RESEARCH PAPER

# Formulation and Evaluation of Herbal Drug Delivery System

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**ABSTRACT**

Bombax ceiba (silk cotton tree) is a deciduous plant widely distributed in tropical and subtropical Asia and traditionally used for the management of various ailments. The plant is rich in diverse phytoconstituents, including alkaloids, triterpenoids, and flavonoids, which contribute to its multiple pharmacological activities such as anti-inflammatory, antidiabetic, anti-obesity, antidiarrheal, analgesic, emetic, and antipyretic effects. The present study focuses on the formulation and evaluation of an immediate-release herbal tablet of Bombax ceiba extract for effective management of inflammation. Phytochemical screening confirmed the presence of bioactive compounds, with significant anti-inflammatory activity demonstrated by 84.91% inhibition of bovine serum albumin denaturation and 86.43% protection against human red blood cell membrane lysis. The tablets were prepared by the wet granulation method using suitable excipients, including starch, sodium starch glycolate, microcrystalline cellulose, lactose, and talc. Compatibility studies using FTIR and DSC indicated no significant drug–excipient interactions. The formulated tablets (200 mg extract) were evaluated for physicochemical parameters such as hardness, thickness, friability, weight variation, and dissolution. The optimized formulation exhibited satisfactory quality control results and achieved 93.6% cumulative drug release within 60 minutes, indicating efficient immediate-release characteristics. These findings support the potential of Bombax ceiba as a promising candidate for herbal anti-inflammatory drug delivery systems.

**Keywords:** Bombax ceiba, Herbal drug delivery system, HRBC membrane stabilization

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## INTRODUCTION

Herbal Drug Delivery Systems (HDDS) are a modern advancement in herbal medicine designed to improve the effectiveness, stability, and targeted action of natural plant compounds (Prajakta N. Dongare et al., 2021). With the growing global interest in natural and holistic healthcare, HDDS combine traditional herbal knowledge with modern drug delivery technologies to solve common problems such as poor solubility and uneven absorption of herbal ingredients (Hoque et al., 2023). These systems use new techniques like nanoparticles, liposomes, and phytosomes to increase the healing power of herbal medicines and ensure a steady release of active compounds. The renewed global interest in herbal medicine, supported by scientific research and international regulations, highlights its growing importance in today's healthcare (Ahmad Khan & Ahmad, 2018). As people move toward safer and eco-friendly treatments, HDDS help modernize traditional herbal practices and support the development of reliable, effective, and standardized natural medicines (Rashrash et al., 2017).

Inflammation is a vital physiological defence mechanism triggered by tissue injury, infection, or exposure to harmful stimuli (Ashley et al., 2012). It serves to eliminate pathogens, remove damaged cells, and restore tissue homeostasis through a highly coordinated immune response. The process involves vascular changes, recruitment of leukocytes, and release of cytokines, chemokines, and other mediators that regulate immune cell activity. While acute inflammation is beneficial and resolves upon repair, chronic inflammation results from prolonged or dysregulated responses, contributing to diseases such as rheumatoid arthritis, diabetes, cardiovascular disorders, and neurodegenerative conditions. Molecular mechanisms underlying inflammation

involve complex interactions between pattern recognition receptors (PRRs), transcription factors such as NF-κB (S. Ghosh & Hayden, 2008), and epigenetic modifications controlling proinflammatory gene expression. Although inflammation is essential for survival, uncontrolled or persistent activation can cause significant tissue damage. Understanding the cellular and molecular pathways of inflammation is crucial for developing targeted therapies for chronic inflammatory and autoimmune diseases (Stankov, 2012).

Immediate-Release Tablets (IRT) are oral solid dosage forms designed to disintegrate and dissolve rapidly in the gastrointestinal tract, enabling quick absorption of the active pharmaceutical ingredient (API) into the bloodstream (Kute et al., 2023). These formulations provide a fast onset of therapeutic action, making them suitable for managing acute symptoms such as pain, fever, and allergic reactions. IRTs are typically composed of the API along with excipients such as fillers, binders, disintegrants, and lubricants that ensure uniformity and rapid drug release (Sharma et al., 2019). They are easy to manufacture, cost-effective, and suitable for drugs with short half-lives. However, frequent dosing is often required due to their short duration of action, which may affect patient compliance. Rapid absorption can also cause fluctuations in plasma drug levels. Despite these limitations, IRTs remain one of the most widely used dosage forms due to their simplicity, effectiveness, and ability to provide quick relief in acute medical conditions (R. Ghosh et al., 2012).

