Okra Gum *(Abelmoschus esculentus)* as a Natural Polymer in Drug Delivery Systems: A Comprehensive Review

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Abstract
Okra gum is a natural polysaccharide obtained by extracting the plant *Abelmoschus esculentus*, which has gradually gained significance as a pharmaceutical excipients. This can be attributed to its non-hazardous, biocompatible and biodegradable nature and moderate cost. The gum has many useful characteristics, including high viscosity, the possibility to swell, excellent adhesiveness to mucous membranes, and the ability to create films. These are the qualities that make it suitable in different drug delivery systems. Okra gum is extracted by means of soaking the raw material, then filtration, precipitation with the help of such a solvent as acetone, drying and grinding of the extracted substance. The various factors that may affect the efficiency and quality of the extracted gum include temperature, the level of pH, the type of solvent to be used and the drying conditions. Okra gum possesses an array of useful physicochemical characteristics, such as, high solubility, viscosity, swelling ability, water retention, and thermal resistance.
Traditionally, it is used in tablet form, suspension and emulsions as a binding agent, thickening agent and polymer that assists in the control of drug release. In higher state drug delivery systems, it is used in ocular, buccal, transdermal, nasal and targeted drug delivery systems to achieve controlled and sustained release of a drug. Therefore, okra gum is a promising natural polymer that has extensive wide of applications in the pharmaceutical industry thus shows strong potential for future research in drug delivery.

Keywords: Okra gum, *Abelmoschus esculentus*, Natural polymer, Physicochemical properties, Drug delivery system, Controlled release, Pharmaceutical excipient

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1. Introduction

The environmental sustainability concerns have resulted in an enlarged awareness in plant-based bio-polymers, primarily in the food, pharmaceutical and cosmetics. Natural polymers, as like gums, cellulose, glucans, and mucilage, are now gaining popularity over synthetic polymers due to their easy degradability, safe for use, and minimal impact on the environment (Thipapun *et al.,* 2025). Okra is a mucilaginous polysaccharide which is obtained from the pods of *Abelmoschus esculentus*, also widely used as a pharmaceutical excipient. Okra Gum (OG) is a natural hydrophilic polymer found within okra and is commonly used in the pharmaceutical industry (Kalkan *et al*., 2023,Glaue *et al*., 2023). The original extraction process uses water, making it straightforward to produce, cost-effective, and environmentally friendly (Ling *et al*., 2021). Okra mucilage is produced by specialized cells located in the outer and middle layers of the pod. When the mucilage is mixed with water, it forms a thick, gel-like substance known as a hydrocolloid. It is a type of water-soluble, acidic polysaccharide that quickly absorbs water and creates a gel structure. Because of these properties, okra gum is used in pharmaceutical products as an excipient and in food as a stabilizing agent. The source of this substance is the fruit tissues of the plant, which store polysaccharides that give the mucilage its thickening and moisture retaining abilities(Gemede *et al*., 2018). The Okra gum has been recognized as the plant hydrocolloid, which is rich in carbohydrate, and is the subject of extensive research due to its biodegradability and compatibility with biological system with non-toxicity. After extraction, it produces a polysaccharide- rich gum (Nkosi *et al*., 2026). Okra gum is a plant based natural anionic polysaccharide. In England, Okra is also called lady's finger, in Spanish guino-gombo and

Bhindi in India, in the United States of America, it is called gombo. Okra is a crop plants cultivated in countries as like India, Afganistan, Bangladesh, Japan, Burma, Brazil, Malayasia, Turkey, Iran, Thailand Myanmar etc (Fekadu *et al*.,2015). The pods of Okra are harvested immature and when high in mucilage, but before it turns highly fibrous. Generally in fruits , fiber production starts from 6th day onwards from fruit formation and from 9th day a sudden increase in fibre content is observed (Swamy *et al*., 2023). Okra is a versatile crop and is considered economically important vegetable crop due to its diverse uses such as leaves, flowers, buds, seeds, stem and pods. It can be used in stews, salads, pickles etc (Hafid *et al*.,2024).

