# Development and Physicochemical Evaluation of a Novel Polyherbal Tablet Containing Moringa oleifera, Tinospora cordifolia, Cyperus rotundus, and Fagonia arabica

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**Abstract**

**Background**: Pain and inflammation represent cardinal features of a wide spectrum of acute and chronic disease states. Although non-steroidal anti-inflammatory drugs (NSAIDs) constitute the current pharmacological mainstay, prolonged use is associated with gastrointestinal irritation, nephrotoxicity, and drug dependence. Herbal formulations derived from traditional medicinal systems offer a multi-targeted and toxicologically favourable alternative.

**Objective**: To develop and evaluate a standardised polyherbal tablet formulation incorporating extracts of Moringa oleifera (Moringa), Tinospora cordifolia (Guduchi), Cyperus rotundus (Nagarmotha), and Fagonia arabica (Dhamasa) for dual analgesic and anti-inflammatory activity.

**Materials and Methods**: Standardised extracts were prepared by Soxhlet extraction (M. oleifera and C. rotundus, ethanol) and decoction (T. cordifolia and F. arabica, aqueous). Three trial batches (F1–F3) were prepared by wet granulation and compressed into 210 mg uncoated tablets. The optimised formulation (F3) was evaluated for organoleptic properties, weight variation, hardness, friability, disintegration time, and dimensional uniformity in accordance with Indian Pharmacopoeia (IP) specifications. Phytochemical identification tests and Fourier transform infrared (FTIR) spectroscopic characterisation were performed on individual extracts.

**Results**: F3 complied with all IP acceptance criteria: mean tablet weight 209 mg (range 200–220 mg; IP limit ±7.5%), hardness 5–7 kg/cm² (IP: 5–8 kg/cm²), friability 0.458% (IP: ≤1.0%), and disintegration time 8.10–14.30 minutes (IP: ≤15 min for uncoated tablets). Mean diameter was 8.66 mm and mean thickness 4.06 mm, both within ±5% of their respective means. Phytochemical screening confirmed flavonoids (M. oleifera), alkaloids (T. cordifolia), saponins (F. arabica), and terpenoids (C. rotundus). FTIR spectra corroborated the presence of characteristic functional groups of the principal bioactive constituents.

**Conclusion**: The optimised polyherbal tablet formulation demonstrated satisfactory physicochemical quality and confirmed the retention of pharmacologically relevant phytoconstituents. These findings provide a scientific basis for further in-vivo pharmacological evaluation and clinical investigation as a potential herbal alternative to conventional NSAIDs.

**Keywords:** Polyherbal tablet; anti-inflammatory; analgesic; Moringa oleifera; Tinospora cordifolia; Cyperus rotundus; Fagonia arabica; wet granulation; NSAID alternative

## 1. Introduction

Pain and inflammation are cardinal features of a wide spectrum of acute and chronic medical conditions ranging from post-traumatic tissue injury to autoimmune and degenerative diseases. Physiologically, inflammation is a coordinated protective response mediated by the release of prostaglandins, leukotrienes, cytokines, and other inflammatory mediators (Medzhitov, 2008). Although this response serves a critical host defence function, unresolved or chronic inflammation causes persistent pain and progressive tissue destruction (Rang et al., 2016). Pain, whether nociceptive or inflammatory in origin, substantially impairs quality of life and constitutes a major global socioeconomic burden.

Non-steroidal anti-inflammatory drugs (NSAIDs) and opioid analgesics constitute the current pharmacological mainstay for pain and inflammation management. NSAIDs principally exert their effects through non-selective inhibition of cyclooxygenase (COX) enzymes, thereby suppressing prostaglandin biosynthesis (Vane and Botting, 1998). Despite their widespread clinical utility, chronic NSAID use is associated with dose-dependent adverse effects including gastrointestinal haemorrhage, nephrotoxicity, cardiovascular events, and — in the case of opioids —

dependence and tolerance (Brunton et al., 2018; Rang et al., 2016). These limitations have generated substantial interest in the development of alternative analgesic and anti-inflammatory agents derived from natural sources.

Traditional systems of medicine — principally Ayurveda, Siddha, and Unani — have documented the therapeutic application of medicinal plants for millennia (Agnivesha, 2014). Compared with synthetic pharmacological agents, herbal preparations generally exhibit higher biocompatibility, multi-targeted mechanisms of action, and more favourable adverse effect profiles (Ekor, 2014). Polyherbal formulations, which combine two or more medicinal plants, exploit synergistic interactions between bioactive phytoconstituents to enhance efficacy while minimising individual component-related toxicity (Peters-Golden and Henderson, 2007).

Four medicinal plants with well-characterised anti-inflammatory and analgesic pharmacology were selected for the present formulation:

Moringa oleifera Lam. (family Moringaceae), the drumstick tree, is rich in flavonoids and phenolic compounds that suppress COX and lipoxygenase (LOX) enzyme activity and reduce circulating concentrations of tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), conferring potent anti-inflammatory and antioxidant properties (Leone et al., 2015).

Tinospora cordifolia (Willd.) Miers (family Menispermaceae), Guduchi or Giloy, contains alkaloids (notably berberine), glycosides, and diterpenoids that mediate immunomodulatory and analgesic effects through free radical scavenging and inhibition of pro-inflammatory cytokine release (Tripathi, 2018; Agnivesha, 2014).

