

Utilization of *Bombax Ceiba* Mucilage as an Emulsifying Agent in Castor Oil Emulsion Formulation

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ABSTRACT

This study evaluated the potential of mucilage extracted from *Bombax ceiba* as a natural emulsifying and stabilizing agent in oil-in-water emulsions, compared to commercial acacia gum. Emulsions prepared with varying concentrations of *Bombax ceiba* mucilage exhibited concentration-dependent improvements in stability, with creaming index decreasing from 35% at 0.6% (w/v) to 17% at 1.2% (w/v), approaching the performance of acacia gum (15% at 1.0% w/v). Organoleptic properties revealed a characteristic brown color and mucilaginous taste for *Bombax ceiba* emulsions, consistent with unrefined tree gums and attributed to natural pigments, in contrast to the off-white, neutral-tasting refined acacia gum. Rheologically, *Bombax ceiba* mucilage emulsions displayed significantly higher viscosity and pronounced shear-thinning (pseudoplastic) behavior, compared to the low-viscosity, near-Newtonian profile of acacia gum (typically 500–874 cP). This enhanced viscosity provides superior anti-creaming effects via reduced droplet mobility per Stokes' law, offering advantages in applications requiring prolonged stability or contact time. Despite minor organoleptic drawbacks common to many unrefined plant mucilages, *Bombax ceiba* mucilage demonstrates comparable physical stability to acacia gum at slightly higher concentrations and confers desirable rheological benefits as both emulsifier and thickener. As a locally abundant resource in tropical regions including Africa and Asia, it represents a promising, sustainable alternative to imported acacia gum for pharmaceutical emulsions, such as oral suspensions, topical creams, and mucoadhesive formulations.

KEYWORDS: *Bombax ceiba*, emulsifying agent, stability, viscosity, natural polymer.

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INTRODUCTION

Pharmaceutical excipients are additives with unique physicochemical properties that help to transform the drug substances into an effective type of dosage forms suitable for patients' administration (Aulton & Somavarapu, 2017). The demand for new and updated excipients for drug delivery systems has been growing in order to meet the needs of new and better formulations. To be used as pharmaceutical excipients, natural polymers are readily available, biodegradable, non-toxic and cost effective, to be used as an excipient for a range of pharmaceutical formulations (Kumar Gupta, 2020). Gums and Mucilages are ideal natural polymers for pharmaceutical emulsion and suspension formulated by increasing the viscosity of the continuous phase. Furthermore, it increases the tensile strength, by

hydrogen bonding and molecular interactions of the hydration layer formed around the suspended particles without minimizing the surface and interfacial tension (Choudhary & Pawar, 2014). Emulsions are biphasic liquid system consisting two immiscible liquids where one is dispersed as small droplet within the other with the aid of emulsifying agent (Balaj & Zarzar, 2020). These systems are widely used pharmaceutical, cosmetics and food industries due to their ability to enhance drug stability solubility and bioavailability (Kumar Verma *et al.*, 2020).

An emulsion is a mixture of two immiscible liquid phases where one phase is dispersed into another. Basically, an emulsion is consisting of a continuous phase which is known as external phase, where the droplets are dispersed, and a dispersed phase which is defined as internal or discontinuous

phase (“Front Matter,” 2013). Emulsions are found in different industries such as food, pharmaceutical, agricultural, cosmetics, and petroleum (Wang *et al.*, n.d.). An emulsion is not contained only water and oil; it may also contain some solid particles and even gas. Inherently, an emulsion is an unstable system due to the unfavorable contact between oil and water phases. Although, some emulsions are stable as a result of the small drop sizes and the existence of interfacial film, which surrounds the drops (Pandey *et al.*, 2016). To form an emulsion a mechanical force is required to disperse one phase into another. However, the emulsions formed without adding any surface-active material would not be stable, and the emulsion phases will start to separate in different layers based on their density differences. Therefore, addition of surfactants is necessary to make a stable emulsion for a period of long time (McClements, 2012).

