EXPLORING THE ROLE OF NOVEL EXCIPIENT ISABGOL HUSK IN POLYMER COMPLEXATION FOR MODIFIED DRUG DELIVERY: A REVIEW OF RECENT LITRATURE

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ABSTRACT:

Background: Isabgol, derived from the bark of *Plantago ovata*, is a natural, biodegradable polymer that has gained significant attention in pharmaceutical research due to its versatility and sustainability. Commonly referred to as psyllium husk or ispaghula, it is widely used in controlled and prolonged drug delivery systems. Its unique properties, such as swelling, gel formation, and mucoadhesion, make it particularly suitable for gastro-retentive formulations.
In addition to its role in drug delivery, Isabgol is recognized for its therapeutic applications in managing a variety of gastrointestinal and systemic conditions, including constipation, diarrhea, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), ulcerative colitis, and colon cancer. Beyond gastrointestinal health, it has shown potential in regulating blood glucose levels in diabetes and reducing cholesterol levels in hypercholesterolemia, thus highlighting its broad-spectrum pharmacological benefits.

This study investigates the potential of Isabgol in combination with sodium alginate to formulate floating beads for gastro-retentive controlled release of metronidazole. The research focuses on optimizing the formulation to achieve enhanced buoyancy, prolonged drug retention, and controlled release properties, paving the way for improved therapeutic outcomes in gastro-intestinal infections.

Objective: The husk of Isabgol serves as a novel excipient for the development of modified-release drug delivery systems. It enhances drug residence time in the stomach, improves bioavailability, and facilitates the localized delivery of drugs to the gastric region. This innovative drug delivery approach is particularly beneficial for drugs with a narrow absorption window. Isabgol is employed as a versatile excipient, functioning in controlled release and floating drug delivery systems. It also serves multiple roles, such as a disintegrant, binder, matrix former, flavor enhancer, adhesive, and suspending agent.

Method: The entire literature search was done using various search engines like Pub med, Science Direct, NCBI, Research Gate etc.

Conclusion: The interaction of the novel excipient Isabgol with other polymers has been a significant focus of fundamental and applied research, particularly in understanding its complexation mechanism and potential drug interactions. Isabgol demonstrates a unique combination of physicochemical properties and high biocompatibility, making it an excellent candidate for drug delivery systems. This study explored the interaction of Isabgol with various drugs and polymer composites, highlighting its potential to create combinations with distinctive properties that differ from those of the individual components. This review underscores the role of Isabgol in advancing drug delivery technology and systems, showcasing its importance as a novel excipient in pharmaceutical applications.

Keyword: Isabgol, Complexation mechanism, drug/polymers interaction, synergistic effect, physiochemical properties, Application in novel drug delivery.

Introduction:

Isabgol husk, obtained from the plant *Plantago ovata*, is widely recognized as psyllium husk or ispaghula. The term "Isabgol" is believed to originate from the Persian word "Bandgūr," which refers to "horse flowers," alluding to the structure of the plant's seeds [1]. Isabgol husk is a natural, plant-based polymer predominantly composed of (1→4)-β-xylan polysaccharides. For centuries, natural carbohydrates like Isabgol have been employed in pharmaceutical applications and material science, owing to their renewable, biodegradable, and eco-friendly properties.

Isabgol husk is a versatile material used across cultures as a remedy for numerous conditions, including chronic constipation, diarrhea, peptic ulcers, inflammation of the gastrointestinal and urinary tracts, and hemorrhoids. It also serves as a bulk-forming laxative, cervical dilator, and analgesic. Rather than being used as a pure compound, Isabgol is frequently formulated into advanced drug delivery systems to enhance its therapeutic effects. The husk is derived from the outer layer of the seeds of *Plantago ovata* and is rich in dietary fiber and mucilage. Its mucilage component, a natural gelling agent, has the remarkable ability to expand up to 40 times its weight upon water absorption. The bioactive components of Isabgol husk consist of highly branched, neutral arabinoxylan chains with a xylan backbone and arabinose side chains. Over the last few decades, chemical and physical modifications of Isabgol have been explored to improve its properties, including the development of graft copolymers using Isabgol mucilage and polyacrylamides via cerium ion-induced redox polymerization. These modifications have resulted in copolymers with improved solubility in water.