Cyperus rotundus L. (family Cyperaceae), Nagarmotha or nut-grass, contains essential oil components — principally cyperene and rotundone — with potent analgesic and anti-inflammatory properties experimentally comparable to aspirin (Raut and Gaikwad, 2006). The plant additionally exhibits antispasmodic and muscle-relaxant activity.

Fagonia arabica Linn. (family Zygophyllaceae), Dhamasa, contains flavonoids, saponins, and alkaloids that act as antioxidants, suppress inflammatory mediators, and promote tissue regeneration (Kumar et al., 2013; Ala, 2007; Pareek et al., 2012). It has been employed in Ayurvedic medicine for the management of fever, wounds, and inflammatory conditions.

Despite the extensive individual characterisation of these four botanicals, no standardised solid oral dosage form combining all four has been reported in the literature. The tablet dosage form offers practical advantages in terms of dose precision, patient compliance, ease of self-administration, portability, and suitability for large-scale manufacture. The present study therefore aimed to: (i) develop a polyherbal tablet formulation incorporating standardised extracts of M. oleifera, T. cordifolia, C. rotundus, and F. arabica; (ii) optimise the formulation through systematic trial batch development; and (iii) characterise the final optimised formulation through physicochemical, phytochemical, and FTIR spectroscopic evaluation in accordance with Indian Pharmacopoeia specifications.

## 2. Materials and Methods

### 2.1 Plant Material and Authentication

Dried plant materials — leaves of Moringa oleifera, rhizomes of Cyperus rotundus, whole plant of Fagonia arabica, and stems of Tinospora cordifolia — (Figure 1) were procured from a certified herbal supplier. All plant materials were authenticated by a qualified pharmacognosist; voucher specimens were deposited at the institutional herbarium [Voucher reference numbers to be inserted]. Materials were cleaned, shade-dried, and coarsely powdered prior to extraction.

### 2.2 Chemicals and Excipients

Pharmaceutical-grade excipients — microcrystalline cellulose (MCC), maize starch, acacia gum, magnesium stearate, talc, and stevia — were procured from [supplier name]. Analytical-grade solvents and reagents — 95% v/v ethanol, distilled water, lead acetate solution, 10% sodium hydroxide, Dragendroff's reagent, Mayer's reagent, Hager's reagent, Wagner's reagent, chloroform, and concentrated sulphuric acid — were obtained from [supplier name].

### 2.3 Instruments and Equipment

Instruments used included: Soxhlet extraction apparatus (Borosil, India); rotary vacuum evaporator; digital analytical balance (Shimadzu AX200); water bath; Monsanto hardness tester; Roche friabilator; disintegration test apparatus (Electrolab ED-2L); calibrated Vernier calliper; single-punch tablet compression machine; and FTIR spectrophotometer (Shimadzu IRAffinity-1).

MORINGA LEAVES

NAGARMOTHA RHIZOMES

DHAMASA ( WHOLE PLANT)

GUDUCHI STEM

Figure 1. Images of the four medicinal plants

**2.4 Preparation of Plant Extracts**

**2.4.1 Soxhlet Extraction (Moringa oleifera and Cyperus rotundus)**

Accurately weighed quantities of coarsely powdered M. oleifera leaf and C. rotundus rhizome were separately loaded into the thimble of a Soxhlet apparatus. Extraction was performed using 95% ethanol for 6–8 hours under continuous reflux. The filtrate was collected, concentrated under reduced pressure using a rotary vacuum evaporator, and further dried on a water bath at 50°C. The resulting semi-solid extracts were stored in airtight containers at 4°C.

**2.4.2 Decoction Method (Fagonia arabica and Tinospora cordifolia)**

Approximately 50 g each of coarsely powdered F. arabica whole plant and T. cordifolia stems were individually boiled with 400 mL of distilled water until the volume was reduced to approximately one-quarter of the original volume (~100 mL). Each preparation was filtered through double-layered muslin cloth, concentrated on a water bath, and dried to a solid residue. Extracts were stored under desiccation at room temperature until use.

**2.5 Phytochemical Identification Tests**

Qualitative phytochemical screening was performed on each extract using established standard procedures (Kokate et al., 2019; Khadabadi et al., 2019) to confirm the presence of pharmacologically relevant phytoconstituent classes:

(i) Flavonoids (M. oleifera): Lead acetate test (yellow precipitate = positive); Alkali test (yellow colour decolorising on acidification = positive).

(ii) Alkaloids (T. cordifolia): Dragendroff's test (reddish-brown precipitate); Hager's test (yellow precipitate); Mayer's test (cream precipitate); Wagner's test (reddish-brown precipitate). Each test: 2 mL reagent + 2 mL extract solution.

(iii) Saponins (F. arabica): Foam test — vigorous shaking of aqueous extract; foam stability ≥15 minutes = positive.

(iv) Terpenoids (C. rotundus): Salkowski test — 1–2 mL chloroform added to extract solution followed by careful layering with 1 mL concentrated $H_2SO_4$; red coloration at interface = positive.

**2.6 FTIR Spectroscopic Characterisation**

Dried extracts were individually characterised by FTIR spectroscopy using the KBr pellet method. Spectra were recorded over 400–4000 $cm^{-1}$. Absorption bands were assigned by comparison with published spectral databases and reference data for the known principal bioactive constituents of each extract.