## MATERIALS AND METHODS

### Plant Material

Bombax ceiba leaves, Bombax ceiba barks and Bombax ceiba roots were collected from the local area of the Oni, Dist. Rajapur and authenticated by Sharadchandraji Pawar College of Agriculture, Kharawate and Bovine Albumin purchased from Molychem. All other chemicals used in the research work are provided by the institution and were purchased from Loba Chemie Pvt. Ltd., Mumbai (Chaudhary & Khadabadi, 2012) (Londonkar et al., 2019)

### Plant Extract

Ethanolic extracts of Bombax ceiba leaf, bark, and root were prepared using the Soxhlet method. Dried, powdered plant material was packed in a thimble and extracted with ethanol for 24 h or until the siphon solvent became colourless. The collected extract was concentrated at 30–40 °C to obtain a dry semisolid mass, which was stored in an airtight container for further analysis (Hait & Goswami, 2017)(Redfern et al., 2014)

### Physicochemical Evaluation of Extraction

### Melting Point

The melting point of the ethanolic extracts of Bombax ceiba leaf, bark, and root was determined using a standard melting point apparatus. A small amount of extract was filled into a capillary tube attached to a graduated thermometer and heated in a paraffin bath until melting was observed**.**

### Phytochemical Screening

Phytochemical screening was conducted on the ethanolic extracts of Bombax ceiba leaves, roots, and bark. Preliminary tests for primary metabolites were carried out to detect alkaloids, saponins, flavonoids, tannins, phenols, proteins, carbohydrates, and volatile oils (Aguoru et al., n.d.; Shaikh & Patil, 2020).

### Determination of λ- max

The absorption maximum of the Bombax ceiba leaf, bark, and root extracts were determined in phosphate buffer (pH 1.2).

### Compatibility Study

Compatibility studies of Bombax ceiba leaf, bark, and root extracts with selected excipients were performed using FTIR and DSC.

### FTIR

FTIR spectroscopy was used to evaluate the compatibility of Bombax ceiba extracts with selected excipients. Spectral analyses of the pure extract, its physical mixture with excipients were compared to identify any potential chemical interactions.

### DSC

Differential scanning calorimetry or DSC is a thermosanalytical technique in which difference in account of heat required to increase the temperature of sample and reference are measured as a function of temperature. Both the sample and reference were mentioned at nearly sample temperature throughout the experiment.

### Anti- inflammatory Activity by HRBC Method

The *In-vitro* anti-inflammatory activity of extracts of *Bombax ceiba* was evaluated by the Human Red Blood Corpuscles (HRBC) membrane stabilization method.

Blood was collected from a healthy human volunteer who had not taken any anti-inflammatory drugs for two weeks prior to the experiment. The collected blood was transferred into heparinized centrifuge tubes and centrifuged at 3000 rpm. The packed cells were washed with isosaline, and a 10% v/v suspension of HRBC in normal saline was prepared. Diclofenac sodium (50 µg/ml) was used as the standard drug. The reaction mixture (4–5 ml) consisted of 2 ml hypotonic saline (0.25% w/v NaCl), 1 ml of 0.15 M phosphate buffer (pH 7.4), 1 ml of test solution (1000 µg/ml) prepared in normal saline, and 0.5 ml of 10% HRBC suspension. For the control, 1 ml of isotonic saline was used instead of the test solution. The reaction mixtures were incubated at 56°C for 30 minutes, followed by cooling under running tap water. The mixtures were then centrifuged at 3000 rpm for 20 minutes, and the absorbance of the supernatant was measured at 560 nm using a visible spectrophotometer. All experiments were performed in triplicate. The control represented 100% hemolysis(K. Anandarajagopal et al., 2013; Monicka & Gomathi, 2021).

**Anti- inflammatory Activity by BSA Method**

Test solution (0.5 mL) consists of 0.45 mL of BSA (5% w/v aqueous solution) and 0.05 mL of test solution (250 µg/mL). Test control solution (0.5 mL) consists of 0.45 mL of BSA (5% w/v aqueous solution) and 0.05 mL of distilled water. Product control solution (0.5 mL) consists of 0.45 mL of distilled water and 0.05 mL of test solution (250 µg/mL). Standard solution (0.5 mL) consists of 0.45 mL of BSA (5%w/v aqueous solution) and 0.05 mL of diclofenac sodium (250 µg/ mL). All the above solutions were adjusted to pH 6.3 using 1N hydrochloric acid. The samples were incubated at 37 °C for 20 min and the temperature was increased to keep the samples at 57 °C for 3 min. After cooling, 2.5 mL of phosphate buffer saline was added to the above solutions. The absorbance was measured using UV Visible spectrophotometer at 416 nm (Londonkar et al., 2019).

**Preparation of Tablet**

Tablets were prepared using the direct compression method. The formulation was selected based on a literature review and considering the type and proportion of polymer and diluent. The active pharmaceutical ingredient (ethanolic extract of *Bombax ceiba* leaves) The *Bombax ceiba* leaf extract showed a stronger anti-inflammatory effect than the bark and root extracts. Because of this, *Bombax ceiba* leaf extract was used as API, along with the binder, disintegrant, lubricant, and glidant, was mixed with starch paste to form a damp mass. This mass was subsequently converted into granules. The diluent and glidant were then added appropriately, and the granules were compressed into tablets using a 16-station rotary tablet compression machine equipped with a 13 mm punch and die set (Behera et al., 2021).