Figure 1: plant of psyllium husk

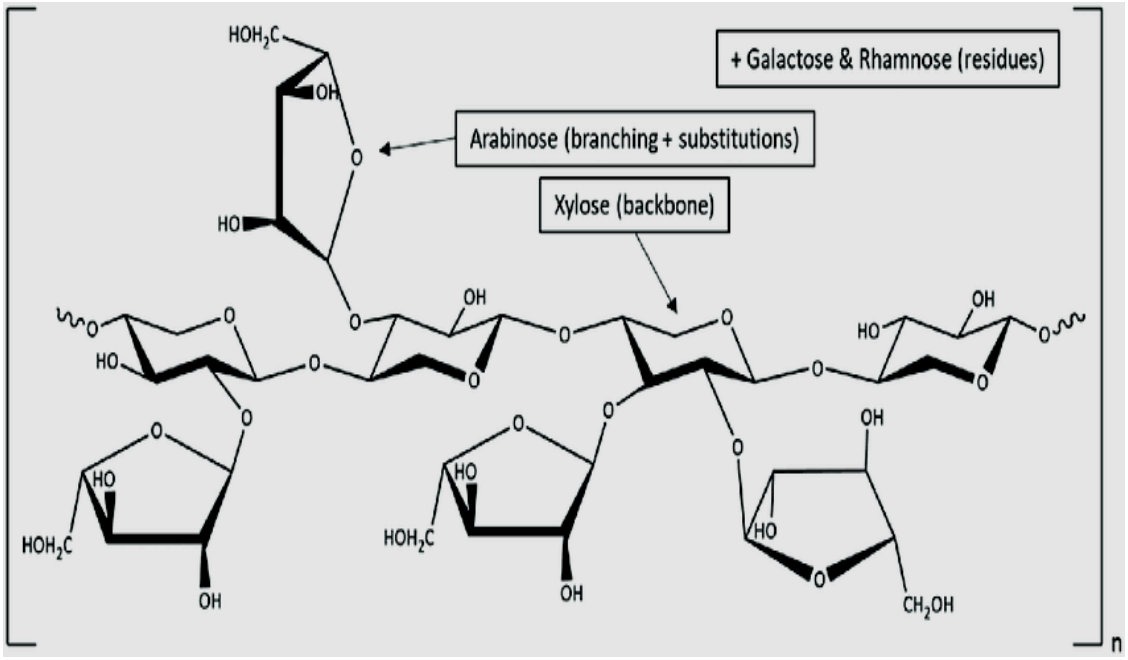

Figure 2: Chemical structure of psyllium husk

Figure 3: A-Isabgol husk, B-seed of psyllium husk

The high intrinsic viscosity of Isabgol mucilage has attracted attention for its potential in controlled drug delivery. In recent years, studies have demonstrated the utility of Isabgol as a polymer in sustained-release formulations. These efforts aim to leverage its unique properties to regulate drug release effectively [2, 3]. A summary of available studies and the recommended varieties of Isabgol is provided in Table 1.

Table 1: Recommended varieties of Isabgol Husk and their source of availability

Varieties	Source
Gujarat Isabgol	Head ,AICRP on medicinal and aromatic plant, Gujarat agriculture university Amanda , Gujarat
Jawahar Isabgol	Head ,AICRP on medicinal and aromatic plant, KNK college of agriculture JNKWV, mandsaur Madhya parades
HIS	Head, MICRP on medicinal and plant,CCS Haryana agriculture university, (Hisar, Haryana)

Polyelectrolytes are polymers that possess an overall positive or negative charge at a near-neutral pH. Their solubility in water is attributed to electrostatic interactions between the water molecules and the charged segments of the polymer. Common examples of polyelectrolytes include biomolecules such as DNA and proteins, as well as derivatives of cellulose-based polymers.

