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# Development And Characterization Of Poly(Lactic-Co-Glycolic Acid)/Ethyl Cellulose Microspheres Loaded With *Boswellia Serrata* And *Aloe Vera* For Controlled Drug Delivery

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***Abstract:*** This study investigates the formulation and detailed characterization of poly(lactic-co-glycolic acid) (PLGA) and ethyl cellulose microspheres encapsulating Boswellia serrata and Aloe vera extracts for controlled drug delivery. Pre-formulation studies assessed the physicochemical properties of the extracts, followed by microsphere preparation using the emulsion-solvent evaporation technique. Evaluations included particle size, percentage yield, drug entrapment efficiency, drug loading capacity, and in-vitro drug release profiles. The microspheres demonstrated uniform particle sizes, high entrapment efficiencies, and sustained release characteristics, indicating significant potential for pharmaceutical applications targeting inflammation, wound healing, and related therapeutic areas.

***Index Terms*** **- Boswellia serrata, Aloe vera, PLGA, ethyl cellulose, microspheres, controlled drug delivery.**

## 1. Introduction

Herbal medicines have gained significant attention in pharmaceutical research due to their therapeutic potential, minimal side effects, and natural origin. *Boswellia serrata*, a resin extract from the Boswellia tree, is renowned for its anti-inflammatory, analgesic, and anti-arthritic properties, primarily attributed to boswellic acids, which inhibit pro-inflammatory enzymes such as 5-lipoxygenase [1, 2]. Similarly, *Aloe vera*, derived from the succulent plant, is widely recognized for its wound-healing, antimicrobial, and anti-inflammatory effects, owing to its rich content of polysaccharides, anthraquinones, and vitamins [3, 4]. Despite their therapeutic benefits, challenges such as poor solubility, low bioavailability, and rapid systemic clearance limit their clinical efficacy [5].

Microsphere-based drug delivery systems have emerged as a promising strategy to overcome these limitations by providing controlled and sustained drug release, enhancing bioavailability, and protecting active compounds from degradation [6, 7]. Poly(lactic-co-glycolic acid) (PLGA), a biodegradable and biocompatible polymer, is extensively used in microsphere formulations due to its tunable degradation profile and ability to encapsulate both hydrophilic and hydrophobic compounds [8]. Ethylcellulose, a non-biodegradable but biocompatible polymer, complements PLGA by providing structural stability and modulating drug release kinetics [9]. The combination of these polymers offers a robust matrix for encapsulating herbal extracts, ensuring prolonged therapeutic effects.

The emulsion-solvent evaporation method is a well-established technique for microsphere preparation, offering simplicity, scalability, and high encapsulation efficiency [10]. This study leverages this method to develop microspheres loaded with *Boswellia serrata* and *Aloe vera* extracts, capitalizing on their distinct solubility profiles to optimize the formulation. The objectives include characterizing the physicochemical properties of the extracts, formulating microspheres with PLGA and ethyl cellulose, and evaluating their performance through particle size, yield, entrapment efficiency, drug loading, and in-vitro release studies. The findings aim to contribute to the development of advanced herbal drug delivery systems for enhanced therapeutic outcomes.

## 2. Materials and Methods

### 2.1 Materials

*Boswellia serrata* and *Aloe vera* plants were collected and authenticated from CSIR-NISCAIR. Poly(lactic-co-glycolic acid) (PLGA, 50:50, MW 30,000–60,000), ethyl cellulose (viscosity grade 10 cP), dichloromethane (DCM), and polyvinyl alcohol (PVA, MW 30,000–70,000) were procured from Sigma-Aldrich, USA. All reagents were of analytical grade, and double distilled water was used throughout the experiments.

### 2.2 Pre-formulation Studies

#### 2.2.1 Physical Description

Approximately 1 g of each extract was placed in a sterile Petri dish and examined visually against a black background for color, odor, and taste, following United States Pharmacopeia (USP) guidelines [11].

#### 2.2.2 Solubility

Solubility was determined by dissolving 1 g of each extract in 10 mL of water or DCM, with observations recorded as per USP solubility criteria [11].

#### 2.2.3 Loss on Drying (LOD)

LOD was measured using a 10 g sample of each extract in a pre-dried LOD bottle with a stopper. The bottle was dried at 105 ± 2°C for 1 hour, cooled in a desiccator, and weighed ($W_1$: empty bottle; $W_2$: bottle + sample before drying; $W_3$: bottle + sample after drying). The percentage LOD was calculated using: Loss on Drying (%) = (Weight before drying - Weight after drying) ÷ Weight of sample × 100. Limits were set at ≤5.0% w/w for *Boswellia serrata* and ≤8.0% w/w for *Aloe vera* [11].

