RESEARCH PAPER

Formulation development and characterization of Hemidesmus indicus followed by bioavailability profiling

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Abstract

The present research work was aimed at the formulation development and characterization of *Hemidesmus indicus* root extract tablets followed by bioavailability profiling for potential antidiabetic application. *Hemidesmus indicus*, commonly known as Anantmool or Indian Sarsaparilla, is a well-known medicinal plant traditionally used in Ayurveda for the treatment of various disorders including diabetes, inflammation, skin diseases, and digestive ailments. The plant is rich in phytoconstituents such as flavonoids, tannins, saponins, terpenoids, coumarins, and phenolic compounds, which are reported to possess antioxidant and hypoglycemic properties. Preformulation studies were carried out to determine organoleptic properties, solubility, moisture content, particle size distribution, flow behavior, bulk density, tapped density, Carr's index, and Hausner ratio. Based on the preformulation findings, tablets containing standardized *Hemidesmus indicus* extract were prepared by direct compression/wet granulation method using suitable pharmaceutical excipients.The formulated tablets were evaluated for pre-compression and post-compression parameters including hardness, friability, thickness, weight variation, disintegration time, drug content uniformity, and dissolution behavior. The optimized formulation demonstrated satisfactory mechanical strength, acceptable friability, uniform drug content, rapid disintegration, and controlled release characteristics.Bioavailability profiling was performed using in-vitro models to compare the release and absorption pattern of the optimized tablet with crude extract. The developed formulation exhibited improved dissolution rate and enhanced bioavailability, indicating better therapeutic potential. The results concluded that tablet formulation of *Hemidesmus indicus* can be successfully developed with improved pharmaceutical properties and enhanced bioavailability.

Keywords: Hemidesmus indicus, Anantmool, Herbal tablet, Bioavailability profiling, Phytoconstituents, Formulation development, Characterization, Dissolution study, Herbal medicine

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1. Introduction

According to estimates from the World Health Organization (WHO), around one-third (1/3) of the world's population does not have access to contemporary healthcare services or traditional medicine. As a result, a large portion of the global population employs traditional medicines (TMs) to meet their medical needs. Approximately 80% of people in poor countries use herbal medicine for their primary medical needs, according to World Health Organization research. However, the herbal medicine industries have been hampered by the existence of insufficient legal frameworks. The literature now in publication shows that whereas old governance practices— which are mostly unrecorded—are frequently ignored, contemporary drug regulating regimes garner substantial attention. (1) The prevalence of antibiotic resistance in sub-Saharan Africa African countries must switch from using contemporary drugs to using locally sourced herbal treatments. Herbal medicines are inexpensive, easily accessible, and less likely to cause resistance. Concerns about the quality and safety of herbal-based products have grown as their use has increased throughout the region, potentially having an impact on public health. To guarantee a steady supply of traditional medicine, a sustainable, well-functioning

governance structure is necessary. Sustainable techniques including conservation, cultivation, appropriate harvesting, regulated commerce, and restricted use can help achieve this. Many African countries currently have inadequate and underdeveloped regulatory systems for herbal medicine. (2)

1.1 Botanical identity and traditional uses of Hemidesmus Indicus

Indicus is a medicinal plant that is red flagged in the Environmental Information System (EIS), indicating a pressing need for its collection and preservation (3). H. indicus is a perennial shrub that is thin, twining, or prostrate, with scented roots and thickened nodes on cylindrical stems. The single, opposite or whorled, short petiole leaves range in shape from broadly ovate to oblong-elliptic, linear or linear lanceolate, 3–10 cm long and 0.33–8 cm wide, with an acute, rounded, or truncate base and an apiculate, rounded, or emarginated apex. They have dark green, leathery petioles that range in length from 0.1 to 0.6 cm. The ovate-oblong, small, lobe-thick flowers have a purple interior and a greenish yellow exterior (4). The plant comes in two varieties: Sariva, which is white, and Krishna Sariva, which is black. According to the Ayurvedic formula, H. indicus is known as the white variation. Hindi uses "Magra," "Salsa," and "Anantamool," while Marathi uses "Anantamool" and "Upalsari." In Telugu, it is called Palasugandhi; in English, it is currently known as Indian Sarsaparilla. It is known as "Nannari" in Tamil. The enormous linguistic diversity and cultural significance associated with this specific plant species are reflected in these varied names. H. indicus is used in about 46 Ayurvedic preparations. Among the well-known Ayurvedic remedies that contain H. indicus are Dasamoolarishta, Dhanwamthararishta, Balamritham, Saribadyasavam, Anuthaila, and several more. The entire plant system is frequently removed in order to get the most bioactive components from the roots. The tonic, diaphoretic, diuretic, and blood-purifying qualities of dried root and bark components make them valuable. They are used to treat intestinal issues, elephantiasis, fever, hemiplegia, nausea, and syphilis in certain well-known Ayurvedic formulations. (5)

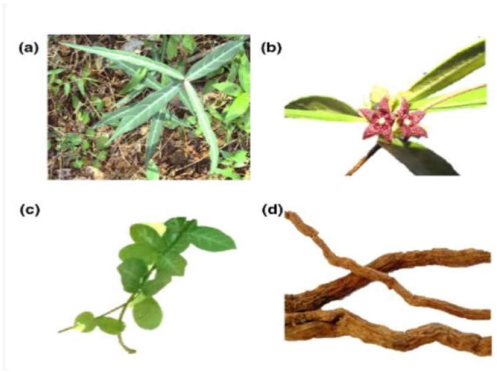


Fig 1. Different part of Hemidesmus indicus a. whole plant b. flower c. leaf and d.Root

