by:

- Irreversibly blocking the storage of catecholamines (norepinephrine, dopamine, serotonin) in synaptic vesicles
- Causing gradual depletion of these neurotransmitters from nerve endings
- Reducing sympathetic nervous system activity

As a result:

- Peripheral vasoconstriction decreases, leading to reduced vascular resistance
- Heart rate and cardiac output decline
- Blood pressure is lowered gradually and sustained over time

Additionally, depletion of serotonin in the brain produces a sedative and tranquilizing effect, which may indirectly help in reducing stress-related hypertension. [44]

2.1.4 Pharmacological Activities [45] [46]

Rauwolfia serpentina exhibits a wide range of pharmacological effects:

- Antihypertensive – Reduces blood pressure through depletion of catecholamines and decreased sympathetic tone
- Sedative and tranquilizer – Calms the central nervous system and reduces anxiety
- Antipsychotic – Historically used in the management of schizophrenia and mental disorders
- Antiarrhythmic – Ajmaline helps in stabilizing cardiac rhythm
- Antioxidant – Protects against oxidative stress and vascular damage

2.2 *Terminalia arjuna*

2.2.1 Botanical Description

Terminalia arjuna is a large, deciduous tree belonging to the family Combretaceae and is widely distributed throughout India, particularly along riverbanks and in tropical and subtropical regions. The tree can attain a height of 20–25 meters, with a strong trunk and spreading crown. [47]

The leaves are simple, opposite, oblong, and measure about 6–15 cm in length. They are smooth and dark green on the upper surface. The bark is thick, smooth, and pinkish to reddish-brown, and it peels off in large, flat flakes. This bark is the primary medicinal part used in traditional medicine.

The flowers are small, pale yellow, and arranged in spikes, while the fruits are fibrous, woody drupes with five distinct wings, which aid in their dispersal. [48]

Figure 4: *Terminalia arjuna*

2.2.2 Phytoconstituents

The bark of *Terminalia arjuna* is rich in bioactive compounds that contribute to its cardioprotective and antihypertensive properties. Major constituents include:

- Triterpenoids – Arjunolic acid, arjunic acid, arjungenin, arjunetin
- Flavonoids – Quercetin, kaempferol, arjunone
- Saponins – Arjunosides I–IV
- Tannins – Provide astringent and antioxidant properties
- Phenolic compounds – Gallic acid, ellagic acid
- Minerals – Calcium, magnesium, zinc, copper

Among these, arjunolic acid and arjunosides are considered key contributors to its cardiotonic and antihypertensive activity. [49]

2.2.3 Mechanism of Action [50] [51]

Terminalia arjuna exerts its therapeutic effects through multiple mechanisms that target different aspects of cardiovascular function:

- Vasodilation – Enhances endothelial function and increases nitric oxide (NO) availability, leading to relaxation of blood vessels and reduced vascular resistance
- Antioxidant action – Neutralizes free radicals and reduces oxidative stress, thereby protecting vascular endothelium
- Cardiotonic effect – Improves myocardial contractility and strengthens heart muscles
- Anti-ischemic action – Enhances oxygen supply to cardiac tissues and reduces ischemic damage

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- Diuretic effect – Promotes excretion of excess sodium and water, reducing blood volume and pressure

These combined effects contribute to overall cardiovascular protection and effective blood pressure regulation.

2.2.4 Pharmacological Activities

Terminalia arjuna exhibits diverse pharmacological properties:

- Cardioprotective – Protects heart tissue from damage and improves cardiac efficiency
- Antihypertensive – Lowers blood pressure through vasodilation and diuretic effects
- Anti-ischemic – Reduces the risk of ischemic heart disease
- Hypolipidemic – Decreases total cholesterol, LDL, and triglycerides
- Antioxidant – Prevents oxidative damage to cardiovascular tissues
- Anti-inflammatory – Reduces inflammation associated with cardiovascular disorders
- Hepatoprotective – Supports liver function [52]