#### 2.2.4 pH of *Boswellia serrata* Suspension

A 1% (w/v) suspension of *Boswellia serrata* in distilled water was prepared, and pH was measured using a calibrated digital pH meter (Hanna Instruments, USA) with the electrode fully immersed. The acceptable pH range was 4.00–6.00.

#### 2.2.5 Foaming Index of *Aloe vera*

A 1 g sample of coarse *Aloe vera* powder was boiled in 100 mL distilled water for 30 minutes, cooled, filtered, and diluted to 100 mL in a volumetric flask. The decoction was shaken vigorously for 15 seconds in a test tube, and foam height was measured after 15 minutes using a calibrated ruler.

### 2.3 Microsphere Formulation

Microspheres were prepared via the emulsion-solvent evaporation method:

1. PLGA (0.5 g) and ethyl cellulose (0.5 g) were dissolved in 5 mL DCM.
2. *Boswellia serrata* (0.2 g) or *Aloe vera* (0.2 g) extract was dispersed in the polymer solution using a magnetic stirrer (500 rpm, 10 min).
3. A 1% (w/v) PVA solution (100 mL) was prepared in distilled water.
4. The organic phase was emulsified into the aqueous phase under high-speed stirring (1000 rpm, IKA Ultra-Turrax, Germany) for 5 minutes.
5. Stirring continued at 500 rpm for 2 hours at 25°C to evaporate DCM.
6. Microspheres were filtered using Whatman No. 1 filter paper, washed 3–4 times with distilled water, and air-dried at 25°C for 24 hours.

### 2.4 Evaluation of Microspheres

#### 2.4.1 Particle Size and Distribution

Particle size was determined using optical microscopy (Olympus BX51, Japan) with a calibrated stage micrometer. A suspension of dried microspheres in distilled water was placed on a glass slide, and 100 particles were measured. Mean particle size was calculated as: Measured using an optical microscope with a stage micrometer.

#### 2.4.2 Percentage Yield

The percentage yield was calculated as: Yield (%) = (Weight of dried microspheres / Total drug & polymer weight) × 100

#### 2.4.3 Drug Entrapment Efficiency (EE%)

Drug content was quantified using high-performance liquid chromatography (HPLC, Agilent 1260 Infinity, USA). Microspheres (50 mg) were dissolved in 10 mL DCM, and the drug was extracted into phosphate buffer (pH 7.4). EE% was calculated as: EE (%) = (Actual drug content / Theoretical drug content) × 100

#### 2.4.4 Drug Loading Capacity

Drug loading was determined as: Drug Loading (%) = (Amount of drug / Weight of microspheres) × 100

#### 2.4.5 In-vitro Drug Release

Microspheres (50 mg) were suspended in 10 mL phosphate buffer (pH 7.4) in a conical flask and incubated at 37 ± 0.5°C with shaking at 100 rpm (Orbital Shaker, Remi, India). Samples (1 mL) were withdrawn at 1, 4, 8,

12, and 24 hours, replaced with fresh buffer, and analyzed by HPLC. Drug release was calculated as: % Drug Released = (Amount of drug released at time t / Total drug content in microsphere) × 100

## 3. Results

### 3.1 Pre-formulation Studies

#### 3.1.1 *Boswellia serrata*

The physicochemical properties of *Boswellia serrata* are summarized in Table 1.

**Table 1: Pre-formulation Parameters of *Boswellia serrata***

| Parameter | Observation/Result | Specification |
|---|---|---|
| Description | Off-white to pale brown powder, characteristic odor | Complies |
| Solubility in Water | Insoluble | - |
| Solubility in Dichloromethane | Freely soluble | - |
| Loss on Drying (% w/w) | 3.8 ± 0.2 | ≤ 5.0 |
| pH (1% w/v suspension) | 5.2 ± 0.1 | 4.00–6.00 |

#### 3.1.2 *Aloe vera*

The physicochemical properties of *Aloe vera* are presented in Table 2.

**Table 2: Pre-formulation Parameters of *Aloe vera***

| Parameter | Observation/Result | Specification |
|---|---|---|
| Description | Brown powder, bitter taste | Complies |
| Solubility in Water | Freely soluble | - |
| Solubility in Dichloromethane | Insoluble | - |
| Loss on Drying (% w/w) | 6.5 ± 0.3 | ≤ 8.0 |
| Foaming Index (mm) | 12 ± 1 | - |

### 3.2 Microsphere Characterization

The evaluation parameters of the microspheres are detailed in Table 3.