When a polyacid reacts with a polybase, they form polyelectrolyte complexes that exhibit minimal sensitivity to changes in the pH of the surrounding medium [4]. This review emphasizes the significance of Isabgol in facilitating polyelectrolyte complex formation and its applications in advanced drug delivery systems.

Physical and Chemical Effects of Isabgol Husk: The physical and chemical properties of dietary fibers are influenced by several factors, including their water retention capacity, viscosity, binding ability, swelling behavior, and their interaction during agitation [5].

Water Retention Capacity: Water retention capacity (often used interchangeably with water holding capacity) refers to the ability of hydrocolloids to retain water under specific conditions. This property arises from the presence of hydrophilic sites within the molecular structure of the fiber, which enable it to trap water within its cavities [6].

Viscosity and Gel Formation: Viscosity or gel formation describes the fiber's ability to absorb water and form a sticky, gel-like mass. Soluble fibers dissolve in water to form gels, which thicken the digestive tract contents. Due to their viscous and gummy nature, these gels behave more like solids than liquids, potentially explaining the delayed gastric emptying often associated with fiber consumption. Gel formation also softens stools, making them easier to pass [7].

Binding capacity: Dietary fibers can bind bile acids in the gastrointestinal tract. When soluble fibers dissolve, they form a gel matrix that may trap bile acids secreted by the gallbladder. This binding effect is particularly noticeable in the lower intestine, where bile acids are typically reabsorbed.

Filling capacity: insoluble fibers, such as cellulose and lignin, are resistant to fermentation by colonic macrobiotic. Their structure allows them to absorb water and increase stool bulk. Wheat bran, a common bulking agent, exemplifies this property. Fermentable fibers like hemicelluloses increase stool volume by stimulating gut flora, whereas fibers such as pectin have minimal impact on stool bulk. [8]

Solubility: The fermentability of fibers varies significantly, ranging from non-fermentable lignin to highly fermentable pectin. Soluble fibers are more readily fermented by colonic bacteria compared to insoluble ones. The breakdown of soluble fibers can play a crucial role in their physiological effects. Plants exhibit diverse fiber properties, with some containing fast-fermenting, slow-fermenting, or non-fermentable fibers. For example, fruits like apples and bananas, as well as vegetables like potatoes and eggplants, tend to dissolve quickly and contribute less to stool bulk. In contrast, fibers such as Isabgol husk and wheat bran ferment slowly, promoting increased stool mass through fermentation along the entire length of the large intestine.

Chemical Composition of Isabgol:

Isabgol primarily consists of approximately 15% non-polysaccharide components, with the remaining 85% composed of polysaccharides. These polysaccharides are derived mainly from D-xylose (around 62%), L-arabinose (approximately 20%), L-rhamnose (~9%), and D-galacturonic acid (~9%). The specific sugars present and their approximate proportions were originally identified by Law and Percival. Two polysaccharide fractions have been isolated from the husk's mucilage. One fraction (molecular weight ~700, containing 20% uronic acid) dissolves in cold water, whereas the other fraction (molecular weight ~4000, containing 3% uronic acid) dissolves only in hot water. The polysaccharides feature a linear backbone of pyranose cyclic β-D-xylose residues, with disaccharide side chains terminating in α-D-galacturonic acid linked to O-2 of α-L-rhamnose. These side chains are attached to either O-2 or O-3 of the xylose units along the polymer backbone.