**Table 1:** Composition of Tablet

| Ingredients | Role | F1 | F2 | F3 | F4 |
|---|---|---|---|---|---|
| *Bombax ceiba* Leaf Extract | API | 200 mg | 200 mg | 200 mg | 200 mg |
| Lactose | Diluent | 224.5 mg | 216.5 mg | 224.5 mg | 216.5 mg |
| Starch | Binder | 26 mg | 26 mg | 26 mg | 26 mg |
| Starch Paste | Granulating Agent | Q.S. | Q.S. | Q.S. | Q.S. |
| Sodium Starch Glycolate | Disintegrant | 21 mg | 29 mg | - | - |
| Microcrystalline cellulose | Disintegrant | - | - | 21 mg | 29 mg |
| Talc | Glidant | 1% | 1% | 1% | 1% |
| Magnesium Stearate | Lubricant | 0.5 % | 0.5 % | 0.5 % | 0.5 % |

**Evaluation of Tablet Formulation**

A Vernier calliper was used to measure the thickness and diameter of twenty tablets. The mean and standard deviation were calculated.

**Hardness Testing**

A Monsanto tablet hardness tester was used to measure the crushing strength of the tablets.

**FriabilityTest**

The friability of twenty tablets was evaluated using a Roche Friabilator. The tablets were weighed and subjected to 100 rotations for 4 minutes. After completion of the specified rotations, the tablets were dedusted and reweighed. The percentage weight loss

was calculated, and the resistance of the tablets to abrasion was determined.

**Weight Variation Test**

The weight variation of individual tablets was determined as an indicator of uniformity in drug content. Twenty tablets were individually weighed using a digital analytical balance, and the average tablet weight was calculated.

**Determination of Drug Content**

The tablets were finely ground, and an accurately weighed quantity of powder equivalent to 10 mg of ethanolic leaf extract of *Bombax ceiba* was taken. To this, 100 mL of 0.1 N hydrochloric acid (pH 1.2) was added. The resulting solution was filtered and appropriately diluted with the same solvent. The absorbance was measured at 205 nm using a UV–visible spectrophotometer. The drug content was determined using a previously prepared calibration (standard) curve.

**Disintegration Test**

Four different herbal tablet formulations (F1–F4) were evaluated for disintegration. Six tablets from each formulation were placed individually in the tubes of the basket-rack assembly of a disintegration test apparatus, and a disc was placed in each tube. The assembly was immersed in 900 mL of 0.1 N hydrochloric acid (pH 1.2) maintained at 37 ± 0.5°C. The apparatus was operated, and the time required for complete disintegration of each tablet was recorded.

**Dissolution Study**

The dissolution studies were conducted using an IP Apparatus I (dissolution apparatus). Tablets containing ethanolic leaf extract of *Bombax ceiba* were placed in the dissolution vessel containing 900 mL of 0.1 N hydrochloric acid (pH 1.2), maintained at 37 ± 0.5°C, and agitated with a paddle at 50 rpm. Samples were withdrawn at predetermined time intervals and replaced with an equal volume of fresh dissolution medium. The samples were filtered through Whatman filter paper, and the concentration of ethanolic leaf extract of *Bombax ceiba* was determined spectrophotometrically at 205 nm.

## RESULT AND DISCUSSION

**Physicochemical Evaluation**

Extractions of ethanolic extracts of *Bombax ceiba* were carried out using the Soxhlet apparatus method. Visual Inspection of Extracts is done.

**Table 2:** Description of Ethanolic Extracts of *Bombax ceiba*

| Sample | Description |
|---|---|
| Ethanolic Extract of *Bombax ceiba* Leaf | Greenish Powder |
| Ethanolic Extract of *Bombax ceiba* Bark | Yellow Brown Powder |
| Ethanolic Extract of *Bombax ceiba* Root | Reddish Brown Powder |

**Melting Point**

Melting Point of Ethanolic Extracts of *Bombax ceiba* were determined by Capillary Method and was also measured by using DSC spectra**.**

**Table 3:** Melting point of Ethanolic Extracts of *Bombax ceiba*

| Sample | Manually | DSC |
|---|---|---|
| Ethanolic Extract of *Bombax ceiba* Leaf | 196° C | 200.1° C |
| Ethanolic Extract of *Bombax ceiba* Bark | 88° C | 90.8° C |
| Ethanolic Extract of *Bombax ceiba* Root | 86° C | 92.4° C |