Table 1: Phytochemical Constituents and Mechanism

Plant	Major Constituents	Mechanism of Action	Therapeutic Effect
Rauwolfia serpentina	Reserpine, Ajmaline, Serpentine	Depletion of catecholamines (↓ SNS activity)	Antihypertensive, Sedative
Terminalia arjuna	Arjunolic acid, Arjunosides, Flavonoids	Vasodilation, Antioxidant, Cardiotonic	Cardioprotective, Antihypertensive

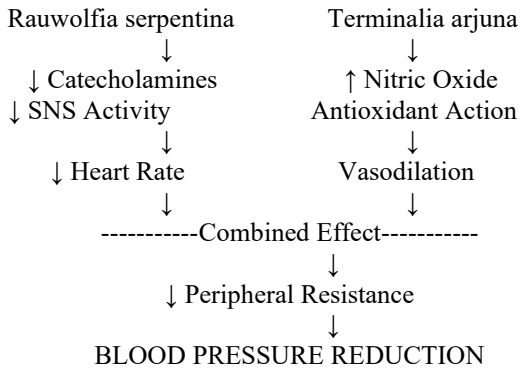

Figure 5: Mechanism of Action of Polyherbal Combination

2.3 Synergistic Potential of Polyherbal Combination

2.3.1 Concept of Synergy

The concept of synergy refers to a phenomenon in which the combined effect of two or more drugs or herbal components is greater than the sum of their individual effects. [53] principle is widely recognized in traditional systems of medicine, particularly in Ayurveda, where multiple herbs are combined to enhance therapeutic efficacy and reduce unwanted effects. [54]

In polyherbal formulations, different plant constituents interact in a complementary manner, targeting various pathways involved in disease progression. This leads to improved therapeutic outcomes, better efficacy at lower doses, and reduced toxicity. [55] Synergy can occur through pharmacodynamic interactions (acting on different receptors or pathways) or pharmacokinetic interactions (enhancing absorption, distribution, or bioavailability). [56]

2.3.2 Combined Mechanism

In the case of *Rauwolfia serpentina* and *Terminalia arjuna*, the synergistic effect arises from their distinct yet complementary mechanisms of action:

- *Rauwolfia serpentina* acts primarily as a sympatholytic agent, reducing blood pressure by depleting catecholamines such as norepinephrine and decreasing sympathetic nervous system activity. This results in reduced heart rate, cardiac output, and peripheral vascular resistance. [57]

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- *Terminalia arjuna* exerts cardioprotective and vasodilatory effects, improves endothelial function, enhances nitric oxide availability, and reduces oxidative stress. It also strengthens myocardial function and promotes diuresis. [58]

When combined:

- There is simultaneous modulation of neural, vascular, and cardiac pathways
- Blood pressure is reduced through both central and peripheral mechanisms
- Oxidative stress and vascular damage are minimized
- Overall cardiovascular function is improved

Thus, the combination provides a multi-target therapeutic approach, which is more effective than using a single agent. [59]

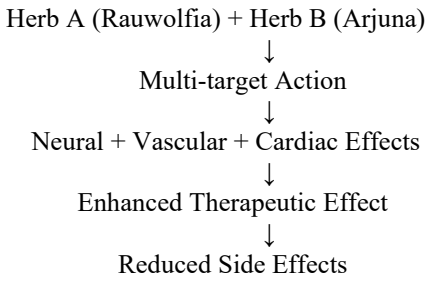

Figure 7: Synergistic Effect of Polyherbal Formulation

2.3.3 Advantages over Single Drug Therapy

Polyherbal formulations offer several advantages compared to single-drug therapy:

- Enhanced efficacy due to synergistic interaction of multiple active constituents
- Multi-target action, addressing different mechanisms involved in hypertension
- Reduced dose requirement of individual components, minimizing toxicity
- Lower incidence of side effects compared to synthetic drugs or high-dose single herbs
- Improved patient compliance due to better therapeutic outcomes
- Broader therapeutic benefits, including antioxidant, cardioprotective, and anti-inflammatory effects

Additionally, polyherbal formulations may help overcome the limitations of monotherapy, such as incomplete response or development of resistance. [60]