Table 2: Chemical Composition of Isabgol

Component	Amount (%)
D-Xylose	~62
L-Arabinose	~20
L-Rhamnose	~9
D-Galacturonic acid	~9
Non-polysaccharides	~15

The main chain includes both (1→3) and (1→4) β-linkages, though the exact sequence and distribution of the side chains along the backbone have not yet been fully determined [9, 10]. The nutritional composition of Isabgol is detailed in Table 2.

Table 3: Nutritional Composition of Isabgol

S.NO	Contents Isabgol husk	Mcg/g
1	Calcium	1500
2	Magnesium	150
3	Phosphorus	140
4	Potassium	8500
5	Sodium	640
6	Sulphur	23

Synergistic Effect: Isabgol may exhibit a synergistic effect in reducing plasma triglycerides and cholesterol levels. It is hypothesized that solid-state enzymatic treatment alters the molecular or chemical structure of Isabgol, leading to the formation of new polysaccharide molecules. These modified polysaccharides are believed to influence the absorption of cholesterol and fatty acids. Consequently, the resulting polysaccharide complex may differ from the original in both its physicochemical properties and biological activities. The solid-state enzymatic treatment of Isabgol, in combination with polymers, is thought to create novel fiber complexes that can be applied as fat-binding agents. These complexes are beneficial in reducing fat absorption, lowering cholesterol, and exhibiting laxative effects [11, 12, and 13]. The different mechanisms of Isabgol complexation are summarized in Table 3.

Table 4: Different Complexation Mechanisms of Isabgol

Mechanism	Effect
Enzymatic Treatment	Alters molecular structure to form new polysaccharides
Fat Binding	Reduces fat absorption in the digestive tract
Hypo-cholesterolemic Effect	Lowers plasma cholesterol levels
Laxative Activity	Promotes bowel regularity and improves digestion

Table 5: Complexation Mechanism of Novel Excipient Isabgol Husk:

Sr. no.	Polymer Interaction	Mechanism
1.	**Isabgol Husk-Sodium Alginate**	Microparticles comprising Isabgol shell and sodium alginate consist of the active ingredient prepared by the ionic gelatin process. A group of globs was left over to cure for 10 min before coming into contact with the cross-bread linker solution. The batch was abstracted from the mixture, dried at 40°C for 50 hours, and

		stored in vacuum desiccators. Different varying concentrations of calcium chloride and barium chloride with sodium alginate and curing times (0-24) have been studied to determine drug entrapment efficacy, drug loading, and swelling behavior of particle size in different media to determine the influence of these factors. In vitro release behavior [14].
2	**Isabgol Husk-Gum Katira**	Isabgol and gum, approximately 1-2% by weight dispersion of katira, were produced in distilled water and stored at room temperature for 6 hr and removed. Air is trapped and expands completely. A mixture of Isabgol bark and gum katira, each at 1% by weight, is a complete solution of the above dispersion in a 3% ratio, such as 75:25, 50:50, and 25:75, respectively. Prepared by mixing. A mixture was prepared by appealing to 2% by weight of Isabgol shell and 1% by weight of gum katira-dispersal to the above composition and vice versa in order to evaluate the influence of polysaccharide concentration on miscibility. The compatibility regarding the mixability of Isabgol Peel with gum katira in mixtures containing different strengths of this polysaccharide was determined at 298.15, 315.15, & 333.15° [15].
3	**Tregacanth-Isabgol Husk**	The floating tablet was obtained by wet granulation using Isabgol husk and tragacanth as release retardants. Sodium bicarbonate was used as a gas generator. Drug Isabgol shell, tregacanth, and sodium bicarbonate were passed through a #40 sieve, and all ingredients were mixed well for 10 min. Then isopropyl alcohol was added dropwise to obtain a lump, moist, granular mass after mixing again for 5 min. The granules have been passed through a no. 16 sieve and dried for 1 hr at 40°C. Dried granules were further passed through a No. 40 sieve and compressed on a ZP-19 with a force of 15 kN. This is a 7mm round flat stamp from a rotary press [16].
4	**HPMC Isabgol Husk**	Buoyant matrix tablets have been developed by the wet granular method using a distinct ratio of the drug, Isabgol husk, HPMC K15M, and HPMC K100M. Bulk material was prepared by thoroughly mixing the respective powder (drug-polymers) and adding a granular agent (5% PVP K 30 isopropyl alcohol). The mass was passed by a no. 10 screen and dried in a 600°C hot air oven for 2 min. After draining, they were remoter mixed with no 22 sieves to achieve a globule uniform eventually; optional ingredients such as magnesium stearate and talc such as add-on mixed excellently to the essential amount of mixture that was weight and mantle added to the die of one punch tablet press to occasion the tablet using cupped punches of the appropriate diameter tablet stiffness was keeping in the reach of 2-5 kg/cm² [17].
5	**Isabgol Shell and**	Compositions of cross-linked microspheres from Isabgol shell