**Phytochemical Evaluation**

**Table 4:** Phytochemical Evaluation of Ethanolic Extracts of *Bombax ceiba*

| Sr. No. | Test | Leaf Extract | Root Extract | Bark Extract |
|---|---|---|---|---|
| 1 | Carbohydrates Test | + | + | + |
| 2 | Glycosides Test | + | + | + |
| 3 | Alkaloids Test | + | + | + |
| 4 | Proteins Test | - | - | - |
| 5 | Amino Acids Test | - | - | - |
| 6 | Steroids & Triterpenoids Test | + | + | + |

| | | | | |
|---|---|---|---|---|
| 7 | Flavonoids Test | + | + | + |
| 8 | Tannins Test | + | + | + |
| 9 | Phenols Test | + | + | + |

**Determination of λ- max**

A simple spectroscopic method for the estimation of *Bombax ceiba* leaf, bark, and root extracts was performed in ethanol using a UV spectrophotometer. The λ-max of the ethanolic extract of *Bombax ceiba* leaf was found to be 205 nm, for *Bombax ceiba* bark extract 214 nm, and for *Bombax ceiba* root extract 213 nm.

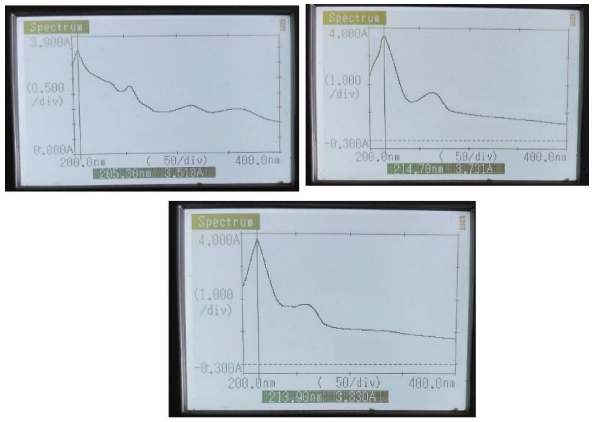



**Fig 1:** UV Spectra of *Bombax ceiba* (A) Leaf Extract (B)Bark Extract (C) Root Extract.

**Calibration Curve**

**Calibration Curve of *Bombax ceiba* Leaf Extract**

The absorbance data of the standard solutions are shown in Table 5.

The values of Absorbance were plotted against respective concentrations (Figure 2). The concentration showed linearity when the curve was plotted indicating it obeyed Beers Law. The regression coefficient value was 0. 9834 in phosphate buffer pH 1.2.

**Calibration Curve of *Bombax ceiba* Bark Extract**

The absorbance data of the standard solutions are shown in Table 5.

The values of Absorbance were plotted against respective concentrations (Figure 2). The concentration showed linearity when the curve was plotted indicating it obeyed Beers Law. The regression coefficient value was 0. 9846 in phosphate buffer pH

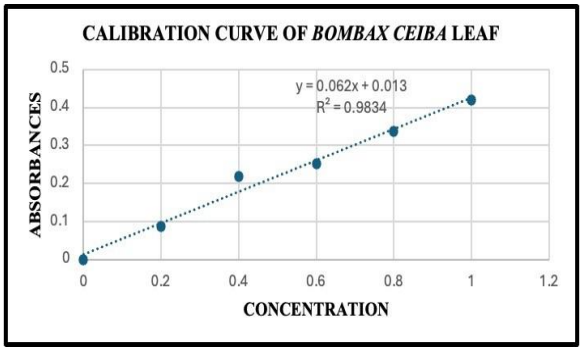
**Calibration Curve of *Bombax ceiba* Root Extract**

The absorbance data of the standard solutions are shown in Table 5.

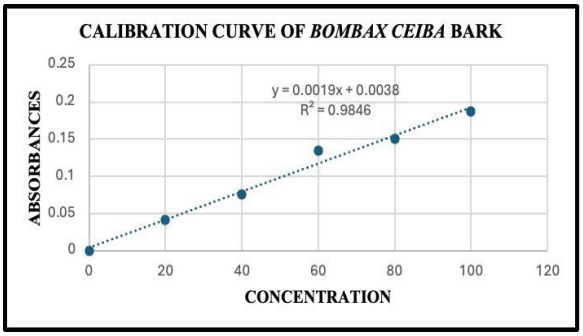
The values of Absorbance were plotted against respective concentrations (Figure 2). The concentration showed linearity when the curve was plotted indicating it obeyed Beers Law. The regression coefficient value was 0. 9896 in phosphate buffer pH 1.2.