According to (Kumar *et al.*, 2022), Emulsifying Agents can be classified as: natural Agents: these are obtained from vegetable sources such as tragacanth, agar, pectin and cholesterol. Animal sources include egg yolk, gelatin, casein, cholesterol and wool fat. Colloidal Clays: The components with the finely divided solids may be used as emulsifying agents. Examples are: Aluminum silicate (Bentonite) and Magnesium aluminum silicate (Vegan). These emulsifying agents are generally for external preparation (Leal-Calderon, 2012). Synthetic Agents: E.g., Anionic, cationic, non-ionic and ampholytic sodium decylsulfate, benzalkonium chloride, PEG 400 monostearate and long chain amino acid derivatives are their examples respectively. Sometimes in addition to emulsifying agent viscosity builders such as glycerin is also used. Emulsion can be used for both internal and external purposes (Hu *et al.*, 2017).

In recent years, plant derived polymers have evoked tremendous interest due to their diverse pharmaceutical applications such as diluents, binders, disintegrants in tablets, thickeners in oral liquids, protective colloids in suspensions, gelling agents in gels and bases in suppository (Hu *et al.*, 2017).

The plant-based polymers have been studied for their application in different pharmaceutical dosage forms like matrix-controlled system, film coating agents, buccal films, microspheres, nanoparticles, viscous liquid formulations like ophthalmic solutions, suspensions, implants and their applicability and efficacy have been proven (Ramos *et al.*, 2021).

Gums and mucilages finds application in tablet formulations as binders (Sharma *et al.*, n.d.), in Emulsifying and Suspending Agents to effectively stabilize the emulsion via interfacial absorption and the subsequent formulation of condensed films of high tensile strength that resist coalescence of droplets (Aulton & Somavarapu, 2017), and increase the tensile strength of the hydration layer formed around the suspended particles, through hydrogen bonding, and molecular interactions (Ramos *et al.*, 2021), as sustaining materials in dosage form, as Coating Agents which can

sustain the drug release, or can protect the drug from degradation in stomach (Murthy, 2015), as Gelling Agents forming numerous inter and intra molecular associations to produce a three-dimensional network within which the water molecules are entrapped, as Mucoadhesive Agents which gets retained in the stomach for longer period of time, thus helping in absorption of drug for the intended duration of time (Singh *et al.*, 2018).

Bombax ceiba is commonly known as silk cotton tree and sepal. It is one of the important medicinal plants in tropical and subtropical India and also occurs in Sri Lanka, Pakistan, Bangladesh, Myanmar, Malaysia, Java, Sumatra and Northern Australia (Hossain *et al.*, 2025). It has number of traditional uses and its medicinal usage has been reported in the Indian traditional systems of medicine such as Ayurveda, Siddha and Unani (Kamble *et al.*, 2017; Ravi & Yogesh, 2019). It is known by different names such as red cotton tree, Indian kapok tree (English), shalmali (Sanskrit), semal (Hindi), shimul (Bengali), mullilavi (Malyalam), kondabrug (Telugu), in different languages (Gupta *et al.*, 2013). *Bombax ceiba*- “Bombax” (Greek) = silkworm; “ceiba” South American vernacular name for silk cotton tree. According to Ayurveda, it has stimulant, astringent, haemostatic, aphrodisiac, diuretic, antidiarrhoeal, cardiogenic, emetic, demulcent, antidiarrhoeal, alterative, and antipyretic properties. It is widely found in temperate Asia, tropical Asia, Africa and Australia. In India, it can be found at altitudes up to 1500m. In peninsular India, the tree is very common in the dry as well as moist deciduous forests and near rivers (Jahan, 2016a; Ravi & Yogesh, 2019). The tree is a strong light demander and fast growing. It grows best on deep sandy loams or other well-drained soils, particularly in valleys, in regions receiving 50 to 460 cm annual rainfall well distributed throughout the year (Rout & Panda, 2017).