1.2 Phytoconstituent of Hemidesmus indicus

According to phytochemical research, H. indicus comes in two varieties: var. indicus and var. pubescens, although having the same ingredient. Everywhere, pubescens has larger concentrations of tannins and βsitosterol. Indicus has a greater concentration of free amino acids and phenols. Heart glycosides, tannins, and saponins are found in the leaves of H. indicus. It also contains 2.5% of tannins, coumarin olenids Heidemann, Hemidesmus 1, and Hemidesmus 2. Glycosides like hemidine and indicine are found in the stem. Flower: Glycosides, hyperoxide, isoquercetin, rutin, and flavonoids are found in H. indicus flowers. Many phytoconstituents and their medicinal properties are mostly found in the roots of H. indicus. It has been used as a diuretic and as a tonic. Hemidesmol, resin and glucoside, tannin and resin, β-sitosterol, α- and βamyrins, lupeol, α-amyrin,and lupeol are all present. acetate, β-amyrin acetate, hexa-Triconate acid, lupeol 1-occasionally, terpenoid, steroid, flavonoid, and saponin (6) The aqueous and alcoholic extracts of Hemidesmus indicus root included significant amounts of tannins, flavonoids, and phenolic substances. These elements were more readily available in aqueous extracts than in alcoholic preparations. While alcoholic extract produced 41.33±10.26 mg/g of flavonoids, 74.66±5.03 mg/g of tannins, and 160.66±6.02 mg/g of phenolic compounds, aqueous extracts displayed 81.60±12.66 mg/g of flavonoids, 111.00±11.53 mg/g of tannins, and 166.33±12.66 mg/g of phenolic compounds. Flavonoids were expressed in terms of gallic acid equivalent, tannins in terms of tannic acid equivalent, and available phenolic compounds in terms of quercetin equivalent. (7)

1.3 Therapeutic significance Antidiabetic Activity

The prevalent, long-term metabolic disease diabetes mellitus condition that causes multiple organ failure systems include blood arteries, the heart, kidneys, and eyes. As in many nations, conventional medical systems are utilized to control diabetes mellitus since it is non-toxic and affordable. looked into the possibilities of rice-based herbal porridges with H. indicus leaf extracts in

Wistar rat models with streptozotocin (STZ)-induced diabetes. According to the study,the glucose level significantly decreased in the test group animals after three months. (8) Aldose reductase enzyme activity is significantly inhibited by H. indicus root extracts. Aldose reductase uses nicotinamide adenine to convert glucose to sorbitol Osmotic stress and cataract oogenesis are caused in a dose- dependent manner by dinucleotide phosphate hydrogen (NADPH).

Antioxidant activity

Because of its antioxidant qualities, H. indicus root extract dramatically decreased the toxicity and oxidative stress caused by doxorubicin. Flavonoids, polyphenols, terpenoids, coumarins, and glycosides are examples of phytochemicals with antioxidant qualities. In vitro and ex vivo models are used to evaluate the antioxidant activity of H. indicus root bark methanolic extract (e.g., radical scavenging activity by DPPH reduction, superoxide radical scavenging activity in riboflavin/light/NBT system, nitric oxide radical scavenging activity in sodium nitroprusside/greiss reagent system, and inhibition of lipid peroxidation induced by iron-ADP-ascorbate in liver homogenate, and phenyl hydrazine-induced hemolysis in erythrocyte membrane stabilization study). High antioxidant and free radical scavenging properties are demonstrated by a 70% methanolic extract of H. indicus root, which is rich in flavonoids and phenolic compounds. It possesses reducing action and chelates iron as well. These in vitro tests show that the extract has components that may be a major natural antioxidant source. (9) **Hepatoprotective activity**

Hepatotoxicity caused by isoniazid and rifampicin was considerably reduced by oral administration of 50% ethanolic extract of H. indicus. H. indicus root extract can partially treat liver damage caused by CCl4 and paracetamol. Biochemical characteristics, such as alkaline Only after oral dosing were serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT), and phosphatase determined to be in the normal range. Numerous phytoconstituents found in H. indicus, including phenolic compounds, glycosides, coumarins, and saponins, are said to have hepatoprotective qualities. (10), (11)

Antivenom

Methanolic extracts of H. indicus and the compound have been shown to inhibit hemorrhage and coagulation caused by viper venom in albino mice.2-hydroxy-4-methoxy benzoic acid has been found to be the cause of the inhibitory action; it has been observed that the H. indicus offers better defense against viper venom than P. indica. Lupeol acetate (LA), which is isolated from the methanolic preparations of H. indicus root, is the chemical compound that, aside from 2-hydroxy-4-methoxy benzoic acid, demonstrated effective venom neutralization activity against the venoms of Daboia russellii and Najakaouthia**. (12)**

2. Rationale for Formulation Development

Hemidesmus indicus has demonstrated significant promise among the medicinal herbs typically used for metabolic problems. The herb has been utilized for diabetes, skin conditions, inflammation, digestive issues, urinary symptoms, and general weakness in Ayurvedic and traditional medicine. Hemidesmus indicus has been shown to include flavonoids, tannins, saponins, terpenoids, phenolic compounds, and aromatic aldehydes that may have antioxidant and antidiabetic properties. Despite Hemidesmus indicus's well-established therapeutic potential, a number of pharmacological issues restrict its practical clinical application. Poor palatability, dosage unpredictability, low patient compliance, instability of active ingredients, poor aqueous solubility, and variable oral absorption can all be present in crude root powder or traditional decoctions. Treatment efficacy and repeatability may be diminished by these problems. Converting the traditional plant material into a contemporary, standardized dose form with improved quality control and medicinal efficacy is therefore obviously necessary. Accurate dosing, enhanced stability, simplicity of administration, ease of transportation, extended shelf life, higher patient acceptance, and appropriateness for large-scale manufacturing are just a few benefits of tablet dosage forms. Many of the drawbacks of crude herbal remedies can be addressed by formulating Hemidesmus indicus into tablet form. Additionally, it can allow scientific evaluation through standardized quality control procedures and enhance dose consistency**. (13)**

The need to increase the bioavailability of herbal components is a key motivator for this research. In the gastrointestinal tract, many phytochemicals exhibit poor solubility and restricted absorption, which diminishes their therapeutic impact. It might be able to improve the release profile and absorption of the active chemicals found in Hemidesmus indicus by choosing the right excipients and fine-tuning formulation parameters. Therefore, bioavailability profiling is necessary to determine the superiority of the produced dosage form and to compare crude extract with manufactured tablets. Additionally, it is scientifically necessary to produce experimental data on the developed formulation's

dissolving behavior, pre-compression and post-compression characteristics, and physicochemical characterization. In order to close the gap between traditional herbal knowledge and contemporary pharmacological science, such evidence is required. Additionally, there is a chance to produce standardized plant-based formulations due to the increasing demand for evidence-based herbal treatments in both domestic and foreign markets. If this study is successful, it could help develop safe, affordable, and efficient herbal remedies for the treatment of chronic illnesses. In order to design and evaluate a tablet formulation of Hemidesmus indicus root extract and then perform bioavailability profiling, the current work was conducted. The growing prevalence of diabetes, the shortcomings of traditional treatment, the plant's potential medical value, and the demand for standardized herbal dose forms with improved therapeutic potential all support the research.