**2.7 Formulation Development and Tablet Manufacture**

**2.7.1 Formulation Composition**

Three trial batches (F1, F2, F3) were developed, each producing tablets of nominal weight 210 mg. Each batch contained equal quantities of all four herbal extracts (30 mg each; 120 mg total API per tablet). Excipient types were held constant across batches; only the quantities of acacia gum (binder) and magnesium stearate (lubricant) were varied to optimise compressibility and surface quality. The full formulation compositions are presented in Table 1.

**Table 1. Composition of polyherbal tablet trial batches (F1, F2, and F3)**

| S. No. | Ingredient | Category | F1 (mg) | F2 (mg) | F3 (mg) |
|---|---|---|---|---|---|
| 1 | Moringa oleifera extract | API — anti-inflammatory | 30 | 30 | 30 |
| 2 | Tinospora cordifolia extract | API — analgesic | 25 | 30 | 30 |
| 3 | Fagonia arabica extract | API — anti-inflammatory | 30 | 30 | 30 |
| 4 | Cyperus rotundus extract | API — analgesic | 25 | 30 | 30 |
| 5 | Microcrystalline cellulose | Diluent | 60 | 43 | 42 |
| 6 | Maize starch | Disintegrant | 16 | 20 | 20 |
| 7 | Acacia gum | Binder | 12 | 15 | 18 |
| 8 | Magnesium stearate | Lubricant | 3 | 4 | 2 |
| 9 | Talc | Glidant | 4 | 4 | 3 |
| 10 | Stevia | Sweetener/taste masking | 5 | 4 | 5 |
| | Total | | 210 | 210 | 210 |

**2.7.2 Wet Granulation Process**

Tablets were manufactured by wet granulation: (1) Herbal extracts and MCC were accurately weighed and blended geometrically. (2) Acacia gum binder solution (prepared in distilled water) was added incrementally to the powder blend to form a suitable wet mass. (3) The wet mass was passed through sieve no. 10 (or no. 12) to produce granules. (4) Granules were dried in a hot-air oven at 40–45°C for 30 minutes. (5) Dried granules were passed through sieve no. 22 to obtain uniform-sized granules. (6) Maize starch, magnesium stearate, and talc were blended with dried granules for 5 minutes. (7) Lubricated blend was compressed into tablets using a single-punch tablet compression machine.

Batch F1 exhibited picking (poor surface finish) attributable to insufficient binder concentration. Batch F2 showed capping due to excessive lubricant content creating a hydrophobic barrier that impaired inter-granular bonding under compression. Batch F3, formulated with an increased binder level (18 mg acacia gum) and a reduced lubricant level (2 mg magnesium stearate), produced tablets of satisfactory mechanical integrity and surface quality and was selected for comprehensive evaluation.

**2.8 Physicochemical Tablet Evaluation**

**2.8.1 Organoleptic Evaluation**

General appearance, colour, odour, taste, shape, and surface quality of F3 tablets were assessed by direct visual and sensory examination.

**2.8.2 Weight Variation Test**

Twenty tablets were individually weighed on a calibrated analytical balance. Mean weight and percentage deviation were calculated. The IP permissible variation limit of ±7.5% for tablets in the 85–250 mg range was applied (Indian Pharmacopoeia Commission, 2022).

**2.8.3 Hardness Test**

Crushing strength of five tablets was determined individually using a Monsanto hardness tester (kg/cm²). IP acceptance criterion: 5–8 kg/cm².

**2.8.4 Friability Test**

A tablet sample of ~6.54 g was weighed ($W_1$) and subjected to 100 revolutions at 25 rpm for 4 minutes in a Roche friabilator. Post-test weight ($W_2$) was recorded. % Friability = $[(W_1 - W_2) / W_1] \times 100$. IP acceptance criterion: ≤1.0%.

**2.8.5 Thickness and Diameter**

Thickness and diameter of five tablets were individually measured using a calibrated Vernier calliper (mm). Acceptance criterion: ±5% of mean value.

**2.8.6 Disintegration Test**

Six tablets were tested individually in a disintegration apparatus using 900 mL of distilled water at 37°C ± 1°C, 28–32 cycles per minute. Time for complete disintegration was recorded. IP acceptance criterion for uncoated tablets: ≤15 minutes.

## 3. Results

**3.1 Phytochemical Identification**

Qualitative phytochemical screening confirmed the presence of all targeted phytoconstituent classes in the respective extracts. Results are summarised in Table 2.

**Table 2. Qualitative phytochemical screening results for individual herbal extracts**

| Extract | Target Phytoconstituent | Test Applied | Observation | Result |
|---|---|---|---|---|
| Moringa oleifera | Flavonoids | Lead acetate test | Yellow precipitate | Present |
| | | Alkali test | Yellow colour; decolorises on acidification | Present |
| Tinospora cordifolia | Alkaloids | Dragendroff's test | Reddish-brown precipitate | Present |
| | | Hager's test | Yellow colour | Present |
| | | Mayer's test | Cream-coloured precipitate | Present |
| | | Wagner's test | Reddish-brown precipitate | Present |
| Fagonia arabica | Saponins | Foam test | Stable foam ≥15 minutes | Present |
| Cyperus rotundus | Terpenoids | Salkowski test | Red coloration at interface | Present |

### 3.2 FTIR Spectroscopic Analysis

The FTIR spectra of individual herbal extracts displayed absorption bands consistent with their principal bioactive phytoconstituents (Tables 3–6; Figures 2–5).