The mucilages are polysaccharides, composed of polymers of sugars and oxidized sugar linked together by glycosidic bonds. The urea cross-linking of mucilage can be a method to modify the physicochemical properties of the gum. The mucilage, i.e. sugar, reacts with urea to form gum urea (Carbamate), a hydrophilic water swell-able polymer (Tosif *et al.*, 2021). The demand for pharmaceutical emulsifying agent is large, especially in the form of Paediatric dosage (Malkawi *et al.*, 2022). The emulsifying agents available are lecithins, tragacanthins and xanthan gum and gum acacia; most of its availability is limited and imported. The production of new emulsifying agents based on domestically available and accessible materials needs time (Adnan *et al.*, 2021).

Bombax Ceiba has medicinal uses such as Nocturnal Emission & Semen Issues; a mixture of *B. ceiba* root powder with *Ipomoea digitata* root, Shatavari, and sugar is consumed with milk twice daily (Adnan *et al.*, 2021), Blood Purification; Ground *B. ceiba* leaves mixed with water is filtered and consumed, Leucorrhoea *B. ceiba* root powder is taken twice daily with water (Jahan, 2016b), Menstrual

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Overbleeding; a mixture of *B. ceiba* root powder (100g), mulethi powder (50g), and swarngeru (25g) is taken twice daily with water or milk (Adnan *et al.*, 2021; Malkawi *et al.*, 2022), Skin Issues (Acne, Pigmentation, Blemishes). A paste made from the thorny stem and root is applied to the affected area, helping lighten scars, freckles, and burns, Wound Healing; bark paste is applied directly to wounds, Weakness; Dried and ground green base particles of *B. ceiba* flowers are mixed with honey, ghee, and milk for consumption (Jahan, 2016b), Lactation Enhancement; Powdered, dried *B. ceiba* root bark is consumed twice daily to improve breast milk production, Cold & Cough; A mixture of *B. ceiba* root powder with black pepper and dry ginger powder is taken in small amounts for relief (Tosif *et al.*, 2021)

Pharmacological activities such as anti-inflammatory activity; The extracts of *B. ceiba* demonstrated membrane-stabilizing properties in human red blood cells (Lavanya *et al.*, 2014). Anti-obesity *B. ceiba* stem bark extract significantly reduces obesity induced by a high-fat diet, (Gupta *et al.*, 2013), Anti-diabetic Activity; a dose of 600 mg/kg of *B. ceiba* extract significantly reduces blood glucose, total cholesterol, and triglyceride levels in diabetic rats, likely due to triterpenoid compounds (Jahan, 2016b), Hypotensive Activity; compounds like shamimin and lupeol exhibit significant blood pressure-lowering effects (Gupta *et al.*, 2013). Antioxidant Activity; the methanolic extract scavenges free radicals and inhibits lipid peroxidation, (Adnan *et al.*, 2021). Analgesic Activity; Mangiferin from *B. ceiba* leaves exhibits strong antioxidant and hepatoprotective properties but does not show acute anti-inflammatory effects. It provides analgesia independent of opioid receptors (Jahan, 2016).

This study aims to explore the potential of *Bombax ceiba* mucilage as readily available source of excipient which could offer a promising and cost-effective alternative to existing emulsifying agents. By investigating its properties, we may uncover new applications in various industries particularly in pharmaceuticals and food productions Additionally, the

modification of *Bombax ceiba* mucilage may create a valuable employment opportunity in local communities promoting economic growth, it could also reduce the reliance on imported excipient contributing to both cost saving and improved accessibility natural and cost-effective emulsifying agent. The mucilage has been collected, identified, and characterized for its physicochemical properties (Mshelia S. *et al.*, 2025), revealing promising qualities as a potential emulsifying agent.

MATERIALS AND METHODS

Machine and Equipment

Weighing balance (model JA3039, Metra), Centrifuge (TDA4 PEC MEDICAL USA), Viscosity Tester (PEC MEDICAL USA), pH meter, Muslin cloth, measuring cylinder, Mortar and pestle, Beakers (50mL and 100ml), Volumetric flask 250mL, Measuring cylinder (10mL, 20mL and 100mL).

Reagents and Chemicals

Acetone (shell chemicals), Ethanol (cargil), Castor oil (BELL SONS & CO LTD PRODUCT), Deionized water (thermo and fisher scientific company).