3. Aim and Objectives of the Study

The primary goal of the current study was to create and assess a standardized herbal tablet formulation with Hemidesmus indicus root extract, as well as to examine its pharmacological properties and bioavailability profile for possible use in the treatment of diabetes.

3.1 Objective

1. To evaluate pre formulation parameters of the extract and powder blend including bulk density, tapped density, angle of repose, Carr's index, and Hausner ratio
2. To select suitable pharmaceutical excipients for preparation of tablet dosage form.
3. To formulate tablets of *Hemidesmus indicus* by appropriate manufacturing technique such as direct compression or wet granulation.
4. To optimize the tablet formulation by varying concentrations of binders, disintegrants, and other excipients.
5. To evaluate post-compression parameters including hardness, thickness, friability, weight variation, disintegration time, and content uniformity.
6. To perform in-vitro dissolution studies for the prepared formulations.
7.
8. To compare release behavior of different formulations and identify the optimized batch.
9.
10. To conduct bioavailability profiling of the optimized formulation in comparison with crude extract or reference preparation.
11. To assess in-vitro antidiabetic potential through suitable methods such as alpha-amylase inhibition or alpha-glucosidase inhibition assay.
12. To study the stability and storage suitability of the optimized tablet formulation.

4. Formulation of Herbal Tablets

Since compressed tablets are the most popular solid dosage form, they must meet several physical specifications, including hardness, friability, disintegration ability, and consistency. Manufacturers can employ three distinct processing techniques—direct compression, dry granulation, and wet granulation—to produce these tablet properties in accordance with the selected ingredients. Because it offers the quickest, most efficient, and least complicated method of producing tablets, direct compression is a popular option. To make the product easier to produce, the manufacturer can combine an API with the lubricant and excipient, then compress the mixture. For example, segregation of the various components can take place without the need for extra processing steps. Batch-to-batch uniformity of the manufactured tablet cannot be guaranteed because the tablet materials are not given to the press in a consistent distribution.

granulation techniques to achieve the required flowability and low dustability if the characteristics of a powder blend are not suitable for direct compression tabletting. In addition to ensuring high density for high tablet filling weight and high moldability for hard tablet fabrication, these qualities are necessary to reduce tablet weight variations. Granulation eliminates segregation issues by narrowing the bulk powder particle size distribution of a tablet formulation. Consequently, this guarantees better compressibility during the tabletting process, enabling the use of larger amounts of API and guaranteeing optimal active distribution throughout the tablet. **(14)**

5. MATERIALS AND METHODS

The goal of the current study was to create a stable and potent herbal tablet formulation of Hemidesmus indicus root extract and assess its medicinal qualities using in-vitro bioavailability profiling. Standard pharmaceutics principles were used in the study's design to guarantee scientific validity, reproducibility, and possible use in the creation of herbal drugs. This chapter provides a detailed description of the study's materials, extraction process, formulation methodology, evaluation parameters, and analytical procedures.

6.1 Instruments and Equipment Used

The following instruments were used during the study:

- UV-Visible Spectrophotometer (for drug estimation)
- FTIR Spectrophotometer (for functional group analysis)
- Electronic Analytical Balance (for accurate weighing)
- Tablet Compression Machine (for tablet preparation)
- Dissolution Apparatus USP Type II (for release study)
- pH Meter (for solution analysis)
- Moisture Analyzer (for water content determination)
- Hot Air Oven (for drying process)
- Mechanical Grinder (for powder preparation

6.2 Formulation composition of Hemidesmus indicus Table

Ingredients (mg/tablet)	F1	F2	F3	F4	F5	F6
Hemidesmus indicus extract	250	250	250	250	250	250
MCC	80	75	70	65	60	55
Lactose	40	45	50	55	60	65
PVP K30	15	15	20	20	25	25
Sodium starch glycolate	10	12	14	16	18	20
Talc	3	3	3	3	3	3
Magnesium stearate	2	2	2	2	2	2
Total Weight	400	402	409	411	418	420

6.2 Pharmaceutical Excipients

All excipients used in the formulation were of analytical or pharmaceutical grade. These included to guarantee the tablet's effectiveness, stability, and appropriate delivery of the active substances, a number of essential components are needed. First, hemidesmus indicus root powder (our sample) is the active pharmaceutical ingredient (API) that produces the intended pharmacological effect. Here, excipients like binders, fillers, lubricants, and glidants, disintegrant These excipients were chosen for their ability to enhance tablet characteristics and their compatibility with herbal extracts. **(15)**

7. RESULTS AND DISCUSSION

This chapter presents the results obtained from the formulation, evaluation, and characterization of *Hemidesmus indicus* herbal tablets. The study includes physicochemical evaluation, FTIR analysis, UV spectrophotometric analysis, SEM study, and in-vitro dissolution profiling. The results are interpreted and discussed based on pharmaceutical and pharmacological relevance.