**Table 3. FTIR spectral assignments for Moringa oleifera ethanolic extract**

| J | Reference Range ($cm^{-1}$) | Vibrational Assignment | Functional Group | Interpretation |
|---|---|---|---|---|
| 3648 | 3600–3650 | O–H stretching (free hydroxyl) | Phenolic –OH | Hydroxyl groups of flavonoids/quercetin |
| 2895 | 2850–2950 | C–H stretching | Alkyl C–H | Aromatic CH groups in plant metabolites |
| 1624 | 1600–1660 | C=C aromatic stretching | Aromatic ring | Conjugated skeletal vibration of flavonoid quercetin |

**Table 4. FTIR spectral assignments for Cyperus rotundus ethanolic extract**

| Peak ($cm^{-1}$) | Reference Range ($cm^{-1}$) | Vibrational Assignment | Functional Group | Interpretation |
|---|---|---|---|---|
| 3706 | 3600–3700 | Free O–H stretching | Alcohol/hydroxyl | Hydroxylated terpenoids or residual moisture |
| 1510 | 1500–1600 | C=C stretching vibration | Conjugated alkene/aromatic | Unsaturated sesquiterpene structure |
| 1096 | 1000–1150 | C–O stretching | Alcohol/ester | Oxygenated terpenoid functionality |

**Table 5. FTIR spectral assignments for Fagonia arabica aqueous extract**

| Peak ($cm^{-1}$) | Reference Range ($cm^{-1}$) | Vibrational Assignment | Functional Group | Interpretation |
|---|---|---|---|---|
| 3702.8 | 3600–3700 | O–H stretching (free –OH) | Phenolic –OH | Hydroxyl groups of saponins and triterpenoids |
| 3445.4 | 3200–3500 | Broad O–H stretching | Alcoholic –OH | Hydroxyl-rich saponins and oleanolic acid |
| 1510 | 1500–1600 | C=C stretching | Aromatic group | Unsaturation in triterpenoid nucleus |

**Table 6. FTIR spectral assignments for Tinospora cordifolia aqueous extract**

| Peak ($cm^{-1}$) | Reference Range ($cm^{-1}$) | Vibrational Assignment | Functional Group | Interpretation |
|---|---|---|---|---|
| 2781.2 | 2700–2850 | C–H stretching (methoxyl) | Methoxyl/aldehyde C–H | Methoxy-bearing alkaloids (e.g., berberine) |
| 1516.3 | 1500–1600 | C=C stretching | Aromatic ring | Aromatic structure of berberine alkaloid |
| 1713.3 | 1700–1725 | C=O stretching | Carbonyl group | Flavonoid- or alkaloid-associated oxygenated compounds |

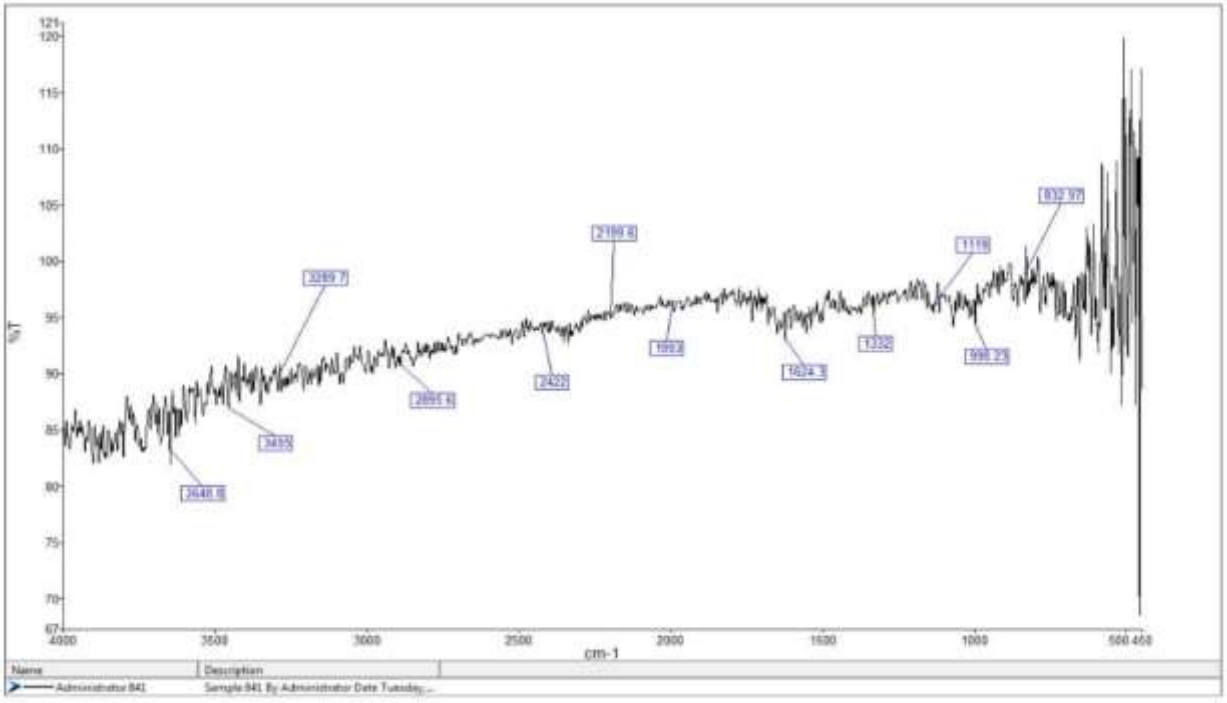


**Figure 2. FTIR spectrum of Moringa oleifera ethanolic extract (characteristic peaks at 3648, 2895, and 1624 $cm^{-1}$).**