**Table 5:** Calibration Curve of *Bombax ceiba* Extracts

| Sr. No. | Concentration (µg) | Absorbance (nm) | | |
|---|---|---|---|---|
| | | Leaf Extract | Bark Extract | Root Extract |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 0.2 | 0.087 | 0.041 | 0.049 |
| 3 | 0.4 | 0.218 | 0.076 | 0.091 |
| 4 | 0.6 | 0.251 | 0.135 | 0.159 |
| 5 | 0.8 | 0.338 | 0.151 | 0.183 |
| 6 | 1 | 0.419 | 0.187 | 0.228 |




(A)

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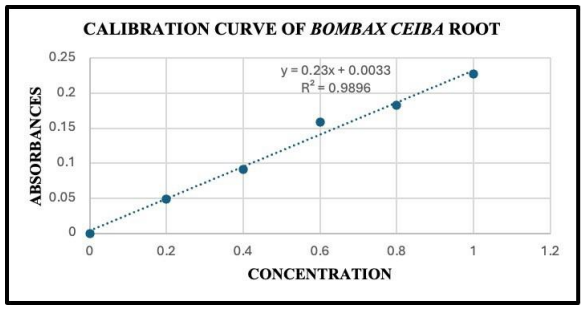



**(C)**

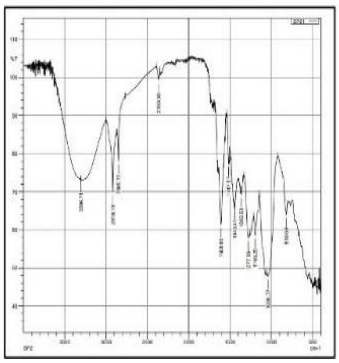
**Fig 2:** Calibration curve of *Bombax ceiba* (A) Leaf Extract (B) Bark Extract (C) Root Extract**.**

**Drug Excipients Compatibility Studies**

The compatibility study of Herbs and excipients was carried out using FTIR and DSC methods. The results are shown below.

**Fourier Transformed Infrared (FT-IR) Spectroscopic Analysis**

- The *Bombax ceiba* leaf extract showed significant bands at 3304.71 $cm^{-1}$ for O-H stretching. The CH3, CH2 stretching was observed at 2918.19 $cm^{-1.}$ The O-C stretching was observed at 1277.96 $cm^{-1}$. The NH2 bending was observed at 1608.86 $cm^{-1}$. The S-OR was observed at 818.69 $cm^{-1}$.
- The *Bombax ceiba* leaf extract and Physical Mixture showed significant bands at 3310.42 $cm^{-1}$ for O-H stretching. The CH3, CH2 stretching was observed at 2918.19 $cm^{-1.}$ The O-C stretching was observed at 1277.96 $cm^{-1}$. The NH2 bending was observed at 1608.86 $cm^{-1}$. The S-OR was observed at 818.69 $cm^{-1}$.
- The *Bombax ceiba* bark extract showed significant bands at 3304.71 $cm^{-1}$ for N-H stretching. The CH3, CH2 stretching was observed at 2918.19 $cm^{-1.}$ The O-H stretching was observed at 2849.73 $cm^{-1.}$ The P-H was observed at 2363.36 $cm^{-1.}$ The O-C stretching was observed at 1042.62 $cm^{-1.}$
- The *Bombax ceiba* bark extract and Physical Mixture showed significant bands at 3310.42 $cm^{-1}$ for N-H stretching. The CH3, CH2 stretching was observed at 2916.76 $cm^{-1.}$ The O-H stretching was observed at 2849.73 $cm^{-1.}$ The P-H was observed at 2360.51 $cm^{-1.}$ The O-C stretching was observed at 1018.37 $cm^{-1.}$
- The *Bombax ceiba* root extract showed significant bands at 3297.58 $cm^{-1}$ for O-H stretching. The O-C stretching was observed at 1282.23 $cm^{-1.}$ The CH3, CH2 stretching was observed at 2918.19 $cm^{-1.}$ The NH2 bending was observed at 1606.00 $cm^{-1.}$
- The *Bombax ceiba* root extract and Physical Mixture showed significant bands at 3301.86 $cm^{-1}$ for O-H stretching. The O-C stretching was observed at 1279.38 $cm^{-1.}$ The CH3, CH2 stretching was observed at 2918.19 $cm^{-1.}$ The NH2 bending was observed at 1608.86 $cm^{-1.}$



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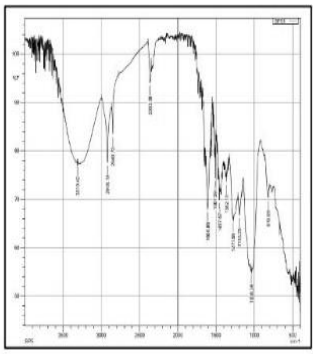