METHOD

Preparation of the Emulsion

An emulsion was prepared by emulsifying castor oil (purchased from a pharmacy store) into deionized (distilled) water as an aqueous phase in a ratio of 2:8 respectively, that is 20 ml of oil +80 ml of water to give 100 ml emulsion. Castor oil 20 ml and *Bombax ceiba* mucilage was first mixed in a mortar, 10ml of water was added and triturated until a crackly sound was heard then transferred into a calibrated container and water was used made to 100ml. To determine the optimum *Bombax ceiba* mucilage concentration with respect to the reference (acacia), a preliminary study was done using different concentrations (0.6%, 0.8 %, 1 %, and 1.2 %).

Table 1: Formula for the Various Emulsion Formulations:

Batch	Gum (g)	Oil (mL)	Water qs (mL)
BCG1	0.6	20	100
BCG2	0.8	20	100
BCG3	1	20	100
BCG4	1.2	20	100
AG	1	20	100

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Key: BCM: Test sample of *Bombax ceiba* mucilage with varying proportion of oil, water and gum ranging from BCG1 to BCG4, **SAG:** Standard Acacia Gum with varying proportion of oil, water and gum.

Creaming Index of the Emulsion

Each of the emulsion formulated with *Bombax ceiba* mucilage at their various concentration and the standard were centrifuge at 3000rpm for 10mins and the height of the layer was measured. The creaming index (C.I) was determined by the following formula:

$$C.I = \frac{H_c}{H_e} 100$$

Where H_c is the height of the cream layer and H_e is the total height of the emulsion in the container (Rosu *et al.*, 2023).

Determination of Emulsion Type

Three drops of Amaranth solution dye were added to 10 ml of the emulsions and the miscibility of the emulsions with water observed (Khan *et al.*, 2013).

Viscosity of the Emulsion

The viscosity of the emulsions was determined using a viscometer (NDJ-8S) at 25°C with shear stresses of 6, 12, 30 and 60 rpm using spindle size 3 and the readings taken.

RESULTS

Evaluation of Emulsion

Organoleptic Properties of the Suspensions.

Table 2: Shows the Organoleptic Properties of the Emulsions.

Parameters	BC	AG
Colour	brown	Off white
Odour	Characteristic Odour	Characteristic Odour
Taste	mucilaginous	Tasteless

KEY: BCMP= Bombax ceiba mucilage powder. AGP= Acacia gum powder.

Table 3: Creaming Index of the Emulsion

Sample	Concentration %w/v	Initial Volume (mL)	BCG Emulsion (mL)	Creaming Index (%)
BCG 1	0.6	10	3.5	35
BCG 2	0.8	10	2.5	25
BCG 3	1.0	10	2.0	20
BCG 4	1.2	10	1.7	17
AG 1	1.0	10	1.5	15