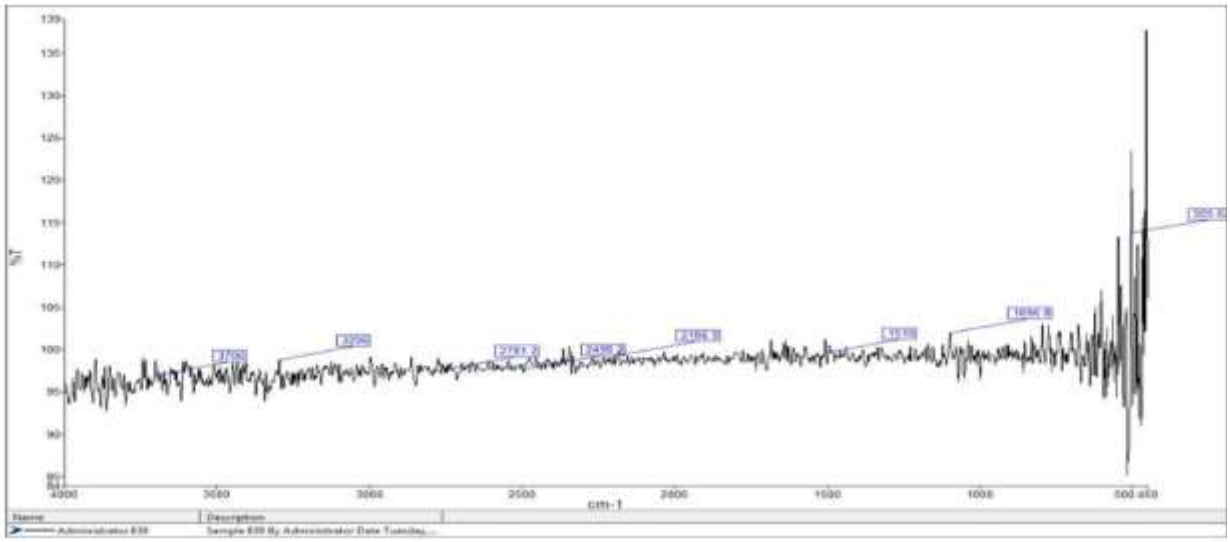


**Figure 3. FTIR spectrum of Cyperus rotundus ethanolic extract (characteristic peaks at 3706, 1510, and 1096 $cm^{-1}$).**