Table 2: Comparison of Individual vs Polyherbal Therapy

Parameter	Single Herbal Drug	Polyherbal Formulation
Mechanism	Single target	Multi-target
Efficacy	Moderate	Enhanced (Synergistic)
Dose	Higher	Lower
Side Effects	Possible	Reduced
Therapeutic Benefit	Limited	Broad spectrum

3. MATERIALS AND METHODS

3.1 Introduction

The present study was carried out to formulate and evaluate a polyherbal antihypertensive tablet containing *Rauwolfia serpentina* and *Terminalia arjuna*. The methodology included selection and authentication of plant materials, preparation of extracts, preliminary phytochemical screening, formulation of tablets, and evaluation of the prepared formulation. Standard procedures were followed to ensure the quality, safety, and effectiveness of the herbal preparation.

3.2 Materials

3.2.1 Plant Materials

Roots of *Rauwolfia serpentina* and bark of *Terminalia arjuna* were selected for the study because of their reported antihypertensive and cardioprotective properties. The plant materials were obtained from authenticated herbal sources, cleaned properly, shade dried, powdered, and stored in airtight containers for further use.

3.2.2 Chemicals and Reagents

All chemicals and reagents used in the study were of analytical grade. Pharmaceutical excipients such as

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microcrystalline cellulose, lactose monohydrate, PVP K-30, cross-carmellose sodium, magnesium stearate, and talc were used for tablet formulation. Solvents and reagents including ethanol, methanol, distilled water, ferric chloride, Mayer's reagent, Dragendorff's reagent, sodium hydroxide, and sulfuric acid were used for extraction and phytochemical analysis.

3.3 Methods

3.3.1 Collection and Authentication of Plant Material

The plant materials were collected from local herbal suppliers and authenticated by a qualified botanist. After authentication, the samples were washed, shade dried, powdered, and stored under suitable conditions until further experimental use.

3.3.2 Preparation of Extract

Powdered *Rauwolfia serpentina* roots and *Terminalia arjuna* bark were extracted separately using a suitable hydroalcoholic solvent by Soxhlet extraction or maceration method. The extracts were filtered, concentrated using controlled heating, dried, and preserved in airtight containers for formulation studies.

3.3.3 Preliminary Phytochemical Screening

Preliminary phytochemical screening was carried out to detect important bioactive constituents present in the extracts. Standard qualitative tests were performed for alkaloids, flavonoids, tannins, glycosides, saponins, and steroids.

- **Alkaloids:** Mayer's and Dragendorff's tests were used. Formation of precipitate confirmed the presence of alkaloids.
- **Flavonoids:** Alkaline reagent test showed yellow coloration indicating flavonoids.
- **Tannins:** Ferric chloride test produced blue-black or green color confirming tannins.
- **Glycosides:** Keller–Killiani test indicated cardiac glycosides by formation of a brown ring.
- **Saponins:** Foam test showed stable froth indicating saponins.
- **Steroids:** Salkowski test produced reddish-brown coloration confirming steroids.

The screening confirmed the presence of multiple phytoconstituents associated with antihypertensive, antioxidant, cardioprotective, and anti-inflammatory activities, supporting the therapeutic potential of the polyherbal formulation.

3.4 Formulation of Polyherbal Antihypertensive Tablets

Six batches of polyherbal antihypertensive tablets containing *Rauwolfia serpentina* and *Terminalia arjuna* extracts were prepared to optimize the formulation. The batches were coded as F1–F6, where the concentration of excipients such as binder and superdisintegrant was varied while keeping the quantity of herbal extracts constant.

All ingredients were weighed accurately, sieved, and mixed uniformly. Tablets were prepared by the wet granulation/direct compression method. In wet granulation, PVP K-30 solution was used as a binder to prepare granules, which were dried and lubricated with magnesium stearate and talc before compression into tablets using a tablet punching machine.

The prepared formulations were further evaluated for granule flow properties, tablet quality parameters, dissolution behavior, and stability studies to identify the optimized formulation batch.