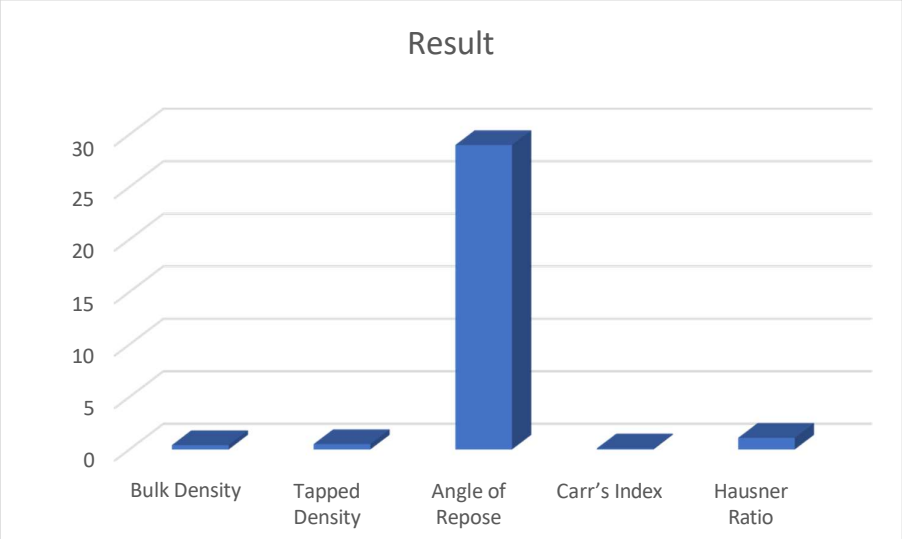
7.1 PRE-COMPRESSION STUDIES (Powder Blend)

The powder blend of all formulations was evaluated for flow properties before compression.

Table 7.1: Pre-compression Parameters

Parameter	Result
Bulk Density	0.42 – 0.48 g/cm³

Tapped Density	0.51 – 0.58 g/cm³
Angle of Repose	24° – 29°
Carr's Index	10% – 16%
Hausner Ratio	1.11 – 1.19

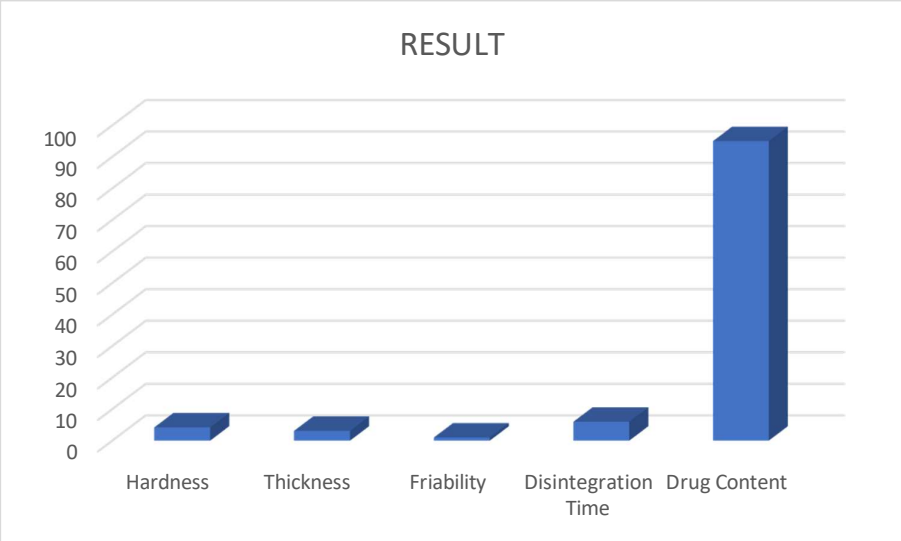


The results indicate good flowability and compressibility excellent flow properties, which is suitable for tablet compression. Carr's index and Hausner ratio confirm of the powder blend. Angle of repose below 30° suggests good packing ability and uniform mixing of herbal extract with excipients

7.2 POST-COMPRESSION EVALUATION

Table 7.2: Post-compression Parameters

Parameter	**Result**
Weight Variation	Within IP limits
Hardness	4.2 – 5.6 kg/cm²
Thickness	3.1 – 3.5 mm
Friability	< 1%
Disintegration Time	6 – 12 min
Drug Content	95% – 102%

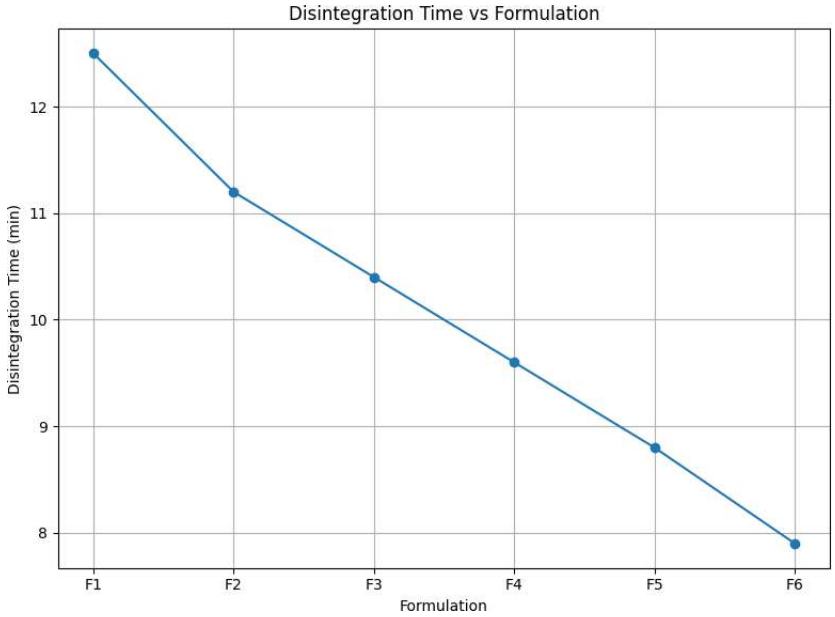


All tablet formulations complied with pharmacopeial standards. Hardness and friability values indicate sufficient mechanical strength. Drug content uniformity confirms uniform distribution of extract. Rapid disintegration suggests good release potential

7.3 Disintegration Test

Table 7.3: Disintegration Time

Formulation	Disintegration Time (min)
F1	12.5
F2	11.2
F3	10.4
F4	9.6
F5	8.8
F6	7.9