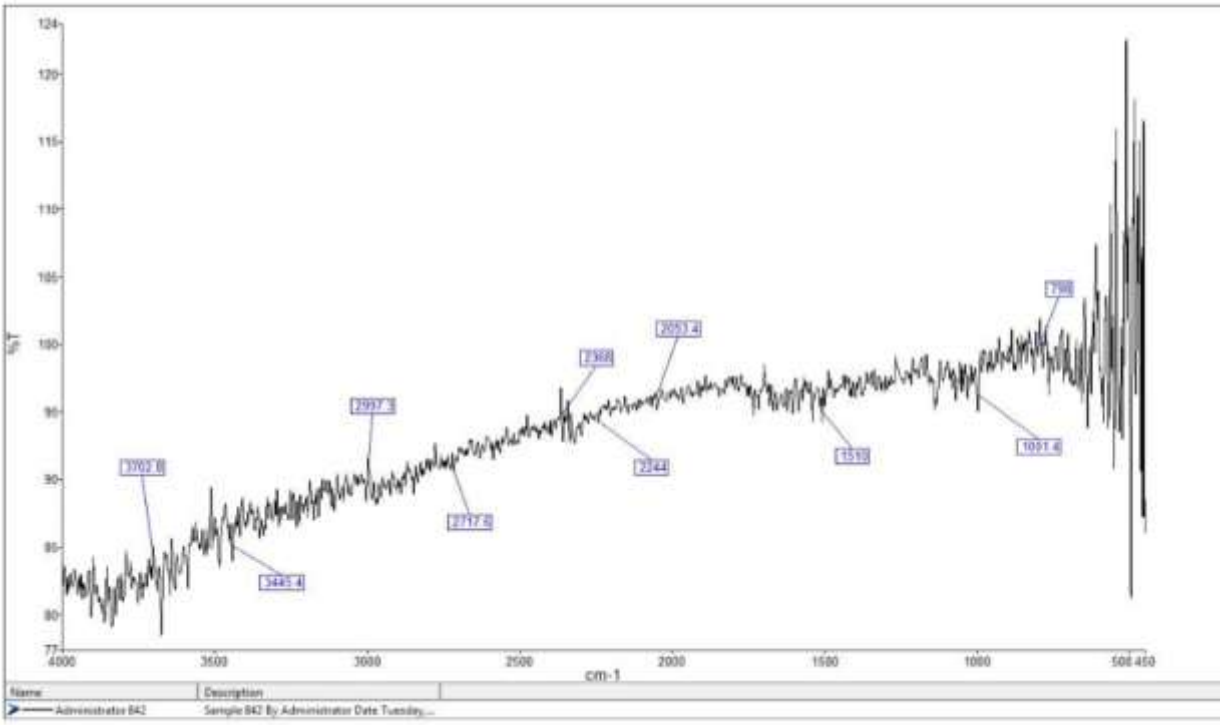


**Figure 4. FTIR spectrum of Fagonia arabica aqueous extract (characteristic peaks at 3702.8, 3445.4, and 1510 cm⁻¹).**

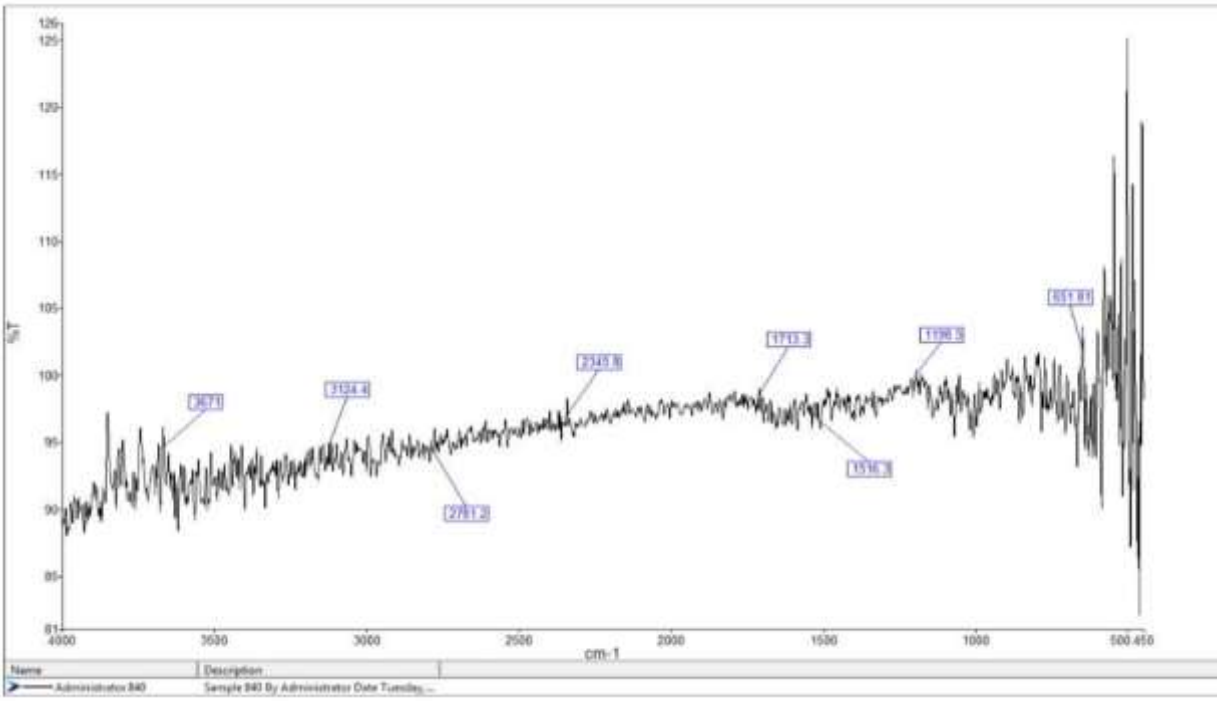


**Figure 5. FTIR spectrum of Tinospora cordifolia aqueous extract (characteristic peaks at 2781.2, 1516.3, and 1713.3 cm⁻¹).**

### 3.3 Organoleptic and General Appearance Evaluation

The optimised formulation (F3) produced round, flat-faced, uncoated tablets with a smooth, uniform surface and minimal inter-tablet variation in shape and size. Organoleptic properties are presented in Table 7.

**Table 7. Organoleptic properties of the optimised polyherbal tablet formulation (F3)**

| Parameter | Observation |
|---|---|
| Colour | Light brown to beige |
| Odour | Characteristic plant-like, slightly aromatic |

| | |
|---|---|
| Taste | Slightly sweet with mild herbal note |
| Shape | Circular, flat-faced |
| Size | Uniform, small |
| Surface finish | Smooth, uniform; free from visible defects (no picking, capping, or lamination) |

### 3.4 Weight Variation Test

Individual tablet weights for 20 randomly selected tablets are presented in Table 8. The mean tablet weight was 209 mg. Applying the IP ±7.5% permissible variation limit, the acceptable range was 193.33–224.68 mg. All 20 tablets fell within this range (Table 8), confirming IP compliance.

**Table 8. Individual tablet weights (n = 20) and weight variation parameters**

| Tablet No. | Weight (mg) | Tablet No. | Weight (mg) |
|---|---|---|---|
| 1 | 210 | 11 | 210 |
| 2 | 210 | 12 | 210 |
| 3 | 210 | 13 | 210 |
| 4 | 200 | 14 | 220 |
| 5 | 220 | 15 | 210 |
| 6 | 200 | 16 | 200 |
| 7 | 210 | 17 | 210 |
| 8 | 200 | 18 | 210 |
| 9 | 210 | 19 | 210 |
| 10 | 210 | 20 | 210 |
| Mean weight | 209 mg | Acceptable range | 193.33–224.68 mg |

### 3.5 Hardness Test

Individual hardness values ranged from 5 to 7 kg/cm² (Table 9), within the IP acceptance criterion of 5–8 kg/cm², confirming adequate mechanical strength.