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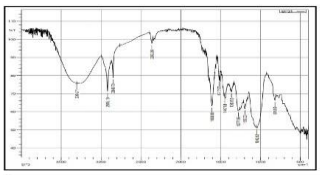
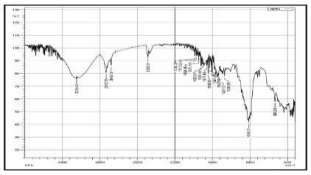
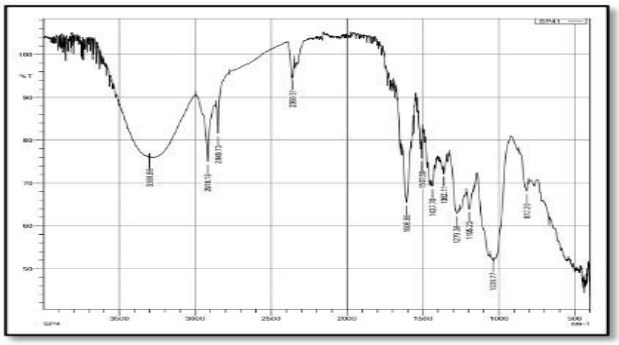
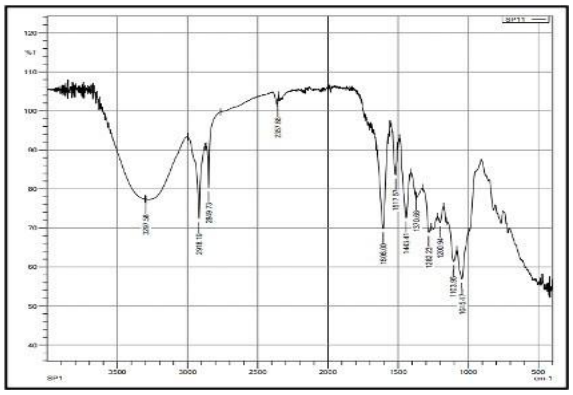






(C) (D) (E)



**(F)**

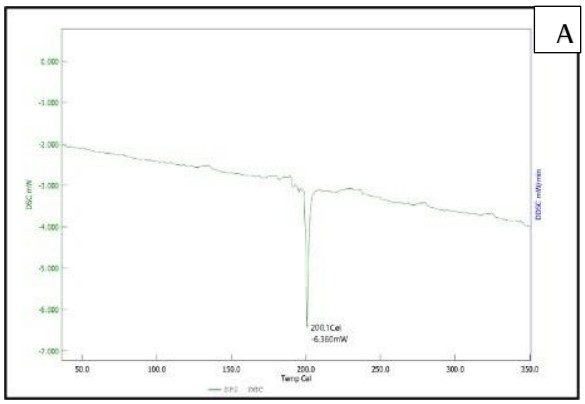
**Fig 3:** FTIR of Bombax ceiba (A) Leaf (B) Leaf and Physical mixture (C)Bark (D) Bark and Physical mixture (E) Root (F) Root and Physical mixture

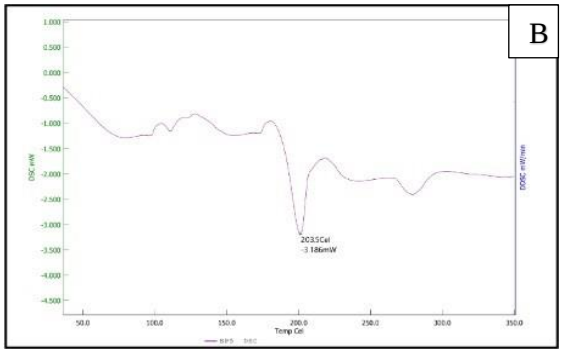
**Differential Scanning Calorimetry**

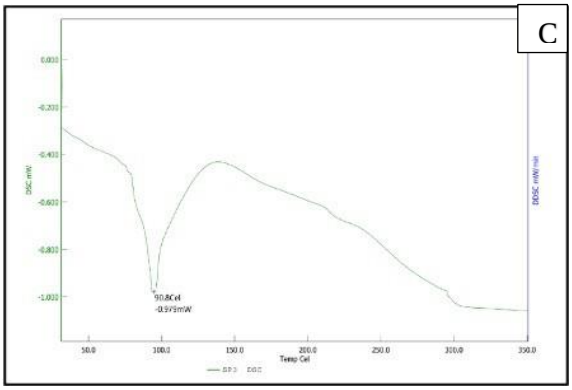
The thermal behaviors of Herbs extract & Physical

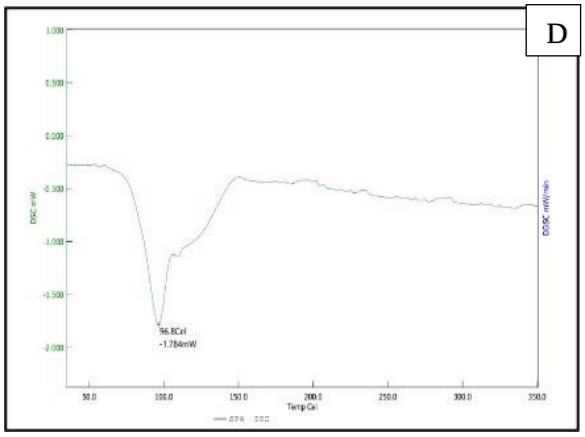
Mixture are shown in the figure.