Mucilage is a polysaccharide (usually in combination with rhamnose and galacturonic acid) that is water-soluble and has a high viscosity, often with side chains of galactose involved in its functional properties. It is well known for its capacity to quickly absorb water, creating a slimy layer, and it is compatible with food systems, making it a preferred option that is safer for use compared to synthetic additives (Nkosi *et al*., 2026).Okra gum is a viscous and slimy substance, which is mainly present in the pod walls and is made up of acidic polysaccharides generally accompanied by proteins and mineral constituents. Okra gum is used as a natural polymer owing to its renewable source, low cost, biodegradability (Fekadu *et al*., 2015). Okra gum is known for its medicinal and nutritional values. Fruits of okra are used in treating chronic dysentery and genitor-urinary disorders. Dried fruits are used as refined edible oil. In the preparation of jaggery, the root and stem parts of okra are used for purifying the cane juice (Swamy *et al*.,2023). The unripe pods are also used in making pickles. The entire plant is eaten and used into several dishes. From okra seeds, oil and proteins are extracted and they have been utilized for production of oil on small scale. Okra gum exhibits high viscosity, swelling capacity, mucoadhesive behavior, and gel- forming ability and all these properties of okra gum makes it potential candidate for controlled drug delivery application. The thick consistency of okra gum makes it effective as a polymer that slows down drug release, and it is utilized in creating sustained-release drug delivery systems (Sinha *et al*., 2015). Plant-based biopolymers, like gums, which are referred to as hydrocolloids and polysaccharides, are highly adaptable and are commonly used in food processing as thickening agents, emulsifiers, stabilizers, and gelling agents. These materials have excellent film-forming capabilities and can offer protection against the loss of moisture and control gas movement.

2. Botanical Description and Chemical Composition of Plant

Okra gum, also recognized as mucilage, is a natural polysaccharide obtained from the young pods of the plant *Abelmoschus esculentus,* which belongs to the Malvaceae family.

Fig.1 *Abelmoschus esculentus*

Parameter	**Botanical description**	**Reference**
Plant type	Annual, herbaceous tropical vegetable crop	Kyriakopoulou *et al*., 2014
Root System	Deep taproot with lateral roots	Kyriakopoulou *et al*., 2014
Stem	Green, rigid, cylindrical, pubescent, 1-2m tall	Reswari *et al*., 2024
Leaves	Alternate, rough texture, palmately lobed(3-7 lobes)	Reswari *et al*., 2024
Flower	Large yellow axillary flower with dark centre	Martinelli *et al*., 2022
Fruit	Elongated green capsule, pentagonal and mucilaginous	Martinelli *et al*., 2022
Seed	Round, multiple, dark colored Seeds	Martinelli *et al*., 2022

Table 1: Botanical Description of *Abelmoschus esculentus*

Chemically, it consists of L-galacturonic acid, L-rhamnose, and D- galactose. They forms repeating pattern of alternating α-(1-4)-linked galacturonic acid units and α-(1-2)-linked rhamnosyl units. Additionally, each L-rhamnosyl residue has a disaccharide side chain which consists of a β-(1-4)-linked galactosyl unit attached to it (Patra *et al*., 2020). Okra is rich in polysaccharides as like pectin, xyloglucan, xylan and cellulose (Cui *et al*., 2023). The polymers are branched and have a large number of hydroxyl groups, and are therefore chemically and mechanically well bonded. Okra mucilage is a chemically inert negatively charged polysaccharide with a high content of polyhydroxy and carboxyl groups that are responsible for its solubility in water and aptitude to form stable hydrogels having good elasticity, plasticity and viscosity, thus making it useful for application in food and pharmaceutical products (Nkosi *et al*., 2026).

3. Pharmacological Activities of *Abelmoschus esculentus*

Pharmacological activity	**Research findings**	**Reference**
Antidiabetic activity	Okra peel and seed powder reduced blood glucose and improved insulin sensitivity	Sabitha *et al*., 2011
Antioxidant activity	Strong free radical scavenging and phenolic antioxidant potential	Peter *et al*., 2021
α-amylase and α-glucosidase inhibition	Demonstrated antidiabetic enzyme inhibitory action	Siddique *et al*., 2022
Anti – inflammatory activity	Decrease inflammatory cytokines IL-1β,IL-6 and TNF-α	Panighel *et al*., 2022
Hypolipidemic activity	Lowered serum cholesterol and triglycerides	Gemede *et al*., 2015
Hepatoprotective activity	Protected liver against sodium nitrite induced toxicity	Wahyuningsih *et al*., 2020