**Table 9. Hardness test results (n = 5)**

| Tablet No. | Hardness (kg/cm²) |
|---|---|
| 1 | 5 |
| 2 | 5 |
| 3 | 6 |
| 4 | 7 |
| 5 | 6 |
| Range | 5–7 |
| IP acceptance criterion | 5–8 |

### 3.6 Friability Test

The initial tablet sample weight ($W_1$) was 6.54 g; the post-test weight ($W_2$) was 6.51 g. The calculated percentage friability was 0.458% (Table 10), substantially below the IP limit of ≤1.0%.

**Table 10. Friability test results**

| Parameter | Value |
|---|---|
| Initial weight ($W_1$) | 6.54 g |
| Final weight ($W_2$) | 6.51 g |
| Weight loss | 0.03 g |
| % Friability | 0.458% |
| IP acceptance criterion | ≤1.0% |
| Result | PASS |

### 3.7 Thickness and Diameter

Individual thickness and diameter measurements are presented in Table 11. Mean diameter was 8.66 mm (range: 8.6–8.8 mm; acceptance range: 8.23–9.09 mm) and mean thickness was 4.06 mm (range: 3.9–4.2 mm; acceptance range: 3.86–4.26 mm). All tablets conformed to the ±5% acceptance limits.

**Table 11. Tablet thickness and diameter measurements (n = 5)**

| Tablet No. | Diameter (mm) | Thickness (mm) |
|---|---|---|
| 1 | 8.6 | 3.9 |
| 2 | 8.8 | 4.0 |
| 3 | 8.6 | 4.2 |
| 4 | 8.7 | 4.2 |
| 5 | 8.6 | 4.0 |
| Mean | 8.66 | 4.06 |
| Acceptance range (±5%) | 8.23–9.09 | 3.86–4.26 |

### 3.8 Disintegration Test

Disintegration times for six tablets ranged from 8.10 to 14.30 minutes (Table 12). All tablets disintegrated within the IP limit of ≤15 minutes for uncoated tablets.

**Table 12. Disintegration test results (n = 6)**

| Tablet No. | Disintegration Time (min) |
|---|---|
| 1 | 8.10 |
| 2 | 8.15 |
| 3 | 10.50 |
| 4 | 11.20 |
| 5 | 12.10 |
| 6 | 14.30 |
| IP acceptance criterion | ≤15 min (uncoated tablets) |
| Result | All tablets: PASS |

### 3.9 Summary of Physicochemical Evaluation

**Table 13. Summary of physicochemical evaluation results for the optimised formulation (F3)**

| Parameter | IP Specification | Observed Result | Compliance |
|---|---|---|---|
| Weight variation | ±7.5% of mean weight | Mean 209 mg; range 200–220 mg | Pass |
| Hardness | 5–8 kg/cm² | 5–7 kg/cm² | Pass |
| Friability | ≤1.0% | 0.458% | Pass |
| Disintegration | ≤15 min (uncoated) | 8.10–14.30 min | Pass |
| Diameter | ±5% of mean diameter | 8.6–8.8 mm (mean 8.66 mm) | Pass |
| Thickness | ±5% of mean thickness | 3.9–4.2 mm (mean 4.06 mm) | Pass |

## 4. Discussion

### 4.1 Polyherbal Rationale and Synergistic Activity

The present study documents, to our knowledge, the first systematic formulation and physicochemical characterisation of a solid oral polyherbal tablet combining M. oleifera, T. cordifolia, C. rotundus, and F. arabica for analgesic and anti-inflammatory application. The selection of these four botanicals is grounded in their complementary and synergistic mechanisms: M. oleifera flavonoids target COX, LOX, and cytokine pathways (Leone et al., 2015); T. cordifolia alkaloids suppress pro-inflammatory cytokine release and mediate immunomodulation (Tripathi, 2018); C. rotundus sesquiterpenes provide peripheral analgesic activity (Raut and Gaikwad, 2006); and F. arabica saponins and flavonoids inhibit inflammatory mediators and provide antioxidant protection (Kumar et al., 2013; Ala, 2007). This multi-target profile is anticipated to confer broader and more sustained relief than either single-herb preparations or conventional NSAIDs (Peters-Golden and Henderson, 2007; Ekor, 2014).

### 4.2 Formulation Optimisation

The wet granulation method was selected due to the cohesive and hygroscopic nature of herbal extracts, which renders them poorly suited to direct compression (Brunton et al., 2018). The trial batch series clearly demonstrated the critical importance of binder–lubricant balance: insufficient binder in F1 caused picking (poor surface adhesion during compression), while excess lubricant in F2 produced capping through hydrophobic coating of granule surfaces that impaired bonding. F3, (Figure 6 ) with acacia gum at 18 mg and magnesium stearate reduced to 2 mg per tablet, achieved optimal tablet quality. These findings are consistent with established literature on herbal tablet optimisation (Kokate et al., 2019; Khadabadi et al., 2019).