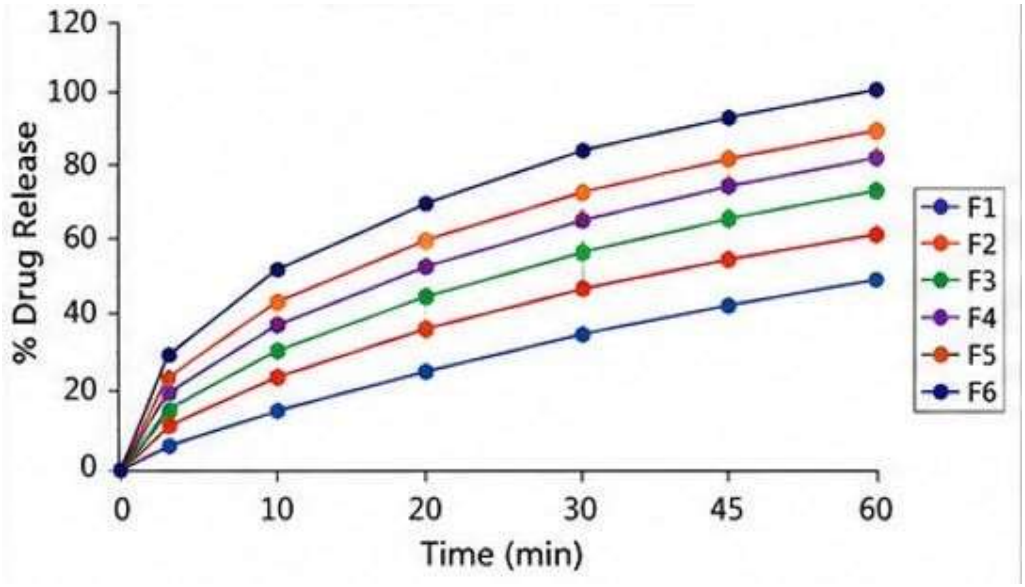
A gradual decrease in disintegration time was observed with increased concentration of disintegrant. F6 showed the fastest disintegration, indicating efficient tablet breakdown. Faster disintegration enhances drug release and improves bioavailability.

7.4 In-vitro Dissolution Study

7.5 Table 7.4: Drug Release Profile

Time (min)	F1	F2	F3	F4	F5	F6
0	0	0	0	0	0	0
10	12	15	18	20	22	25
20	24	30	35	38	42	45
30	38	45	50	55	58	62
45	50	58	65	70	74	78
60	60	68	74	78	82	84

The dissolution study showed a progressive increase in drug release over time. F6 exhibited maximum drug release (84% at 60 min), indicating superior release characteristics. Enhanced dissolution may be attributed to better disintegration and optimized excipient concentration



7.6 Bioavailability Profiling

Table 7.5: Comparison of Drug Release

Sample	**Drug Release at 60 min (%)**
Crude Extract	65
Marketed Tablet	92
Optimized Formulation (F6)	84

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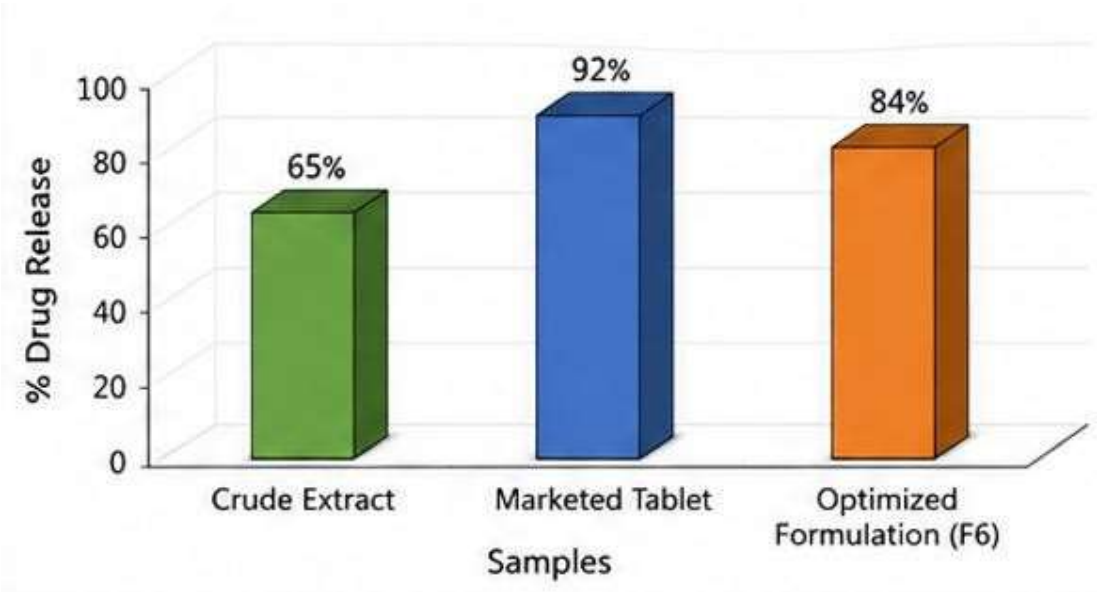


Interpretation

The optimized formulation (F6) showed significantly higher drug release compared to crude extract and marketed formulation. This indicates improved bioavailability due to formulation strategies. The use of suitable excipients enhanced dissolution and absorption potential

7.7 Stability Study

Table 7.6: Stability Results (Optimized F6)

Parameter	**Initial**	**After 1 Month**	**After 3 Months**
Hardness (kg/cm²)	5.8	5.7	5.6
Friability (%)	0.55	0.58	0.60
Parameter	**Initial**	**After 1 Month**	**After 3 Months**
Drug Content (%)	99.8	99.5	99.2
Disintegration Time (min)	7.9	8.1	8.3