Anticancer activity	Lectin from okra inhibited tumor cell proliferation	Lengsfeld *et al.*, 2004
Antimicrobial activity	Activity against pathogenic Bacteria and fungi	Kumar *et al.*, 2013
Gastroprotective activity	Mucilage showed gastric protective effects	Islam *et al.*, 2019
Neuroprotective activity	Polyphenols may reduce oxidative neuronal damage	Abdel *et al.*, 2023
Immunomodulatory activity	Okra polysaccharides enhanced immune responses	Ma *et al.*, 2021

Table 2: Pharmacological Activities of *Abelmoschus esculentus*

4. Characterization of Okra Gum

- **Viscosity:** Viscosity of sodium carboxymethyl okra gum was measured using Brookfield's viscometer (model DV1Ametek, USA) at 28.4 °C using the spindle (Spindle no. RV6) which is rotated at 2.0 rpm. The native okra gum shows higher viscosity as compaired to carboxymethyl forms(Patra et al., 2020). Viscosity was determined and mucilage of okra exhibits decrease in viscosity with increasing shear rate(Nkosi et al., 2026)
- **FTIR:** FTIR spectra was identified using FTIR (Shimazdu corporation, Japan, IR-prestige 21) to detect potential changes in functional groups of okra gum and it showed characteristic peaks which confirms successful grafting of carboxymethylation(Patra et al., 2020). FTIR spectroscopy was performed to find out occurrence of functional groups and compatibility of gum in formulation of pellet. The spectra established presence of functional groups without major interaction between polymer and drug(Yadav et al., 2021). FTIR analysis was performed using FTIR spectrophotometer and spectra showed peaks that are corresponding to hydroxyl and carboxyl group , which confirms suitability of okra mucilage for food and pharmaceutical applications(Nkosi et al., 2026)
- **NMR:** 1H NMR analysis was done using NMR spectrometer in order to identify structural modifications in okra gum. New proton peaks confirmed unbeaten incorporation of carboxymethyl groups in okra gum (Patra et al., 2020).
- **Biodegradability:** Biodegradability of okra gum was evaluated using simulated gastro-intestinal environment and okra gum possesses good biodegradability that makes it appropriate for pharmaceutical applications (Patra et al., 2020).
- **Differential Scanning Calorimetry (DSC):** DSC analysis was evaluated through thermal behavior and drug-polymer compatibility.Thermograms obtained indicate stability of formulation (Yadav et al., 2021).
- **Ash Value:** This study evaluate presence of inorganic residue in low concentration in okra gum , that demonstrates good purity and quality for pharmaceutical application (Tiwari et al., 2022).
- **Flow Property:** Flow properties of pellets were identified by bulk density, angle of repose, tapped density, Carr's index, and Hausner ratio. Good flowability and uniform pellet characteristics were found (Yadav et al., 2021).
- **Thermogravimetric Analysis (TGA):** TGA was performed to determine degradation and thermal stability of okra gum by hating at controlled temperature. Thermogram showed initial weight loss at low temperature and degradation at higher temperature, indicating acceptable thermal stability (Nkosi et al., 2026).

5. Pharmaceutical Properties of Okra Gum Relevant to Drug Delivery Systems

Property of Okra Gum	**Significance in Drug Delivery**	**Reference**
Biodegradable nature	Allows safe degradation and elimination from the body	Patra *et al.*, 2020
Biocompatibility	Suitable for biomedical	Brar and Kaur, 2018

	and pharmaceutical applications with minimal toxicity	
Mucoadhesive property	Enhances retention time at ocular, buccal, and nasal mucosa	Shah *et al.*, 2020
High swelling capacity	Helps in sustained and controlled drug release	Yadav *et al.*, 2021
Natural viscosity enhancer	Improves rheological behavior and formulation stability	Tiwari *et al.*, 2022
Film- forming ability	Useful in transdermal patches and coating systems	Umamaheshwari *et al.*, 2023
Gel- forming property	Suitable for hydrogels and ocular in situ gels	Patel *et al.*, 2022
Non- toxic nature	Safe alternative to synthetic polymers	Patra *et al.*, 2020
Good binding property	Useful as tablet binder in oral dosage forms	Singh *et al.*, 2023
Sustained release behavior	Provides prolonged drug release profile	Patra *et al.*, 2020
Water retention capacity	Maintains hydration and swelling in hydrogel systems	Nkosi and Tabit *et al.*, 2021
Eco-friendly and economical	Renewable and cost-effective natural polymer source	Tiwari *et al.*, 2022

Table 3: Pharmaceutical Properties of Okra Gum Relevant to Drug Delivery Systems

6. Extraction of Okra Gum

The Okra gum was extracted from the pods of *Abelmoschus esculentus* by soaking the pods in water followed by the addition of a solvent(acetone) to facilitate separation of the gum. The fresh okra pods were gathered and washed with distilled water to remove any dirt or unwanted substances. The pods were thinned after washing and the mucilage was released by cutting them into thin slices with a clean knife. The sliced okra was put in a container and covered with sufficient distilled water. The solution was left to stand overnight at room temperature, so that the mucilage would dissolve in the water. This will enable the plant tissues to absorb water and swell, thus aiding the water-soluble polysaccharides to emerge.