Key: BCM = Bombax ceiba Mucilage, AG= acacia gum

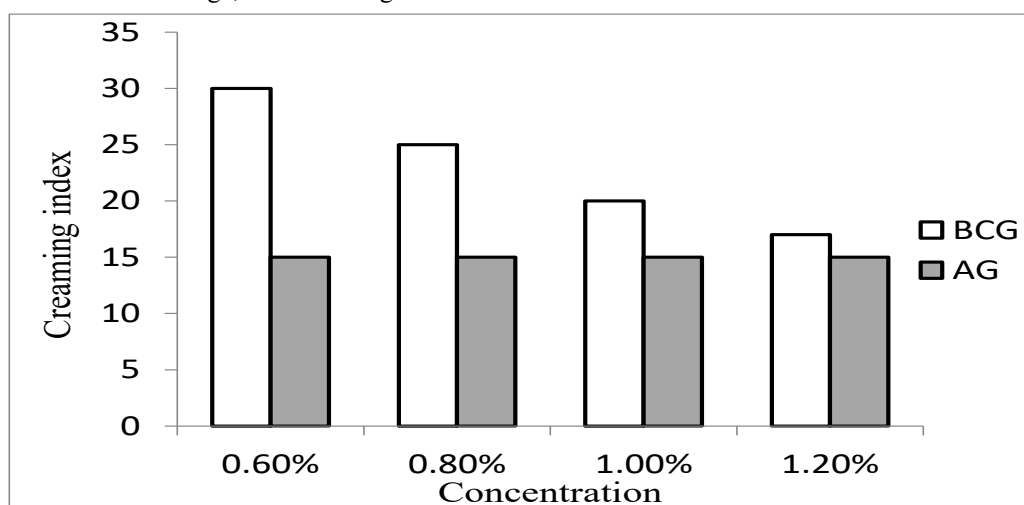


Figure 1: Relationship Between Index Creaming and Concentration

Key: BCG = Bombax ceiba mucilage, AG = acacia gum

Table 4: Viscosity of the Emulsion at Various Shear Strength

Sample (%w/v)	6 (rpm)	12 (rpm)	30 (rpm)	60(rpm)
BCM (1)	2509.8	2559.6	9452.0	9447.0
BCM (2)	3012.3	1240.9	542.1	9345.0
BCM (3)	5412.6	2267.2	950.9	9251.0
BCM (4)	7525.8	4534.1	2229.3	8121.0
SAG1(1)	874.0	624.2	634.2	500.0

Key: BCM: Test sample of Bombax ceiba Mucilage with varying proportion of oil, water and gum ranging from BCM1 to BCM4, SAG1 and that of Acacia gum in different rpm: Revolution per minute

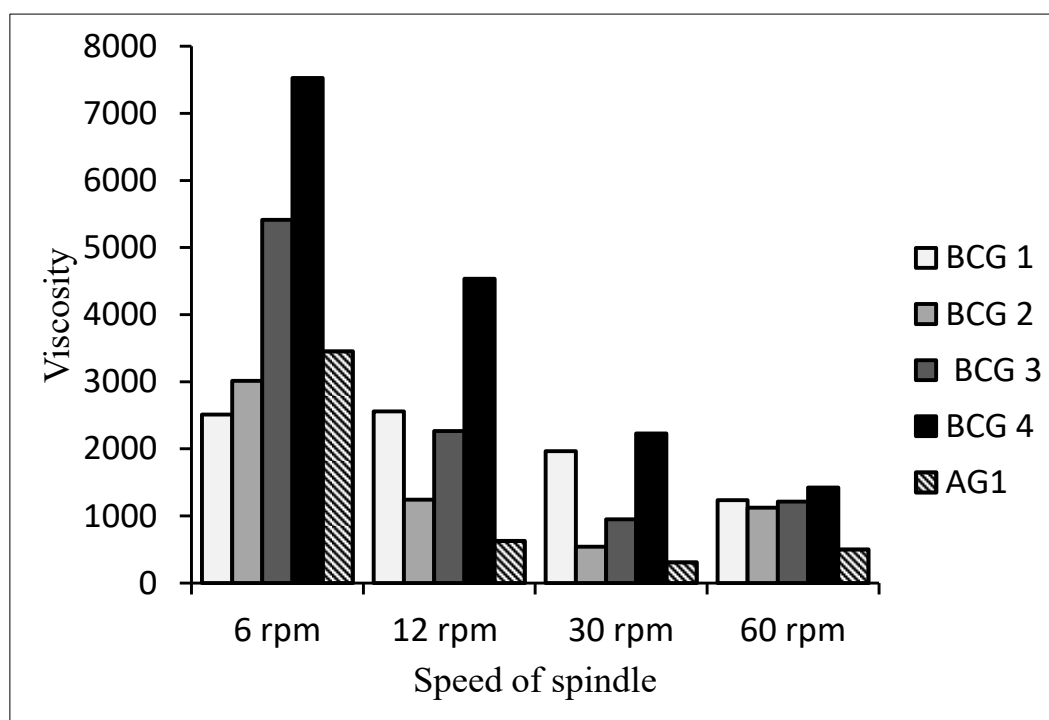


Figure 2: Relationship between viscosity and shear rate

Key: BCM: Bombax ceiba Mucilage, AG: Acacia Gum

DISCUSSION

The outcome of this study demonstrates that Bombax ceiba mucilage functions effectively as a natural emulsifying and stabilizing agent in oil-in-water emulsions, it has performance trends that are concentration-dependent and of rheological advantages. While the organoleptic, creaming, and viscosity data are promising, they also highlight areas where BCM differs from the commercial

The brown colour of the Bombax ceiba emulsion matches the brownish hue consistently reported for extracted Bombax ceiba mucilage powder (yield ~18.75 % w/w) (Table 1). This is attributed to natural pigments and is typical of unrefined tree gums. In contrast, refined acacia gum is off-white, which is preferred for aesthetic reasons in commercial products.