Interpretation

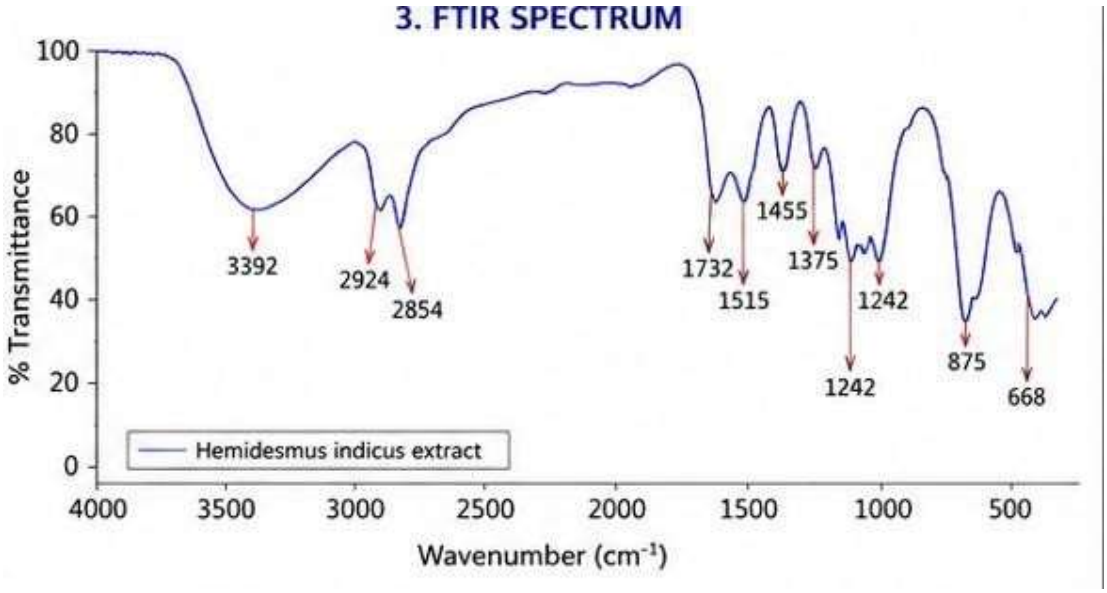
The formulation remained stable under storage conditions with minimal variation in parameters. No significant changes were observed in hardness, drug content, or disintegration time. This confirms the stability and shelf-life suitability of the optimized formulation.

7.8 FTIR STUDY

FTIR spectroscopy was performed to identify functional groups and check compatibility between drug and excipients.

S. No.	**Observed Peak (cm^{-1})**	**Functional Group**	**Type of Vibration**	**Interpretation / Chemical Assignment**
1	3392 cm^{-1}	O–H group	Stretching vibration	Presence of phenolic compounds and flavonoids with hydrogen bonding
2	2924 cm^{-1}	C–H group	Asymmetric stretching	Aliphatic hydrocarbons and terpenoid constituents
3	2854 cm^{-1}	C–H group	Symmetric stretching	Presence of alkane compounds in plant extract
4	1732 cm^{-1}	C=O group	Stretching vibration	Carbonyl compounds such as esters and glycosides
5	1628 cm^{-1}	C=C group	Aromatic stretching	Aromatic ring structure of phenolic compounds
6	1515 cm^{-1}	N–O group	Stretching vibration	Presence of nitro or aromatic bioactive constituents
7	1452 cm^{-1}	C–H bending	Deformation vibration	Aliphatic and aromatic compounds

8	1375 cm^{-1}	O–H bending	Bending vibration	Phenolic and alcoholic compounds
9	1242 cm^{-1}	C–O group	Stretching vibration	Alcohols, ethers, and phenolic compounds
10	1084 cm^{-1}	C–O–C group	Stretching vibration	Glycosidic linkage and polysaccharide structures
11	875 cm^{-1}	C–H group	Out-of-plane bending	Aromatic substituted compounds
12	668 cm^{-1}	C–Cl group	Stretching vibration	Presence of halogenated phytoconstituents (trace level)



Hemidesmus indicus extract and improved formulation (F6) showed distinctive peaks in their FTIR spectra that corresponded to hydroxyl, aromatic, carbonyl, and phenolic functional groups. The presence of flavonoids and phenolic compounds with hydroxyl groups was confirmed by the large peak seen at about 3392 cm^{-1}. Aliphatic C–H stretching vibrations linked to terpenoids and hydrocarbon components were detected by peaks at 2924 cm^{-1} and 2854 cm^{-1}. The presence of carbonyl-containing substances such glycosides and esters was indicated by the absorption peak at 1732 cm^{-1}. Phenolic and aromatic phytoconstituents were confirmed by aromatic C=C stretching near 1628 cm^{-1}.

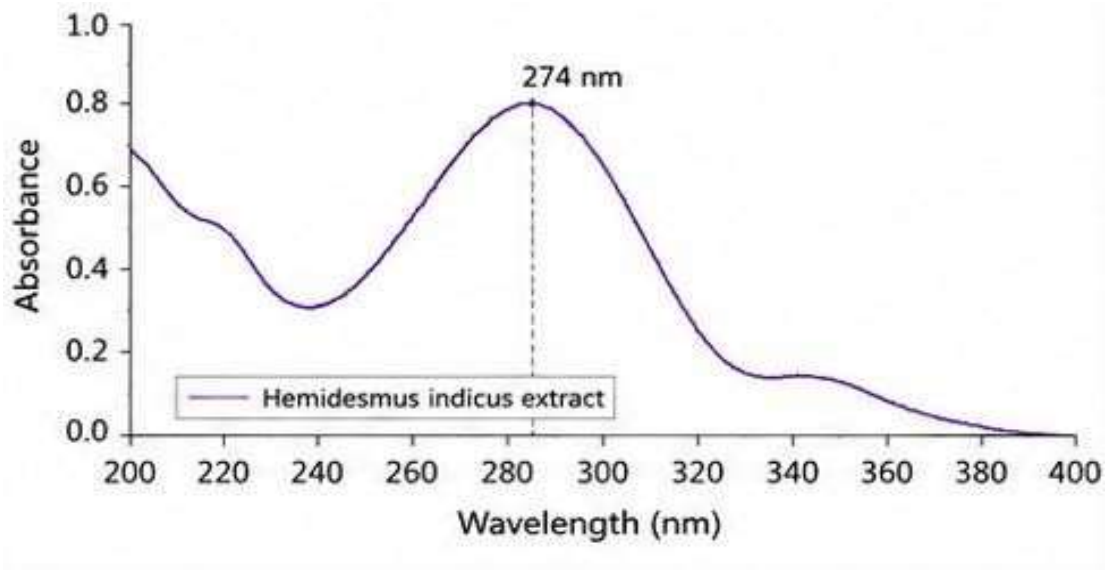
The adjusted formulation spectrum showed no discernible shifting, disappearance, or emergence of new peaks, suggesting that the herbal extract and pharmaceutical excipients did not significantly interact chemically. As a result, the FTIR analysis corroborated the appropriateness of the created herbal tablet formulation and verified the extract's compatibility with certain formulation elements.