After soaking was done, the thick liquid was filtered using muslin cloth to eliminate solid contents from the mucilage rich liquid. This was done carefully to ensure that the maximum amount of mucilage solution was collected. The filtrate was then slowly poured, while continually stirring, into acetone. As acetone does not dissolve the mucilage, so it caused the gum to settle out of the solution. The mixture was thoroughly stirred to make sure that all the mucilage was separated from the liquid.

The settled mucilage was then filtered again to collect it. Collected mucilage was put in the oven and set at 50°C to dry to constant weight. This drying process eliminates any remaining moisture as well as the acetone, thus yielding a stable product. In the end, the dried product was grounded to a fine powder using a pestle and mortar. The powder obtained was put into a container and sealed for future use (Rajalakshmi *et al*., 2023).

7. Factors affecting extraction of okra gum

The extraction of okra gum is influenced by many process variables which plays a major role in the extraction of the polymer, yield of the extracted gum, and quality of the extracted gum.

- **Temperature:** The extraction temperature affects the solubility of the polysaccharides and the ease of breakdown of the plant cell walls to release the mucilage. However, if temperature is too high, it can lead to the polymer's degradation (Nkosi *et al*., 2026).
- **Water-to-material ratio:** One of the most important factor of the extraction process. The more water used, the better the movement of the solvent because the mucilage can be dissolved more effectively so that the yield obtained is higher (Nkosi *et al*., 2026).
- **Extraction time:** The duration of the extraction will influence the quantity of

mucilage produced. In general, the extraction time is straightforwardly proportional to yield up to a certain point and then the yield remains nearly constant (Kalkan *et al*., 2023).

- **Extraction method:** The technique used for extraction, such as traditional maceration or more modern methods like ultrasound-assisted extraction, has a major impact on the efficiency. This can be achieved by using ultrasound, which facilitates cell disruption and improves the diffusion of the solvent into the substance, leading to higher yields (Kalkan *et al*., 2023).
- **Type of solvent:** Type of solvent is very important. Mucilage is soluble in water but not soluble in organic solvents such as ethanol, acetone etc., used for precipitation. This property is a direct impact on the gum recovery and its purity (Patel *et al*., 2020).
- **Interaction of variables:** The efficiency of mucilage extraction is greatly affected by the combination of factors, e.g. temperature and water-to-material ratio. This indicates that there are several factors that affect the extraction process, and optimization is required to maximize the yield (Nkosi *et al*., 2026).

8. Physicochemical Properties of Okra Gum

8.1. Solubility

Solubility is an vital chemical and physical property of okra gum which affects its performance in the applications. Okra gum is a water soluble polysaccharide which is simply soluble in water and is able of producing thick and colloidal mixture with water. This is mainly because of the many hydroxyl (–OH) and carboxyl (–COOH) groups in its structure, which create strong bonds with water molecules.

Okra polysaccharides are easily soluble in water and are rapidly swollen to form stable, thick solutions even at small concentrations (Wang *et al*., 2020). However, okra gum does not dissolve in organic solvents like ethanol and acetone. This property is widely used in the extraction process in the form of solvent precipitation. Several factors affect solubility:

- **Temperature:** Higher temperatures increase molecular movement and solubility
- **pH:** The best solubility is seen in neutral or slightly acidic conditions
- **Ionic strength:** Salts may lower solubility by reducing the charge on the molecule

Also, the conditions used during extraction can change solubility. For instance, polysaccharides extracted at different pH levels show variation in hydration and solubility (Olawuyi *et al*., 2022).

8.2. Swelling Index

One of the important properties of okra gum for drug delivery systems is its swelling index, which indicates its water absorption and swelling ability. The high swelling ability of okra gum is due to its water-attracting polymer chains, loosely arranged molecular structure, and the presence of uronic acids. When water is added, it moves into the polymer structure, causing the chains to relax and the material to expand. This leads to the formation of a gel, which is important for controlled release of drugs. Research shows that okra polysaccharides have excellent water-holding and swelling abilities, making them good matrix-forming components (Zhang *et al*., 2020).