Both gums show characteristic (plant-like) odour, but the mucilaginous taste of Bombax ceiba is a common trait in many plant mucilages (e.g., Moringa oleifera gum or almond gum), whereas acacia is notably tasteless/neutral.

Similar colour and taste limitations appear in studies of other tree gums (karaya, khaya) used as emulsifiers; purification steps (e.g., bleaching) are often recommended to improve acceptability without compromising functionality.

Creaming index falls from 35 % (0.6 % w/v) to 17 % (1.2 % w/v) for Bombax ceiba mucilage, approaching Acacia gum's 15 % at 1.0 % w/v. This concentration-dependent stabilisation is classic behaviour for hydrocolloid emulsifiers and directly mirrors findings in acacia gum emulsions.

In detailed stability studies using 5 % limonene oil emulsions, acacia (Acacia senegal) creaming index dropped from ~7.5 % (low concentration ~1.3 %) to ~2.9 % at higher levels (~17 %), with stability improving markedly above a critical protein content (~0.2 % w/w). Acacia gum here results (15 % at 1.0 %) is consistent with typical low-concentration performance of acacia in simple pharmaceutical emulsions. Bombax ceiba at 1.2 % (17 %) performs comparably, requiring only a modest increase in concentration to match the standard.

Overall, Bombax ceiba mucilage provides acceptable physical stability (creaming <20 % at ≥1.0 %), slightly behind

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acacia at equal concentration but competitive at slightly higher use levels a common trade-off seen with most natural alternatives.

Bombax ceiba mucilage emulsions display markedly higher viscosity (thousands of cP at low shear) and clear shear-thinning (pseudoplastic) flow compared with Acacia gum (~500–874 cP) (Table 2 and Figure 1). This is highly desirable for pharmaceutical emulsions because of improved pourability under shear while maintaining rest stability.

Acacia gum solutions/emulsions exhibit low Newtonian-to-slightly pseudoplastic viscosity (typically 1.9–48 mPa·s / cP range even at 17 % concentration). The acacia gum values align perfectly with this benchmark. Higher-viscosity mucilages like Bombax ceiba mucilages therefore confer superior anti-creaming protection via Stokes' law (reduced droplet rise velocity), as confirmed in acacia studies where bulk viscosity was the dominant factor for long-term stability. Earlier physicochemical characterisation of Bombax ceiba mucilage (hot-water extract) showed relative viscosity increases ~3 times faster with concentration than acacia or cold-water extracts. This matches the Bombax ceiba data obtained. Reviews confirm that most plant mucilages (Moringa, almond, karaya) provide higher viscosity than acacia, enabling dual roles as emulsifier and thickener, an advantage Bombax ceiba mucilage shares.

Bombax ceiba mucilage emerges as a viable, locally abundant (tropical Africa/Asia) alternative to imported acacia gum. Its brown colour and mucilaginous taste are shared drawbacks of many unrefined plant gums, but its creaming performance (approaching acacia at 1.2 %) and promising viscosity/shear-thinning gives it an edge in applications requiring enhanced physical stability or prolonged contact time (e.g., oral suspensions, topical creams, or mucoadhesive formulations).

CONCLUSION

Bombax ceiba mucilage as a promising, high-viscosity natural emulsifier that performs comparably to acacia gum in stability while offering rheological advantages as seen in other successful plant mucilages. This represents a valuable contribution, especially for resource-limited settings like Nigeria where Bombax ceiba is readily available.

DECLARATION OF INTEREST

The authors declared no conflict of interest.

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