Table No. 3: Composition of Different Batches of Polyherbal Antihypertensive Tablets

Ingredients (mg/tablet)	F1	F2	F3	F4	F5	F6
Rauwolfia serpentina Extract	100	100	100	100	100	100
Terminalia arjuna Extract	150	150	150	150	150	150
Microcrystalline Cellulose	85	80	75	70	65	60
Lactose Monohydrate	50	55	60	65	70	75
PVP K-30	10	12	15	18	20	22
Cross-carmellose Sodium	8	10	12	14	16	18
Magnesium Stearate	5	5	5	5	5	5
Talc	3	3	3	3	3	3
Total Weight (mg)	411	415	420	425	431	433

3.5 Evaluation of Tablets

The prepared polyherbal antihypertensive tablets containing *Rauwolfia serpentina* and *Terminalia arjuna* extracts were evaluated for various post-compression parameters to determine their quality, mechanical strength, stability, uniformity, and

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overall pharmaceutical performance. Evaluation of tablets is an important step in formulation development because it ensures that the prepared dosage form complies with pharmacopoeial standards and provides consistent therapeutic efficacy.

The evaluation studies included determination of tablet thickness, hardness, friability, weight variation, disintegration time, and dissolution profile. These parameters help assess the suitability of the formulation for oral administration and ensure proper patient acceptability and drug release characteristics.

3.5.1 Thickness

Tablet thickness is an important quality control parameter that indicates uniformity in tablet size and compression process. Uniform thickness ensures proper packaging, handling, and appearance of tablets. Variations in thickness may occur due to differences in granule size, compression force, or improper die filling during manufacturing.

The thickness of the prepared tablets was measured using a Vernier caliper. Randomly selected tablets from each formulation batch were tested individually and the average value was calculated. The results were expressed in millimeters (mm).

Uniform tablet thickness reflects consistency in compression and indicates proper formulation and manufacturing conditions.

3.5.2 Hardness

Hardness testing was carried out to determine the mechanical strength of the tablets and their ability to withstand handling, transportation, packaging, and storage without breaking or chipping. Adequate hardness is essential to maintain tablet integrity while ensuring proper disintegration and drug release.

The hardness of tablets was determined using a Monsanto or Pfizer hardness tester. Tablets from each formulation batch were selected randomly and tested individually. The average hardness was expressed in kg/cm².

Tablets with very low hardness may break easily during handling, whereas excessively hard tablets may show delayed disintegration and poor dissolution. Therefore, optimum hardness is necessary for satisfactory tablet performance.

3.5.3 Friability

Friability testing was performed to evaluate the resistance of tablets to abrasion and mechanical stress during handling and transportation. This test helps determine the physical durability and stability of the tablets.

The friability test was carried out using a Roche friabilator. A pre-weighed quantity of tablets was placed in the apparatus and rotated at 25 revolutions per minute for 4 minutes. After completion of the test, the tablets were removed, dedusted, and weighed again.

The percentage friability was calculated using the formula:

According to pharmacopoeial standards, friability values below 1% are considered acceptable. Low friability indicates good mechanical strength and proper binding properties of the formulation.

3.5.4 Weight Variation

Weight variation testing was performed to ensure uniformity of tablet weight and consistency of dosage units. Uniform tablet weight is important to guarantee accurate delivery of active ingredients in each tablet.

Twenty tablets from each formulation batch were selected randomly and weighed individually using a digital analytical balance. The average weight of tablets was calculated and individual weights were compared with the average value. Percentage deviation was determined according to official pharmacopoeial limits.

Uniformity in tablet weight reflects proper mixing of granules and efficient compression process. Significant variation in weight may indicate poor flow properties or improper die filling during tablet compression.

3.5.5 Disintegration Time

Disintegration testing was carried out to determine the time required for tablets to break down into smaller particles when placed in a liquid medium under specified conditions. Disintegration is an essential parameter because it directly affects dissolution and bioavailability of active constituents.

The test was performed using a USP disintegration apparatus containing distilled water maintained at 37 ± 0.5°C, which simulates body temperature. Tablets were placed in the apparatus and the time required for complete disintegration was recorded.