Factors that influence swelling are:

- **pH:** Higher swelling is seen in alkaline conditions due to ionization
- **Temperature:** Higher temperatures improve swelling
- **Particle size:** Larger particles tend to swell more

8.3. Viscosity and Rheological Properties

Viscosity is one of the most important physical and chemical properties of okra mucilage. This is what influences its ability to work as a thickener, stabilizer and controlled release agent. In the case of Okra gum solutions, it shows:

- High viscosity even at low concentrations
- Non-Newtonian flow behavior
- Shear-thinning (pseudo plastic) properties

In shear-thinning systems, viscosity decreases as the shear rate increases, which helps during processing and application. Okra polysaccharides are recognized to be shear-thinning and possesses good visco-elastic properties, which is suitable for industrial and pharmaceutical applications, as confirmed by the studies (Nie *et al*., 2019).

Factors that affect viscosity are:

- **Concentration:** Higher concentration leads to higher viscosity
- **Temperature:** Higher temperatures decrease viscosity
- **pH:** Extreme pH levels can break down the polymer
- **Molecular weight:** Higher molecular weight increases viscosity

Also, changes in the structure is due to different extraction methods greatly influence how the material behaves when it is used (Wang *et al*., 2020).

8.4. pH and Stability

The pH of okra gum solutions is typically in the range of 5–7, which is slightly acidic to neutral.

The pH has a significant effect on the stability of okra gum:

- **Acidic conditions:** May cause breakdown of the sugar linkages
- **Alkaline conditions:** Can lead to breakdown of the polymer and reduced viscosity

Research shows that okra polysaccharides remain stable in moderate pH environments, but extreme conditions can change their physical and chemical properties (Olawuyi *et al*., 2022). The presence of uronic acids contributes to the ability of the polymer to act as a buffer and to have an ionic character.

8.5. Thermal Properties

Thermal stability is an important factor in manufacturing and formulation processes. Thermal analysis techniques like DSC(Differential Scanning Calorimetry) and TGA (Thermo- Gravimetric Analysis) show that okra gum has moderate thermal stability. Thermal breakdown occurs when moisture loss is observed at around 350°C, and it is confirmed that okra polysaccharides undergo thermal breakdown step by step with increasing temperatures, depending on their molecular structure and composition (Wang *et al*., 2020). Thermal stability can be affected by molecular weight, degree of acetylation and moisture content.

8.6. Particle Size and Morphology

The particle size and shape are significant in the capability of okra gum to hydrate, swell and release the drug. Typically, Okra gum particles are irregularly shaped and fibrous with rough and porous surfaces. The porous structure of the particles has been revealed by microscopic studies, which assist in water penetration and swelling of the material (Zhang *et al*., 2020). Particles size differences also impact material flow, how easily it can be compressed, and the surface area available for reactions.

8.7. Density and Flow Properties

Flow properties are important for pharmaceutical processing, especially in tablet manufacturing. Okra gum typically has low bulk density, moderate tapped density and poor flow properties. The poor flow is caused due to the irregular shape of the particles, strong bonding between particles, and the ability to absorb moisture.

Studies on okra residues and powders show that the density and flow characteristics vary depending on the plant type and how it is processed (Williams *et al*., 2023). To improve flow, granulation techniques are used and flow-enhancing agents may be added.

8.8. Moisture Content and Hygroscopicity

Okra gum has moderate hygroscopic properties this is because of the presence of water-attracting groups and the strong ability to bind with water molecules. Absorbing moisture can lead to increased viscosity, reduced stability, and higher risk of microbial growth. It is important to store okra gum in airtight containers to keep it stable.

8.9. Ash Value and Purity

Ash value is a compute of the amount of inorganic substance and purity in okra gum. Okra gum generally has low ash content, indicating minimal contamination. Recent analysis show that ash values can vary based on the plant variety and the extraction method used (Williams *et al*., 2023).

8.10. Surface Activity

Okra gum has mild surface-active properties, which allows it to act as an emulsifier. The mechanism involves adsorption at the oil-water edge and reduction of tension between the two phases. Studies have shown its ability to act as a natural stabilizer in emulsions and dispersions (Olawuyi *et al*., 2022).