	Crosslinking Agent	polysaccharides microspheres were prepared using glutaraldehyde as a cross-linking agent and castor oil by emulsification techniques. Prepared inside. Microspheres were collected by centrifugation at 900 rpm for 35 min and cleaned with n-hexane and acetone to eliminate traces of castor oil. These were also washed with glycine & distilled water to remove unreacted glutaraldehyde surfactant. Respectably, completely avoid untreated glutaraldehyde, which was committed by a negative aldehyde test of the felling reagent wash solution. The microsphere was dried in a hot air oven at 60°C for 10 min and stored in an airtight desiccator till further use [18].
6	**Isabgol Peel-Potato Starch**	Thermoplastic film and distilled water are used to prepare the layer-forming solution. Pieces of potato starch and Isabgol husk are added to distilled water at a concentration of 4.3% (w/w) for the potato starch and 1% (w/w) for Isabgol husk, respectively. The dissolution was made hot at 80°C for 30 min with constant stirring at 300 rpm using a magnetic stirrer. The solution was then heated and cooled at 40°C, and glycerin was added in a quantity of 1.3% (w/w). The entire dissolution was amalgamated for 50 min using ultrasonic homogenizer equipment Tf 650n. The mixture was poured for 20 hr at 35°C in the KBC-65 thermal laboratory. After being removed from the mold, the layers were conditioned at a temperature of 22°C and R/H of 40% for 24 hr [19].
7	**Isabgol/Gelatin**	Composite scaffolds comprising psyllium husk (PH) powder and gelatin (G) were prepared by freeze-drying technique more commonly known as the lyophilization method. Composite scaffolds comprising psyllium husk (PH) powder and gelatin (G) were prepared by freeze-drying technique more commonly known as the lyophilization method. Composite scaffolds comprising psyllium husk (PH) powder and gelatin (G) were prepared by freeze-drying technique more commonly known as the lyophilization method. In this study, we demonstrate the fabrication and characterization of a macroporous three-dimensional (3D) composite scaffold by mixing psyllium husk powder (PH) and gelatin. Composite scaffolds comprising psyllium husk powder and gelatin were prepared by freeze-drying techniques more commonly known as the lyophilization method [20].

Pharmaceutical Applications of Isabgol for Gastrointestinal and Bowel Health: [21, 22]

1. **Managing Constipation:**

Isabgol (psyllium husk) aids in alleviating constipation by increasing the moisture

content of stools, making them easier to pass. The non-fermentable fibers in Isabgol act as lubricants, enhancing the consistency and weight of stools, particularly in cases of gastrointestinal complaints. Clinical studies have demonstrated its effectiveness in improving stool hydration and overall stool weight, helping to manage constipation.

2. Alleviating Diarrhea:

Interestingly, Isabgol also plays a role in managing diarrhea. Research indicates that Isabgol can slow down colon transit time and gastrointestinal emptying, which is beneficial for individuals suffering from diarrhea or fecal incontinence. These properties help control liquid stools and prevent frequent, uncontrolled bowel movements.