**Table 3: Evaluation Parameters of Microspheres**

| Parameter | *Boswellia serrata* Microspheres | *Aloe vera* Microspheres |
|---|---|---|
| Mean Particle Size (µm) | 45.6 ± 3.2 | 52.3 ± 4.1 |
| Percentage Yield (%) | 82.4 ± 2.5 | 78.9 ± 3.0 |
| Drug Entrapment Efficiency (%) | 87.3 ± 1.8 | 84.6 ± 2.1 |
| Drug Loading Capacity (%) | 22.5 ± 1.2 | 19.8 ± 1.5 |
| Drug Release (24 h, %) | 78.4 ± 2.0 | 72.6 ± 2.3 |

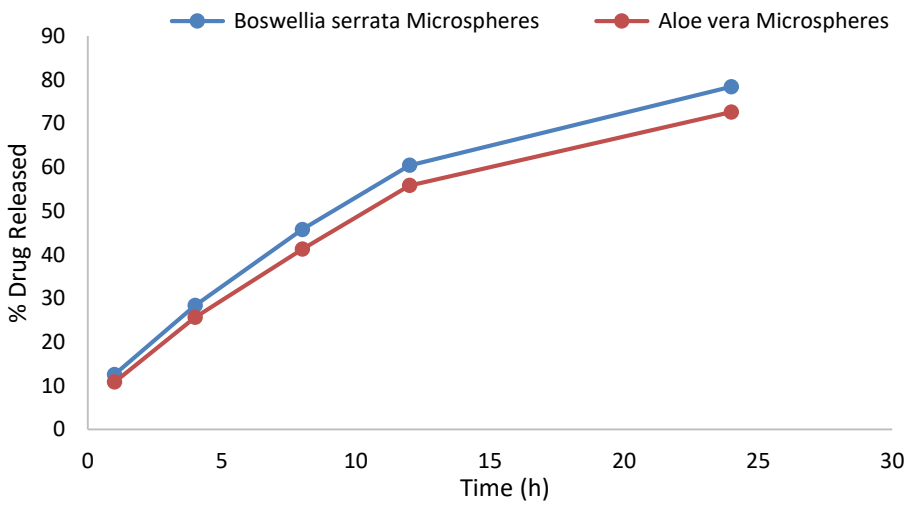
#### 3.2.1 In-vitro Drug Release Profile

The in-vitro drug release profiles are shown in Table 4 and Figure 1.

**Table 4: In-vitro Drug Release Profile (% Drug Released)**

| Time (h) | *Boswellia serrata* Microspheres | *Aloe vera* Microspheres |
|---|---|---|
| 1 | 12.5 ± 1.0 | 10.8 ± 0.9 |
| 4 | 28.3 ± 1.5 | 25.6 ± 1.3 |
| 8 | 45.7 ± 1.8 | 41.2 ± 1.6 |
| 12 | 60.4 ± 2.0 | 55.8 ± 1.9 |
| 24 | 78.4 ± 2.0 | 72.6 ± 2.3 |

**Figure 1: In-vitro Drug Release Profiles of *Boswellia serrata* and *Aloe vera* Microspheres**



## 4. Discussion

The pre-formulation studies confirmed the suitability of *Boswellia serrata* and *Aloe vera* extracts for microsphere formulation. The lipophilic nature of *Boswellia serrata* facilitated its dissolution in DCM, while the hydrophilic properties of *Aloe vera* aligned with the aqueous phase, optimizing the emulsion-solvent evaporation process [10]. LOD values (3.8% for *Boswellia serrata*, 6.5% for *Aloe vera*) and pH (5.2 for *Boswellia serrata*) complied with pharmacopeial standards, ensuring stability and compatibility [11]. The microspheres exhibited uniform particle sizes (45–52 µm), ideal for controlled release applications [7]. High entrapment efficiencies (84–87%) and drug loading capacities (19–22%) reflect efficient encapsulation, likely due to the synergistic matrix formed by PLGA and ethyl cellulose [8, 9]. The sustained release profiles (78.4% for *Boswellia serrata*, 72.6% for *Aloe vera* over 24 hours) indicate prolonged drug release, potentially enhancing therapeutic efficacy for chronic conditions such as inflammation and wound healing [1, 3]. The slightly faster release of *Boswellia serrata* may be attributed to its lipophilicity, facilitating diffusion through the polymer matrix.

## 5. Conclusion

The PLGA/ethyl cellulose microspheres loaded with *Boswellia serrata* and *Aloe vera* extracts demonstrated excellent physiochemical properties, high entrapment efficiencies, and sustained release profiles, positioning them as promising carriers for controlled drug delivery. These findings support their potential in pharmaceutical applications, particularly for anti-inflammatory and wound-healing therapies. Future research should focus on in-vivo studies, pharmacokinetic profiling, and clinical trials to validate therapeutic efficacy and safety.

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