**Figure 6. Photograph of the optimized tablet (F3)**

**4.3 Phytochemical and Spectroscopic Characterisation**

Qualitative phytochemical screening confirmed the retention of all target phytoconstituent classes following extraction and processing. FTIR spectroscopic analysis provided corroborative evidence of chemical identity: the phenolic O–H stretch at 3648 $cm^{-1}$ and aromatic C=C stretch at 1624 $cm^{-1}$ in the M. oleifera spectrum are consistent with flavonoid/quercetin structure (Leone et al., 2015). The C=C absorption at 1510 $cm^{-1}$ and oxygenated C–O stretch at 1096 $cm^{-1}$ in C. rotundus are characteristic of its sesquiterpene scaffold (Raut and Gaikwad, 2006). The dual hydroxyl stretches at 3702.8 and 3445.4 $cm^{-1}$ in the F. arabica spectrum reflect the multi-hydroxylated saponin and oleanolic acid skeleton (Ala, 2007), while the methoxy C–H stretch at 2781.2 $cm^{-1}$ and aromatic C=C stretch at 1516.3 $cm^{-1}$ in T. cordifolia are consistent with berberine-type alkaloid structure (Tripathi, 2018).

**4.4 Physicochemical Quality Parameters**

All six physicochemical parameters of F3 met IP specifications (Table 13). The friability value of 0.458% — substantially below the 1.0% threshold — confirms adequate inter-particulate bonding within the tablet matrix. Hardness of 5–7 $kg/cm^2$ is consistent with values reported for comparable herbal tablet systems (Khadabadi et al., 2019). The weight uniformity data (all tablets within 193.33–224.68 mg of mean 209 mg) demonstrate satisfactory die-fill consistency and adequate granule flow. Disintegration within 8.10–14.30 minutes is clinically important: prompt disintegration is a prerequisite for dissolution and absorption of herbal bioactives. Performance of maize starch as disintegrant compares favourably with published herbal tablet systems (Kokate et al., 2019). Taste masking by stevia addresses the inherent bitterness of T. cordifolia and F. arabica extracts and is expected to support patient acceptability.

**4.5 Comparison with Published Studies**

Preclinical pharmacological studies have individually validated the four constituent herbs. Ethanolic M. oleifera leaf extracts have demonstrated significant inhibition of carrageenan-induced paw oedema and acetic acid-induced writhing in murine models (Leone et al., 2015). Aqueous T. cordifolia extracts have produced analgesic and anti-arthritic effects in clinical investigations (Tripathi, 2018). C. rotundus ethanolic extracts have shown analgesic effects comparable to aspirin at equimolar doses (Raut and Gaikwad, 2006). F. arabica extracts have demonstrated anti-inflammatory and antithrombotic activity in in-vitro models (Ala, 2007). The present formulation consolidates these validated activities into a single standardised dosage form not previously described in this combination.

**4.6 Limitations and Future Directions**

The current study has several limitations that must be acknowledged. First, in-vivo pharmacological validation — including carrageenan-induced paw oedema, hot-plate latency, and writhing tests — was not performed and is essential to directly establish the analgesic and anti-inflammatory efficacy of the combined formulation. Second, in-vitro dissolution profiling, critical for bioavailability prediction, was not conducted. Third, long-term stability data are absent. Future work should address: (i) in-vivo pharmacological assessment in validated animal models; (ii) dissolution profile development and comparative bioavailability studies; (iii) subacute and chronic toxicity evaluation per regulatory guidelines; (iv) exploration of alternative dosage forms (oral thin films, modified-release capsules); and (v) scale-up, stability, and clinical evaluation studies. The formulation additionally represents a candidate for novel herbal product patenting.

## 5. Conclusion

A novel polyherbal tablet formulation incorporating standardised ethanolic extracts of Moringa oleifera and Cyperus rotundus and aqueous extracts of Tinospora cordifolia and Fagonia arabica was successfully developed and characterised. The wet granulation process was systematically optimised through three trial batches; the final formulation (F3) satisfied all Indian Pharmacopoeia quality criteria for weight uniformity, hardness, friability, disintegration, and dimensional uniformity.

Phytochemical screening confirmed the retention of flavonoids, alkaloids, saponins, and terpenoids — the principal pharmacologically active phytoconstituent classes responsible for the established analgesic and anti-inflammatory activities of the constituent herbs. FTIR spectroscopic data provided corroborative evidence for the chemical identity of these constituents in the processed extracts.

The polyherbal tablet is anticipated to provide synergistic, multi-targeted analgesic and anti-inflammatory activity through complementary phytochemical mechanisms. As a standardised solid oral dosage form, it offers improved dose precision, patient compliance, and portability compared with traditional herbal preparations, and may represent a safer, affordable, and ecologically sustainable alternative to conventional NSAIDs. These findings provide a sound scientific foundation for in-vivo pharmacological evaluation, dissolution profiling, and eventual clinical investigation of this formulation.

**Acknowledgements**

**I**t is an honor to pay our respect and heartfelt thanks to our most respected correspondent Sandip Institute of Pharmaceutical Sciences, Sandip Foundation, Mahiravani, Nashik, for giving essential facilities, to carry out these project work successfully with sincere note of gratitude. **Conflict of Interest**

The authors declare that there are no conflicts of interest associated with this manuscript. No financial or personal relationships influenced the work reported herein.

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