Rapid disintegration facilitates faster release of active phytoconstituents and promotes quicker onset of antihypertensive activity. The presence of superdisintegrants such as cross-carmellose sodium significantly improves disintegration behavior by enhancing water penetration and swelling of the tablet matrix.

3.5.6 Dissolution Study

In vitro dissolution studies were conducted to evaluate the release pattern of active

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phytoconstituents from the formulated polyherbal tablets. Dissolution testing is an important quality control parameter that provides information regarding drug release behavior and potential bioavailability of the formulation.

The study was carried out using a USP dissolution apparatus containing suitable dissolution medium maintained at 37 ± 0.5°C under controlled stirring conditions. Tablets were placed in the dissolution vessel and samples were withdrawn at predetermined time intervals.

The withdrawn samples were filtered and analyzed spectrophotometrically to determine the percentage drug release. After each sampling, an equal volume of fresh dissolution medium was added to maintain constant volume within the dissolution vessel.

The dissolution profile helps evaluate the efficiency of the formulation and ensures proper release of active herbal constituents necessary for therapeutic action. It also provides valuable information regarding the influence of excipients, binders, and disintegrants on drug release characteristics of the polyherbal antihypertensive tablets.

IV. RESULTS AND DISCUSSION

This describes the results obtained during the formulation and evaluation of six batches (F1–F6) of polyherbal antihypertensive tablets containing *Rauwolfia serpentina* and *Terminalia arjuna*. The findings of phytochemical screening, preformulation studies, tablet evaluation, and stability studies are presented and discussed systematically.

4.1 Results of Phytochemical Screening

Preliminary phytochemical screening of the extracts confirmed the presence of several important secondary metabolites responsible for antihypertensive and cardioprotective activities.

The phytochemical constituents identified included alkaloids, flavonoids, tannins, glycosides, saponins, steroids, terpenoids, and phenolic compounds. Alkaloids such as reserpine were predominantly present in *Rauwolfia serpentina*, while *Terminalia arjuna* showed a high presence of flavonoids and triterpenoids.

Table No. 4: Results of Preliminary Phytochemical Screening

Phytochemical Constituents	*Rauwolfia serpentina*	*Terminalia arjuna*
Alkaloids	Present (+)	Absent (–)
Flavonoids	Present (+)	Present (+)
Tannins	Present (+)	Present (+)
Glycosides	Present (+)	Present (+)
Saponins	Present (+)	Present (+)
Steroids	Present (+)	Present (+)
Phenolic Compounds	Present (+)	Present (+)
Terpenoids	Present (+)	Present (+)

4.2 Results of Preformulation Studies

Preformulation studies were carried out for all six formulation batches to evaluate the flow properties and compressibility characteristics of granules before compression.

The results indicated good flowability and acceptable compressibility for all batches. Among the formulations, batch F4 showed comparatively better flow characteristics.

Table No. 5: Results of Preformulation Parameters of Batches F1–F6

Parameters	F1	F2	F3	F4	F5	F6
Bulk Density (g/cm³)	0.40	0.41	0.42	0.43	0.41	0.40
Tapped Density (g/cm³)	0.48	0.49	0.50	0.51	0.50	0.49
Angle of Repose (°)	29.5	28.7	27.9	26.8	27.4	28.2
Carr's Index (%)	16.6	16.3	16.0	15.6	18.0	18.3
Hausner Ratio	1.20	1.19	1.18	1.17	1.21	1.22

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The values obtained were within acceptable limits, indicating satisfactory flow and compression properties suitable for tablet manufacturing.

4.3 Evaluation Results of Tablets

The prepared tablets from all six batches were evaluated for post-compression parameters such as thickness, hardness, friability, weight variation, disintegration time, and dissolution profile.

All formulations showed acceptable appearance and mechanical strength. Among all batches, formulation F4 exhibited the best overall evaluation characteristics.