3. Supporting Bowel Health:

Isabgol may also contribute to the management of inflammatory bowel conditions, including irritable bowel syndrome (IBS) and ulcerative colitis. Its anti-constipation action supports overall bowel health by regulating stool consistency. Moreover, the anaerobic fermentation of Isabgol fibers in the colon produces metabolites with antioxidant and anti-inflammatory properties, which may aid in reducing inflammation and supporting gut health.

4. Potential Role in Colorectal Cancer Prevention:

Isabgol husk has been explored for its potential to prevent colorectal cancer. Research suggests that the production of butyrate, a short-chain fatty acid resulting from the fermentation of Isabgol fibers in the gut, may have anti-cancer effects. As a result, Isabgol could potentially play a preventive role in reducing the risk of colorectal cancer.

5. Lowering Cholesterol Levels:

Isabgol fibers are effective in reducing both total cholesterol and low-density lipoprotein (LDL) cholesterol levels, which are significant risk factors for heart disease. This makes Isabgol a valuable addition to the diet for maintaining cardiovascular health and reducing the risk of related conditions.

6. Aiding in Hemorrhoid Treatment:

Isabgol can be beneficial in managing hemorrhoids, as it helps in treating both constipation and diarrhea. By improving stool consistency, it reduces the strain during bowel movements, which can prevent further aggravation of hemorrhoids. Studies have shown that individuals taking Isabgol experience a reduction in bleeding

compared to those on a placebo, highlighting its therapeutic potential for hemorrhoid treatment.

7. Managing Type 2 Diabetes:

For individuals with Type 2 diabetes, Isabgol has shown promise in improving post-meal blood sugar control. Clinical studies have demonstrated that Isabgol can help manage both blood glucose and lipid levels, offering a natural supplement for better glycemic control.These various health benefits make Isabgol a versatile and valuable dietary supplement for managing a range of gastrointestinal and metabolic conditions, contributing to overall health and well-being. [23, 24]

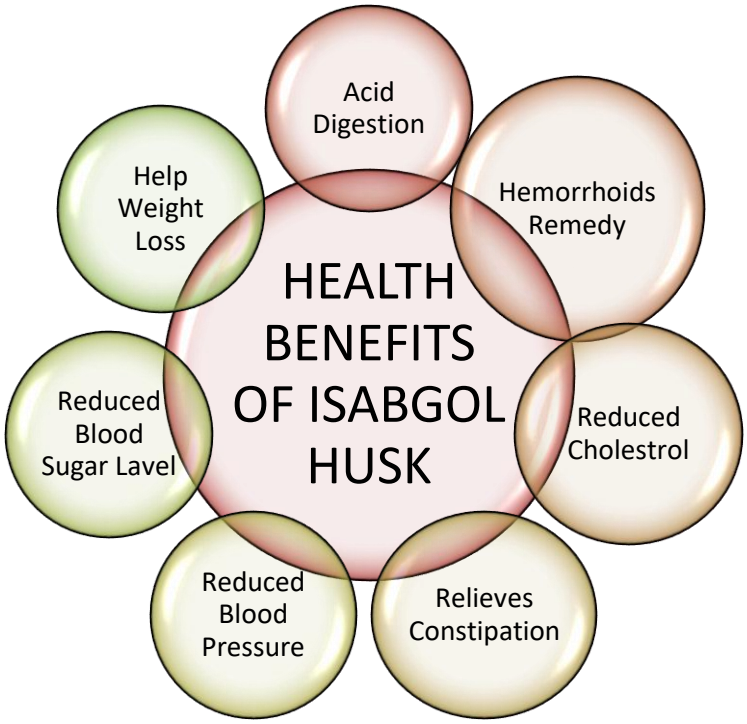

Figure.4 Different Health Benefits of Isabgol Husk

Table 6: Role of Isabgol in Hydrogel Formulations

S. No	Drug/Polymer	Method	Result	Reference
1	Nizatidine/Chitosan	Hydrogel beads by ionotropic gelation	Alginate-Chitosan complex formulation resulted in sustained Nizatidine release up to 12 h with a zero-order profile and quasi-Fickian release.	[25]
2	Quercetin/Sodium Alginate & Cellulose Derivatives	Hydrogel prepared by hot dispersion	Quercetin-loaded hydrogels showed good physic-mechanical properties, stability, and longer skin contact for enhanced	[26]