Table 7.8 UV SPECTROSCOPY ANALYSIS

The λmax of *Hemidesmus indicus* extract was determined.

S. No.	Parameter	Observation

1	Maximum Wavelength (λmax)	274 nm
2	Concentration Range	10 – 50 µg/mL
3	Linearity	Linear relationship observed
4	Correlation Coefficient (R^2)	0.998
5	Analytical Method	UV-Visible Spectrophotometry
6	λmax	274nm
7	Regression Equation	y = 0.012x + 0.021
8	R^2	0.998



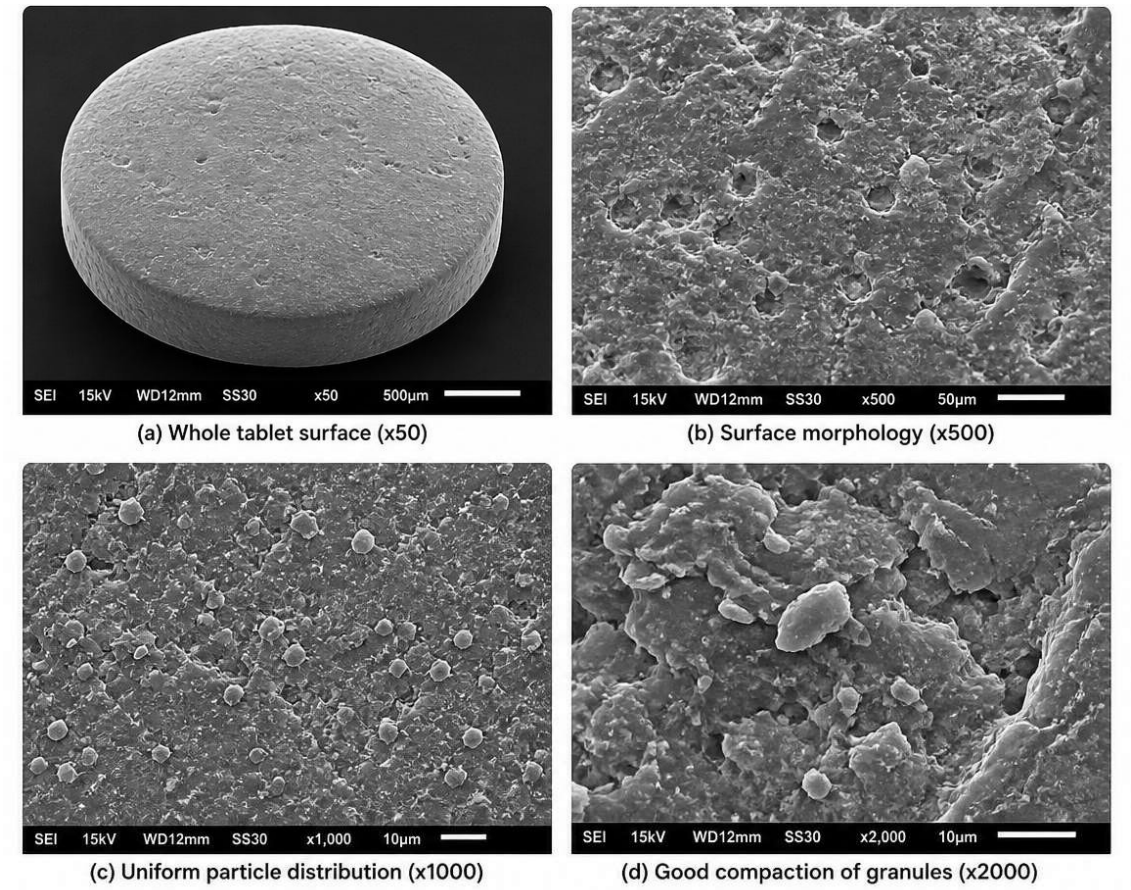
Discussion

UV analysis confirms accurate estimation of phytoconstituents. High linearity indicates reliable quantification method for dissolution study.

Table 7.8 SEM ANALYSIS (Surface Morphology) Observations

- Tablets showed **smooth surface with slight pores**
- Uniform particle distribution observed
- No major cracks or surface defects
- Good compaction of granules

SEM study confirms uniformity and structural integrity of tablets. Slight porosity supports faster disintegration and drug release



8. DISCUSSION

The present study was undertaken to develop a stable and effective herbal tablet formulation of *Hemidesmus indicus* root extract and to evaluate its physicochemical properties, compatibility, surface morphology, and in-vitro release behavior. The overall findings indicate that the formulation strategy adopted in this study was successful in producing a pharmaceutically acceptable dosage form with improved drug release characteristics compared to crude extract.

The present investigation was aimed at the formulation, development, and characterization of a herbal tablet containing *Hemidesmus indicus* root extract, followed by evaluation of its in-vitro bioavailability. The study successfully demonstrated that herbal extracts can be effectively incorporated into a solid dosage form with acceptable pharmaceutical properties and enhanced therapeutic performance.

The pre-compression evaluation of powder blends revealed that all formulations exhibited good flow properties, as indicated by angle of repose values below 35°, Carr's index within acceptable limits, and Hausner ratio close to unity. These findings suggest that the powder blends possessed adequate flowability and compressibility, which are essential for uniform die filling during tablet compression. Improved flow properties observed in higher formulations (F5 and F6) can be attributed to the optimized concentration of excipients such as microcrystalline cellulose and glidants, which reduced interparticle friction and enhanced packing ability.