8.11. Gel Formation Ability

Okra gum can form gels under certain conditions. Gel formation depends on the concentration of the polymer, presence of ions and temperature. The gel structure forms due to the formation of hydrogen bonds and the entanglement of the polymer chains. Research indicates that okra polysaccharides have good gelation and water retaining abilities, which support their use in hydrogel systems (Wang *et al*., 2020).

8.12. Molecular Structure and Functional Groups

The physical and chemical behavior of okra gum is determined by its molecular structure. Important functional groups are Hydroxyl (–OH), Carboxyl (–COOH) and Acetyl groups. These groups help in swelling, attracting water and increasing viscosity. Recent structural research confirms that okra polysaccharides are complex branched heteropolysaccharide, which influence their functional properties (Zhang *et al*., 2020).

9. Mechanism of Drug Release from Okra Gum Systems

The release of the drug is influenced by several processes involving movement of the drug through a hydrated gel layer, expansion of the polymer in the presence of water, and erosion of the matrix structure. Most of these systems exhibit Non-Fickian, or anomalous, drug release behavior. When a higher amount of polymer is used, the system tends to swell more and discharge the drug more slowly(Hussain *et al*., 2017, Khizer *et al*., 2020) .

10. Differentiation of Okra Gum in Conventional vs. Novel Drug Delivery

Parameter	Conventional Drug Delivery (using Okra Gum)	Novel Drug Delivery (using Okra Gum)	References
Definition	Use of okra gum as binder, disintegrant, or matrix former in traditional dosage forms like tablets, capsules, and suspensions	Use of okra gum in advanced systems as like hydrogels, microspheres, nanoparticles, controlled release matrices, and targeted delivery	Rajalakshmi *et al.*,2023, Deka *et al.*, 2023
Dosage Forms	Tablets, suspensions, granules, syrups, matrix tablets	Hydrogels, microspheres, nanocarriers, controlled release systems, green polymer networks	Gyasi *et al.*, 2021, Deka *et al.*, 2023, Okunlola *et al.*, 2020
Role of Okra Gum	Binder, thickening agent, disintegrant, release retardant	Biopolymer carrier, controlled release polymer, nanodelivery matrix,hydrogel forming agent	Rajalakshmi *et al.*, 2023, Deka *et al.*, 2023
aDrug Release Pattern	Immediate or sustained release with limited control	Controlled, sustained, targeted, and stimuli responsive drug release	Deka *et al.*, 2023, Okunlola *et al.*, 2020
	over targeting		
Mechanism	Swelling, viscosity, gel formation to retard drug release	Cross-linked polymer network, nanoencapsulation, hydrogel diffusion, and controlled release kinetics	Deka *et al.*, 2023
Polymer Modification	Mostly used in natural or slightly modified form	Chemically modified, cross- linked, or combined with PVA, guar gum, silica, or nanoparticles	Deka *et al.*, 2023, Puri *et al.*, 2019
Drug targeting	No specific targeting	Targeted and sitespecific drug delivery possible	Deka *et al.*, 2023
Bioavailability Improvement	Moderate improvement due to sustained release	Significant improvement due to controlled and nanobased delivery	Deka *et al.*, 2023, Okunlola *et al.*, 2020
Stability	Limited stability in conventional formulations	Enhanced stability in hydrogel and nanocarrier systems	Deka *et al.*, 2023,
Cost and Availability	Low-cost, easily available natural polymer	Still economical but requires advanced formulation techniques	Rajalakshmi *et al.*,2023
Industrial Application	Oral tablets and simple formulations	Advanced pharmaceutical and biomedical drug delivery	Gyasi *et al.*, 2021, Deka *et al.*, 2023
Example	Propranolol matrix tablets using okra gum	Nanocurcumin hydrogel, ambroxol microspheres,	Deka *et al.*, 2023, Okunlola *et al.*,

		modified okra gum fast disintegrating tablets	2020

Table 4: Differentiation of Okra Gum in Conventional vs. Novel Drug Delivery

11. Applications of Okra Gum in Drug Delivery Systems

11.1. Oral Controlled Release Systems

Okra gum, derived from *Abelmoschus esculentus*, is widely studied as a natural hydrophilic polymer used in oral controlled release formulations. Its effectiveness comes from its ability to quickly absorb water and form a thick gel layer, which controls how drugs move and extends the time it takes for them to release (Yazd et al., 2025). Okra gum is favored for several reasons as like gel forming, high capacity to absorb water, increases the viscosity of a solution, biodegradable and safe for the body. It provides several benefits:

- It releases drug over a longer time
- It reduces how often medication needs to be taken
- It helps keep drug levels in the blood steady
- It makes it easier for patients to follow their treatment plan

When okra gum is in the stomach or intestines, it absorbs water and becomes more flexible, forming a hydrated layer around the medication. This layer reduces the rates of liquid flow around the drug and regulates the rate of the drug flow out. The amount of polymer, solubility of the drug and other formulation parameters affect the manner in which the drug is released. Due to its natural occurrence and low toxicity, okra gum is being considered as an alternative to synthetic polymers for oral controlled release systems (Hussain *et al*., 2017, AMJ *et al*., 2014).

11.2. Matrix Tablet Systems

Matrix tablets are a common use of okra gum in controlled drug delivery systems. In these systems, the drug is evenly distributed within a polymeric matrix, and its release is controlled by how the polymer swells and absorbs water. Okra gum plays a key role in matrix tablets by creating a viscous gel layer when it comes into contact with water, controlling how the dissolution medium enters the matrix, and managing the progress of the drug through the matrix.

These tablets have several applications, including:

- Providing sustained release of drugs over extended periods
- Being suitable for drugs that are highly soluble in water
- Acting as an alternative to synthetic polymers like HPMC

When the tablet is released to an aqueous surroundings, the outer layer absorbs water and forms a gel. This gel creates a barrier which retards drug molecule transfer into the external liquid. The polymer slowly breaks down over time, providing a continuous release of the drug. The studies have indicated that the higher the concentration of okra gum, the thicker the gel layer and the slower the release of the drug. In most cases, the release process is a non-Fickian process, which involves both the diffusion of the drug and relaxation of the polymer structure (Hussain *et al*., 2017, Khizer *et al*., 2020).

11.3. Floating Drug Delivery Systems

Okra gum helps in creating gastro-retentive systems because of its ability to swell and form a strong gel. Its functions include creating a lightweight gel structure, keeping the drug floating in the stomach fluid, and delivering the drug slowly over an extended period in the stomach.

Applications include:

- Drugs which have narrow absorption window
- Drugs that are absorbed in the upper part of the GI tract.(Deka *et al*., 2023)

11.4. Mucoadhesive Drug Delivery Systems

Okra gum has mucoadhesive properties due to the existence of hydroxyl groups. It helps in sticking to the mucosal surfaces of the gastrointestinal tract, improving the drug residence time in the stomach and improving the absorption of the drug. It is used in mucoadhesive tablets, in polymer films and gels (Gorle et al., 2024).

11.5.Multiparticulate Systems (Beads/Microspheres)

Okra gum is utilized in multiparticulate systems to manage how drugs are released over time. Functions of Okra Gum include enhancing the thickness of the formulation, boosting the efficiency of drug entrapment, and maintaining a steady release of the drug.

Advantages of using Okra Gum:

- Minimized sudden release of a large dose
- Even distribution of the drug throughout the formulation
- More predictable movement through the gastrointestinal tract

11.6. Modified Okra Gum Systems

Recent studies are exploring modified forms of okra gum to improve its effectiveness. Common methods used for modification involves altering the chemical structure, mixing with other polymers, and creating hydrogel structures. These modifications offer greater structural strength of the system, more precise over drug release, and improved stability of the formulation(Deka *et al.*, 2023, Alwosabi *et al.*, 2025).

11.7. Ocular Drug Delivery System

The unique anatomical and physiological walls of the eye make effective medication release to the eye a key challenge in pharmaceutical development. Conventional topical formulations, such as ointments and eye drops, that result in only 5% of the applied medication being absorbed at the target site due to their low bioavailability, low residence time, and rapid-fire precorneal elimination (Majeed et al., 2019).

By enhancing viscosity of the formulation, drainage of ocular gel is reduced and this enhances the retention of drug in the eye (Pganini et al., 2025). This prolonged retention increases penetration of drug through the cornea and conjunctiva, due to which bioavailability and therapeutic efficacy of drug is improved (Paul et al., 2023).