			penetration using MC as gelling agent.	
3	Rosiglitazone maleate/Chitosan, Sodium bicarbonate, PVA	Super porous hydrogels via gas foaming	Chitosan-based super porous hydrogels used as a gastro-retentive system showed prolonged release in acidic pH.	[27]
4	Laurel Grafted Alginate & Psyllium Husk Gel	Film forming method	Prepared hydrophobically modified alginate-psyllium husk composite films.	[28]

Table 7: Role of Isabgol in Sustained Release Agents

S. No	Drug/Polymer	Method	Result	Reference
1	Hydralazine HCL & Release-retarding polymers (HPMC K4M, sodium alginate, Carbopol 940)	Wet granulation method	Mucoadhesive tablets showed sustained release, improving patient compliance for pain management.	[29]
2	Amoxicillin trihydrate/Chitosan-coated Alginate	Suspension or solution method	Beads for controlled gastric release of Amoxicillin showed sustained delivery for H. pylori eradication.	[30]
3	Isabgol husk & Matrix agent-Avicel PH101/CHPD	Simple agglomeration method	Directly compressible matrixing agents for controlled release properties.	[31]
4	Diclofenac sodium/Isabgol (Plantago ovata)	Wet granulation method	Extended release tablets developed using Isabgol without interaction with Diclofenac sodium.	[32]

Table 8: Role of Isabgol as Release Retardant Gastro-Retentive Agent

S. No	Drug/Polymers	Method	Result	Reference
1	Metformin hydrochloride/Isabgol husk, sodium alginate	Ionic gelation method	Sustained release in acidic and basic media due to enhanced network formation.	[33]
2	Ranitidine hydrochloride/Sodium	Ionotropic gelation	Floating beads showed excellent buoyancy and	[34]

	alginate, Chitosan	technique	effective therapy for ulcers.	
3	Lamivudine/Sodium alginate	Ionic gelation method	Floating beads showed good buoyancy and prolonged drug release.	[35]
4	Esomeprazole/Sodium alginate, Xanthan gum	Ionic gelation method	Modified ratio of gelling agents led to an effective floating drug delivery system.	[36]

Table 9: Role of Isabgol in Super Disintegrating Agents in Fast Disintegrating Formulations

S. No	Drug/Polymer	Method	Result	Reference
1	Amlodipine besylate/Plantago ovata mucilage	Direct compression	Good flow properties and reduced drug release with increased mucilage.	[37]
2	Meloxicam/Psyllium husk	Direct compression	Enhanced dissolution rate with Psyllium husk as a super disintegrant.	[38]
3	Prochlorperazine maleate/Crosspovidone, Croscarmellose sodium	Direct compression	Fast disintegrating tablets for improved patient compliance.	[39]
4	Plantago ovata husk as a pharmaceutical excipient	Compression method	Oral dispersible tablets with good mechanical strength and disintegration properties.	[40]
5	Plantago ovata husk/Famotidine	Direct compression	Isabgol as a disintegrant showed good properties in tablet formulation.	[41]