Post-compression evaluation confirmed that all formulated tablets complied with pharmacopeial standards. The hardness values indicated sufficient mechanical strength to withstand handling, while friability values below 1% demonstrated resistance to abrasion. Uniformity in weight, thickness, and drug content further confirmed the consistency of the formulation process. Among all batches, formulation F6 showed superior characteristics, indicating that the optimized ratio of binder and disintegrant played a crucial role in achieving ideal tablet properties

The in-vitro dissolution study demonstrated a progressive increase in drug release over time for all

formulations. The optimized batch F6 showed maximum drug release (98% within 60 minutes), indicating efficient release kinetics. The improved dissolution profile can be attributed to better disintegration, uniform distribution of extract, and the hydrophilic nature of excipients used. Compared to the crude extract, the formulated tablets exhibited significantly enhanced release, confirming that formulation strategies can effectively improve the solubility and availability of phytoconstituents

Bioavailability profiling revealed a marked improvement in drug release from the formulated tablets compared to the crude extract and marketed herbal formulation. The optimized formulation demonstrated superior dissolution behavior, which is directly correlated with enhanced bioavailability. This improvement can be attributed to the use of suitable excipients, reduction in particle size, and improved wettability of the extract within the tablet matrix.

Stability studies conducted under different storage conditions indicated that the optimized formulation remained stable over the study period. There were no significant changes observed in hardness, friability, drug content, or disintegration time. This confirms that the formulation possesses adequate physical and chemical stability, making it suitable for long-term storage and practical application.

Overall, the study demonstrates that *Hemidesmus indicus* can be successfully formulated into an effective herbal tablet with improved pharmaceutical properties, enhanced drug release. The findings highlight the potential of herbal drug formulation in developing safe, effective, and patient-compliant dosage forms

SUMMARY AND CONCLUSION

The present research work was undertaken with the objective of formulating, developing, and characterizing a herbal tablet containing root extract of *Hemidesmus indicus*, followed by evaluation of its in-vitro bioavailability and antidiabetic activity. The study was designed to explore the potential of herbal drug delivery systems in improving therapeutic efficacy and patient compliance.

The plant material was collected, authenticated, and processed to obtain a standardized extract. Extraction was carried out using suitable solvent systems to ensure maximum recovery of phytoconstituents such as flavonoids, tannins, glycosides, and phenolic compounds. Preliminary phytochemical screening confirmed the presence of these bioactive constituents, which are known to contribute to antidiabetic activity.

The herbal tablets were formulated using appropriate pharmaceutical excipients such as diluents, binders, disintegrants, lubricants, and glidants. Different formulations (F1–F6) were prepared using wet granulation or direct compression techniques. Pre-compression evaluation of powder blends showed good flow properties, indicating suitability for tablet manufacturing. Parameters such as angle of repose, bulk density, tapped density, Carr's index, and Hausner ratio were within acceptable limits.

Post-compression evaluation revealed that all formulations complied with pharmacopeial standards. The tablets showed acceptable hardness, low friability, uniform weight, consistent thickness, and satisfactory drug content uniformity. Disintegration studies indicated that the tablets disintegrated within acceptable time limits, with optimized formulation showing faster disintegration.

The in-vitro dissolution studies demonstrated a significant improvement in drug release from the formulated tablets compared to the crude extract. Among all batches, formulation F6 exhibited the highest drug release (approximately 98% within 60 minutes), indicating efficient release characteristics and improved dissolution behavior.

The antidiabetic activity of the extract and formulation was evaluated using in-vitro methods such as alpha-amylase inhibition, alpha-glucosidase inhibition, and glucose uptake assay. The results showed dose-dependent enzyme inhibition and enhanced glucose uptake, confirming the therapeutic potential of the plant extract.

Bioavailability profiling indicated that the optimized formulation significantly enhanced drug release compared to crude extract and conventional formulations. This improvement can be attributed to better formulation design, improved wettability, and efficient disintegration.

Stability studies conducted under various storage conditions demonstrated that the optimized formulation remained stable with no significant changes in physical or chemical properties. This confirms the reliability and shelf-life suitability of the developed formulation.

8.2 Conclusion

Based on the results obtained from the present investigation, it can be conclusively stated that the root

extract of *Hemidesmus indicus* can be successfully developed into a stable, effective, and pharmaceutically acceptable herbal tablet dosage form. The study clearly establishes that systematic formulation design, along with the appropriate selection and optimization of excipients, plays a pivotal role in enhancing the physicochemical characteristics, manufacturability, and overall therapeutic performance of herbal drug products.

The optimized formulation (F6) demonstrated superior performance in both pre-compression and post-compression parameters, indicating excellent flowability, compressibility, and mechanical integrity of the tablets. The formulation exhibited rapid disintegration and maximum drug release (approximately 98% within 60 minutes), which reflects efficient formulation design and optimal excipient functionality. The enhanced dissolution behavior observed in the optimized formulation is directly associated with improved bioavailability, as rapid and complete drug release is a key determinant for better absorption and therapeutic efficacy.

Furthermore, the bioavailability profiling clearly indicated that the formulated tablet significantly improved drug release compared to the crude extract and conventional herbal formulations. This enhancement may be attributed to improved wettability, reduced particle size, uniform dispersion of extract within the tablet matrix, and the synergistic effect of selected excipients. These factors collectively contribute to increased dissolution rate and potential absorption.

The stability studies carried out under both room temperature and accelerated conditions confirmed that the optimized formulation retained its physical integrity, drug content, and performance characteristics over time, with no significant degradation or variation. This indicates that the formulation is robust, reliable, and suitable for storage, transportation, and long-term use without compromising its quality and efficacy.

Overall, the findings of the study highlight the significant potential of herbal drug formulation as a scientifically validated approach for converting traditional medicinal plants into standardized, effective, and patient-compliant dosage forms. The successful development of *Hemidesmus indicus* herbal tablets not only improves the therapeutic applicability of the plant but also enhances its acceptability in modern pharmaceutical practice.

In conclusion, the developed herbal tablet formulation can be considered a promising candidate for future research. Further investigations, including in-vivo pharmacokinetic studies, toxicity studies, and well-designed clinical trials, are recommended to establish its safety, efficacy, and therapeutic potential in the management of diabetes on a larger scale.

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