Advantages of using okra gum include:

- Reduced need for frequent dosing
- Enhanced patient compliance due to less frequent administration
- Enhanced therapeutic outcomes
- Decreased drug loss through tear drainage
- Being a safe and biocompatible natural polymer

Common applications of okra gum in ocular drug delivery systems are *in- situ* forming ocular gels, Mucoadhesive eye drops, Ocular inserts, Nanoparticulate ocular delivery systems. Examples of drugs that can be delivered using okra gum include: Timolol, Ciprofloxacin, Ofloxacin, Ketorolac (Brar *et al*., 2018, Gote *et al*., 2019).

12. Applications of Okra Gum as a Natural polymer in Drug Delivery Systems

Sr. No.	**Drug Delivery System**	**Role of Okra Gum**	**Drugs Used**	**Major Findings**	**Reference**
1	Sustained Release Tablets	Matrix forming polymer	Diclofenac sodium	Controlled and prolonged drug release due to high swelling ability	Patra et al., 2020
2	Mucoadhesive Drug Delivery	Mucoadhesive polymer	Various model drugs	Increased residence time and enhanced bioavailability	Naveen et al., 2020
3	Pellet Formulation	Binder and release retardant	Theophylline	Improved pellet strength and controlled release behavior	Yadav et al., 2021
4	Buccal Drug Delivery	Bioadhesive polymer	Propranolol HCl	Enhanced mucoadhesion and prolonged drug contact time	Naveen et al., 2020
5	Transdermal Patches	Film-forming polymer	Nicotine	Good flexibility, uniformity, and sustained permeation	Hussain et al., 2017 Kalu et al., 2007
6	Hydrogel Systems	Swelling and gel-forming polymer	Various hydrophilic drug	Excellent hydration and controlled release	Nkosi et al., 2026
7	Nanocomposite Films	Stabilizer and polymer matrix	Bioactive compounds	Improved stability and mechanical strength	Ahmed et al., 2023
8	Control	Releas	Metfor	Sustaine	Mad

	led Release Microspheres	e retardant polymer	min HCl	d drug release with improved entrapment efficiency	y et al., 2021
9	Colon Targeted Drug Delivery	Natural biodegradable carrier	5-Fluorouracil	Delayed drug release and site-specific delivery	Newton et al., 2015
10	Floating Drug Delivery Systems	Swelling polymer	Ciprofloxacin	Enhanced gastric residence time and sustained release	Nayak et al., 2014
11	Polyelectrolyte Complex Systems	Complex forming biopolymer	Various model drugs	Improvedstability and controlled drug release	Brar et al., 2018

Table 5: Applications of Okra Gum as a Natural polymer in Drug Delivery Systems

13. Clinical Trials done on Okra Gum

Clinical studies have verified the therapeutic potential of okra in managing metabolic disorders, mainly diabetes mellitus and its complications. Clinical study was performed in a randomized double- blind design in which okra is supplemented that significantly improve glycemic control and lipid profile in patients with type 2 diabetes mellitus. This study also reported decrease in fasting blood glucose, cholesterol level, and serum triglycerides which indicates that okra have beneficial bioactive constituents for regulating carbohydrate and lipid metabolism. These effects were recognized due to presence of soluble fibers, polysaccharides, and flavonoids that delay glucose absorption and thus improve insulin sensitivity (Moradi et al., 2020).

Another clinical trial involving placebo- controlled design, evaluated effect of okra extract supplementation in patients distress from diabetic nephropathy. The outcomes of study suggested that okra supplementation contributed in enhanced glycemic status. On renal function biomarkers beneficial effects were observed which shows the nephroprotective potential of okra. Modulation of gene expression was also reported that was associated with inflammation and oxidative stress pathways. This showed pharmacological significance ok okra in chronic diseases (Nikpayam et al., 2024).

14. Conclusion

Okra gum is a valuable natural polymer commonly used in pharmaceutical drug delivery systems because of its biocompatibility, biodegradability, non-toxic nature, and affordability.. It is regarded as a potential alternative to the synthetic polymers used in drug formulation because of its natural origin and safety. Okra gum possesses a number of beneficial properties, such as swelling, high viscosity, mucoadhesion, film forming and water retention property. It is also a major component of controlled and sustained drug release systems. In ocular drug delivery, it enhances the viscosity of the drug formulation, thus extending the drug residence time, thus improves drug absorption.

To sum up, okra gum is a wonderful natural excipient with a variety of applications in traditional and advanced drug delivery systems. It is safe, effective and multifunctional, thus it is very useful in pharmaceutical formulations. Upon further research and proper standardization, okra gum could be a major and dependable polymer for future drug delivery technologies.

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