The DSC thermogram of *Bombax ceiba* leaf extract showed a characteristic endothermic peak at 200.1ºC. The DSC thermogram of *Bombax ceiba* bark extract showed a characteristic endothermic peak at 90.8ºC. The DSC thermogram of *Bombax ceiba* root extract showed a characteristic endothermic peak at 92.4ºC. The DSC thermogram of physical mixture containing *Bombax ceiba* leaf extract, Lactose, Starch, Sodium Starch Glycolate, Microcrystalline cellulose, Magnesium Stearate and Talc showed the peak at $203.5^0$ C. The DSC thermogram of physical mixture containing *Bombax ceiba* bark extract, Lactose, Starch, Sodium Starch Glycolate, Microcrystalline cellulose, Magnesium Stearate and Talc showed the peak at $96.8^0$ C. The DSC thermogram of physical mixture containing *Bombax ceiba* root extract, Lactose, Starch, Sodium Starch Glycolate, Microcrystalline cellulose, Magnesium Stearate and Talc showed the peak at $94.3^0$ C.



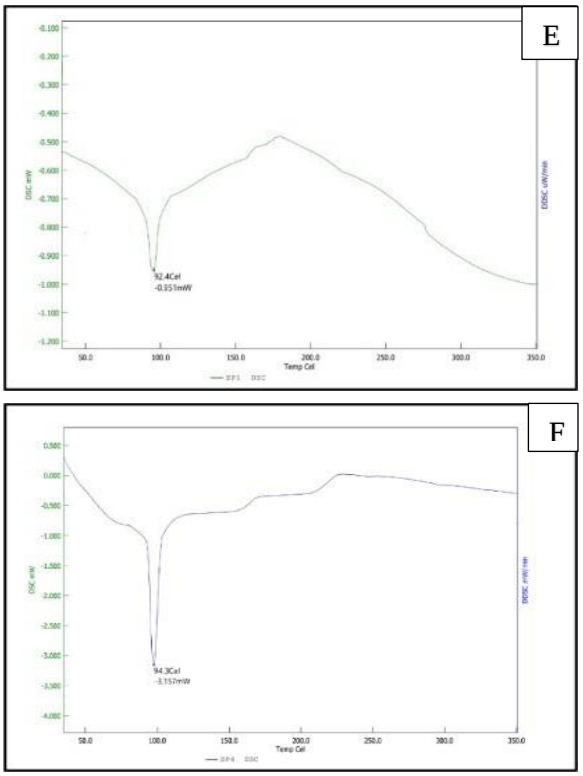



**Fig 4:** DSC of Bombax ceiba (A) Leaf (B) Leaf and Physical mixture (C)Bark (D) Bark and Physical mixture (E) Root (F) Root and Physical mixture

***In-vitro* Anti-inflammatory Activity of *Bombax ceiba* Extracts**

The *in-vitro* anti-inflammatory activity of *Bombax ceiba* leaf, bark, and root extracts was evaluated using two methods: the HRBC membrane stabilization method and Bovine Serum Albumin (BSA) protein denaturation assay. The HRBC method assesses how well the extracts protect red blood cells from lysis, simulating the stabilization of cell membranes during inflammation. The BSA method uses UV spectroscopy to measure the inhibition of protein denaturation, a key indicator of inflammation. The leaf extract showed a stronger anti-inflammatory effect than the bark and root extracts. Because of this, *Bombax ceiba* leaf extract was used for further studies.

**Table 6:** *In-vitro* Anti-inflammatory Activity of *Bombax ceiba* Extracts by BSA

| Sr. No. | Conc. µg/ ml | Leaf % Inhibit ion | Bark % Inhibit ion | Root % Inhibit ion | Standard Drug % Inhibit ion |
|---|---|---|---|---|---|
| 1 | 50 | 66.12 % | 63.57 % | 57.3 % | 70.53 % |
| 2 | 100 | 70.53 % | 67.74 % | 61.94 % | 75.63 % |
| 3 | 150 | 78.65 % | 74.01 % | 67.98 % | 83.29 % |
| 4 | 200 | 84.91 % | 79.58 % | 72.85 % | 88.39 % |

**Table 7**: *In- vitro* Anti- inflammatory Activity of *Bombax Ceiba* Extracts by HRBC

| Sr. No. | Conc. µg/ml | Leaf | Bark | Root | Standard Drug |
|---|---|---|---|---|---|
| 1 | 50 | 71.92 % | 68.65 % | 61.63 % | 74.85 % |
| 2 | 100 | 75.78 % | 71.22 % | 66.19 % | 79.06 % |
| 3 | 150 | 83.04 % | 76.95 % | 70.64 % | 85.02 % |
| 4 | 200 | 86.43 % | 82.33 % | 75.78 % | 90.17% |