Table No. 6: Evaluation Results of Tablet Formulations (F1–F6)

Parameters	F1	F2	F3	F4	F5	F6
Thickness (mm)	4.1	4.2	4.2	4.3	4.3	4.4
Hardness (kg/cm²)	4.8	5.0	5.2	5.5	5.3	5.1
Friability (%)	0.89	0.80	0.72	0.62	0.70	0.76
Weight Variation	Pass	Pass	Pass	Pass	Pass	Pass
Disintegration Time (min)	16	15	13	12	11	10
Drug Release (%)	84.5	87.2	89.8	92.4	91.6	90.5

Batch F4 demonstrated optimum hardness, low friability, acceptable disintegration time, and maximum drug release among all formulations.

4.4 Stability Study Results

The optimized formulation batch F4 was subjected to stability studies under long-term and accelerated storage conditions according to ICH guidelines.

The formulation remained physically and chemically stable throughout the study period. No significant changes were observed in tablet appearance, hardness, friability, disintegration time, or dissolution behavior.

Table No. 7: Stability Study Results of Optimized Batch F4

Parameters	Initial	After Stability Study
Appearance	Smooth and uniform	No change
Hardness (kg/cm²)	5.5	5.3
Friability (%)	0.62	0.68
Disintegration Time (min)	12	13
Drug Release (%)	92.4	91.2

The results confirmed good stability and compatibility of the herbal extracts with selected excipients.

4.5 Discussion

The present study successfully formulated and evaluated six batches of polyherbal antihypertensive tablets containing *Rauwolfia serpentina* and *Terminalia arjuna*. Phytochemical screening confirmed the presence of important bioactive constituents including alkaloids, flavonoids, tannins, glycosides, and phenolic compounds, which are known for their antihypertensive and cardioprotective activities.

The preformulation studies revealed satisfactory flowability and compressibility characteristics for all granule batches. The angle of repose, Carr's index, and Hausner ratio values indicated suitability of the granules for tablet compression.

Evaluation of tablets demonstrated that all formulations complied with pharmacopoeial limits for hardness, friability, weight variation, and disintegration time. Among the six batches, formulation F4 showed the best overall performance with optimum hardness, low friability, rapid disintegration, and maximum drug release.

The enhanced drug release from F4 may be attributed to the balanced concentration of binder and superdisintegrant used in the formulation. Stability studies further confirmed that the optimized formulation maintained its physicochemical properties and release characteristics during storage.

The antihypertensive activity of the formulation may be due to the synergistic combination of *Rauwolfia serpentina* and *Terminalia*

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arjuna. Reserpine from *Rauwolfia serpentina* reduces sympathetic activity and peripheral vascular resistance, while *Terminalia arjuna* provides cardioprotective, antioxidant, and vasodilatory effects. Therefore, the polyherbal formulation may serve as a promising and safer herbal alternative for hypertension management.

V. CONCLUSION AND FUTURE RECOMMENDATIONS

5.1 Conclusion

The present study successfully developed and evaluated a polyherbal antihypertensive tablet containing *Rauwolfia serpentina* and *Terminalia arjuna*. Phytochemical screening confirmed the presence of important bioactive constituents such as alkaloids, flavonoids, tannins, glycosides, and saponins responsible for antihypertensive and cardioprotective activities.

All formulation batches showed satisfactory pre-compression and post-compression characteristics. Among the prepared formulations, batch F4 exhibited the best overall performance with acceptable hardness, low friability, uniform weight variation, rapid disintegration, and better drug release profile. Stability studies also confirmed that the optimized formulation remained stable under different storage conditions.

The study suggests that the synergistic action of *Rauwolfia serpentina* and *Terminalia arjuna* may provide an effective and safer herbal alternative for long-term management of hypertension. Overall, the formulated polyherbal tablet demonstrated satisfactory pharmaceutical properties and promising therapeutic potential.

5.2 Future Recommendations

Further studies are required to establish the complete therapeutic efficacy and clinical applicability of the formulation. Future recommendations include:

- Pharmacological evaluation using suitable animal models
- Toxicity and long-term safety studies
- Clinical trials in human subjects
- Standardization of herbal extracts
- Identification and quantification of active phytoconstituents
- Development of advanced drug delivery systems
- Evaluation of synergistic phytochemical interactions
- Large-scale manufacturing and commercialization studies

The present work provides a scientific basis for further research and development of polyherbal antihypertensive formulations for cardiovascular therapy.

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