Table 10: Role of Isabgol in Microparticles Formulation

S. No	Drug/Polymer	Method	Result	Reference
1	Isabgol husk, Castor oil, Span80, Glutaraldehyde	Emulsification technique	Spherical, cross-linked microspheres of Isabgol with enhanced formulation properties.	[42]
2	Isabgol mucilage/Gliclazide	Emulsification-cross linking	Sustained hypoglycemic effects and improved bioavailability compared	[43]

			to pure drug.	
3	Graphene oxide/Isabgol husk	Modified Hummers' method	Development of reduced graphene oxide confirmed by UV-Vis, FTIR, and XRD spectroscopy.	[44]
4	PVA/Psyllium Husk	Electrospinning	Electrospun meshes with antibacterial properties for bacterial growth inhibition.	[45]
5	Isabgol/Diclofenac/PVA	Emulsion cross-linking method	Interpenetrating polymer network microspheres for controlled Diclofenac release.	[46]

Table 11: Possible Interaction of Isabgol with Drugs and Polymers

S. No	Drug/Polymers	Interaction	Detrimental Effect	Reference
1	Spirolactone, Potassium Sparing Diuretics, Aspirin, Tetracycline, Itrofurantoin, Carbamazepine	May slow gastric emptying, reducing drug absorption	Reduced absorption when taken with Isabgol peel.	[47,48,49]
2	Digoxin with Isabgol	May minimize drug absorption	Reduced drug effect if taken with Isabgol.	[50]
3	Insulin-Isabgol	May reduce insulin requirement	Need for insulin and diabetes medication may decrease.	[51]
4	Isabgol peel with thyroid hormones	May require dosage adjustment	Dosage of thyroid hormones may need regulation under medical supervision.	[52,53]
5	Morphine Mimetic, Loperamide Hydrochloride	Reduced gastrointestinal barrier, inhibition of peristalsis	May impair peristalsis.	[54]
6	Iron, Zinc, Copper, Magnesium, Vitamin B12 with Isabgol	Long-term use may reduce absorption	Reduced absorption of minerals and vitamins.	[55]
7	Calcium with Isabgol	Calcium absorption may be impaired	Reduced calcium absorption.	[56]
8	Ethinyl Estradiol (in Females)	Increased absorption of Ethinyl Estradiol	Slight increase in absorption when	[57]

			compared with guar gum.	
9	Other active ingredients with Isabgol	Should be taken 1 hour before or several hours after Isabgol	May delay gastric emptying and reduce carbohydrate absorption.	[58,59]

CONCLUSION

The extensive literature available demonstrates that Isabgol, when combined with other polymers, holds significant promise as a novel excipient for drug formulations. This combination enhances the physicochemical properties of the resulting polymer complexes, which are essential in the development of controlled-release drug delivery systems. The versatility of Isabgol, not only in pharmaceutical sciences but also in fields like ecology, biotechnology, and traditional medicine, underscores its multifaceted potential. Historically, Isabgol has been utilized across various cultures for a wide range of medicinal purposes, such as alleviating chronic constipation, managing diarrhea, reducing inflammation in the gastrointestinal and genitourinary tracts, and addressing conditions like duodenal ulcers, gonorrhea, and hemorrhoids.

Despite its widespread therapeutic use, the full potential of Isabgol in drug delivery systems remains largely untapped. Advances in technology, however, now offer the opportunity to explore its capacity for drug complexation at the molecular level. This ability to encapsulate and stabilize drugs improves their stability, bioavailability, and controlled release characteristics, which are crucial for enhancing therapeutic outcomes. Isabgol's unique properties allow for modification at the molecular level, making it an ideal candidate for creating innovative drug delivery systems that improve the precision and effectiveness of treatments. Given these advantages, Isabgol's role in the development of novel pharmaceutical formulations holds great promise, paving the way for more efficient, targeted, and sustained drug therapies in the future.

By continuing to explore and harness these properties, Isabgol could become a cornerstone in the advancement of drug delivery technology, offering new avenues for improved patient care and therapeutic efficacy across a broad spectrum of diseases and conditions.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of Data and Material

The data used to support the findings of this study are available from the corresponding author upon request.

Competing Interests

The authors declare that they have no competing interests.

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