**Evaluation Test for Tablet**


**Fig 5.** Prepared Tablets of *Bombax ceiba* Leaf Extract

Prepared Tablets of *Bombax ceiba* Leaf Extract The post-compression evaluation of all formulations (F1–F4) demonstrated satisfactory pharmaceutical characteristics. All tablets showed a uniform diameter of 13 mm and thickness of 4.00 mm, indicating consistency in tablet dimensions. The hardness of the tablets ranged from 5.00 to 8.00 kg/cm², with F2 exhibiting the highest hardness. Friability values for all formulations were below 1% (0.40–0.80%), complying with Indian Pharmacopoeia

limits and confirming adequate mechanical strength. The disintegration time varied significantly among formulations, with F4 showing the fastest disintegration (42 sec), followed by F1 (69 sec), F3 (88 sec), and F2 (139 sec). Drug content ranged from 72.29% to 91.42%, with F4 exhibiting the highest drug content, indicating better uniformity and drug distribution. All formulations passed the weight variation test as per IP standards. Overall, formulation F4 demonstrated optimal post-compression characteristics, making it the most suitable formulation among all batches.

**Table 8:** Evaluation of Formulated Tablets

| Formulation | Diameter (mm) | Thickness (mm) | Hardness (kg/cm²) | Friability (%) | Disintegration Time (Sec) | Drug Content (%) | Uniformity of Weight |
|---|---|---|---|---|---|---|---|
| F1 | 13 | 4.00 | 5.50 | 0.80 % | 69 | 84.30 % | As per IP |
| F2 | 13 | 4.00 | 8.00 | 0.57 % | 139 | 77.30 % | As per IP |
| F3 | 13 | 4.00 | 6.00 | 0.40 % | 88 | 72.29 % | As per IP |
| F4 | 13 | 4.00 | 5.00 | 0.45 % | 42 | 91.42% | As per IP |

### *In-vitro* Drug Release Studies


**Fig 6:** IP Apparatus I (Dissolution apparatus) The *In-vitro* dissolution study demonstrated a progressive increase in cumulative drug release for all formulations (F1–F4) over a period of 60 minutes by using IP Apparatus I (dissolution apparatus). At 10 minutes, drug release ranged from 5.7% (F2) to 10.8% (F4), indicating an initial rapid release phase. This trend continued with time, and at 30 minutes, F4 showed the highest release (37.3%) compared to F1 (34.42%), F2 (26.4%), and F3 (31.4%). By 50 minutes, formulations F1 and F3 exhibited comparable release profiles (69.3% and 69.9%, respectively), while F4 maintained the highest release (72.8%). At the end of 60 minutes, the optimized formulation F4 achieved the maximum cumulative drug release of 93.6%, followed by F1 (89%), F3 (84.8%), and F2 (73.2%). These results indicate that formulation F4 provides a more efficient and rapid drug release profile compared to the other formulations, making it the most suitable candidate for further development.

**Table 9:** *In-Vitro* Drug Release of Ethanolic Leaf Extract of *Bombax ceiba* Tablet

| Sr. No. | Time (Mins) | Formulation | | | |
|---|---|---|---|---|---|
| | | F1 | F2 | F3 | F4 |
| 1. | 0 min | 0 % | 0 % | 0 % | 0 % |
| 2. | 10 min | 8.87 % | 5.7 % | 7.7 % | 10.8 % |
| 3. | 20 min | 20.33 % | 15.1 % | 18.2 % | 23 % |
| 4. | 30 min | 34.42 % | 26.4 % | 31.4 % | 37.3 % |
| 5. | 40 min | 51.26 % | 39.6 % | 47.7 % | 54.4 % |
| 6. | 50 min | 69.3 % | 55 % | 69.9 % | 72.8 % |
| 7. | 60 min | 89 % | 73.2 % | 84.8 % | 93.6 % |

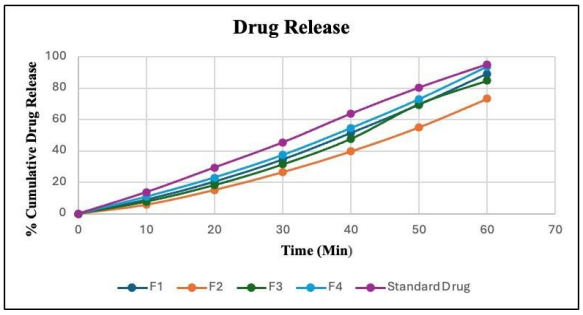



**Fig 7:** Graphical Representation of % Cumulative Drug Release

## CONCLUSION

The present study successfully formulated and evaluated an herbal tablet containing *Bombax ceiba* leaf extract for anti-inflammatory activity. Preformulation and compatibility studies using FTIR and DSC confirmed the absence of drug–excipient interactions. Among all formulations, F4 demonstrated superior flow properties and complied with pharmaceutical standards in terms of hardness, friability (<1%), drug content (91.42%), and rapid disintegration (42 sec). The optimized formulation (F4) showed a high drug release of 93.6% within 60 minutes, indicating effective drug delivery. Thus, the developed formulation may serve as a promising herbal therapeutic option for the management of inflammation.

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