- **Review paper**

Phytochemical, Biochemical and Pharmacological Properties of *Plantago ovata* (Ispaghula Husk) – A Review

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ABSTRACT: The plantation, evolvement, phytochemical, pharmaceutical and pharmacological properties of *Plantago ovata* have been reviewed to reconnoiter the plant's diverse properties. *P. ovata* belonging to the family Plantaginaceae is a perennial plant native to the Mediterranean area, particularly Southern Europe, North Africa and West Asia. It has a variety of medicinal and pharmacological effects as it is frequently employed in a variety of medications for its medicinal features such as mucilage, super-disintegrant, gelling agent and suspending agent as well as pharmacological effects such as anti-diarrheal, anti-constipation, wound curer, hypocholesterolemic and hypoglycemia. That's why, *P. ovata* may be utilized to make a variety of medicinal products as well as a safe and effective ethnobotanical cure for different health problems. A number of market preparations of Ispaghula are also available in the local market of Bangladesh. Information regarding diversified properties of *P. ovata* collected from different electronic databases (PubMed, Springer link, MDPI link, ResearchGate, Google, Google Scholar and Science Direct) have been summarized here to support the researchers to retrieve information about *P. ovata*.

Key words: Ispaghula Husk, *P. ovata* (Psyllium), gelling agent, disintegrant, suspending agent, hypoglycemia.

INTRODUCTION

Psyllium has been applied as a laxative since hoary antiquity, but novel pharmacological applications have recently been found.[1] Psyllium is a general term for legionary species of the *Plantago* genus whose seeds are commercially used for mucilage emanation. *Plantago* seed, psyllium seed or plantain seed is a refined, anhydrous, inveterate seed of *Plantago psyllium* or *P. indica* that belongs to the Plantaginaceae family. *Plantago* is a genus with around 200 species. Three principal species are *P. ovata*, *P. psyllium* and *P. indica*. These are commercially contrived in a number of European nations, the former Soviet Union, Pakistan and India. Ispaghula, the conventional denomination for *P. ovata* in India, is derived from the Persian words isapî and gholî, which mean hoss lug and relate the form of the seed. In terms of psyllium emanation and freight, India subjugates the global market.[2] The exterior seed coat of *Plantago* seeds contains 10-30% hydrocolloid, which may be divided into acidic and neutral polysaccharides and hydrolyzed to provide

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L-arabinose, D-galactose, D-galacturonic acid, L-rhamnose and D-xylose. *Plantago* gum solution is thixotropic, however, its mucilage is extremely disintegrant. The husk is the rosy-white film coverture of the seed that contains the medicinal values which is mostly used as a secure laxative, especially for wonted constipation, chronic diarrhea and dysentery. It is a spontaneous substance that is dissolvable and forms a gel in aqueous solution. *P. ovata* is usually taken in 7.5 g doses.[3,4] The present review has been done with the goal of togethering elements impacting *P. ovata* plantation, evolution, pharmaceutical and pharmacological characteristics in order to expose its usefulness as a medicinal plant.

MATERIALS AND METHODS

Various electronic databases, such as - PubMed, Springer link, MDPI link, ResearchGate, Google, Google Scholar and Science Direct were extensively searched for the review of the article.

Cultivation and growth of *p. ovata.* Ispaghula (*P. ovata* Forsk.) is a perennial herb that has recently been developed as a therapeutic plant. Medicinal plants are high in secondary metabolites and their production is genetically regulated and heavily influenced by variables of ambience.[5] Formerly, under silty-clay soil states, an experiment was conducted to assess the influence of planting dates (20th April, 5th and 20th May) and nitrogen-compost ranges (0, 50, 100 and 150 kg/ha) on evolvement, seed outturn, and seed lumping factor (mucilage content) of Ispaghula in Iran. A split-plot layout of randomized full block model with three duplicates was used in the statistical model. The major and sub-major plots were evaluated individually as the planting dates and nitrogen compost. According to the data acquired from the findings, the 5th of May was the optimal cultivating period for Ispaghula in this location and the appropriate quantity of nitrogen compost was 100 kg/ha. In addition, seed output found to have a significant favorable impact on seed lumping.[6] Similarly, Mousavi *et al.*[2] investigated the influence of sowing date and plant population on output, morphological characteristics and water utilize efficiency (WUE) of *P. ovata* in Iran a few years ago. Another experiment was conducted during the Rabi season (2006-07) to investigate the effect of moisture stress on the development, gain and efficiency of *P. ovata*. The outcomes revealed that in Ispaghula, moisture stress applied from development to bud production resulted in the highest seed output and husk percentage.[7] Likewise, the influence of several procedures on seed germination of *Descurainia sophia* and *P. ovata* obtained in 2009 from Tehran. The effect of several procedures on the germination % of two medicinal plant species was substantially variant ($p<0.05$), however pre-chilling was perhaps the most fruitful remedy on seed germination of the both species. According to the literature assessment, irrigation scheduling of native plants in semi-arid and arid regions provides a chance to maximize irrigation proficiency and water stores in water-stressed areas. Formerly, Bannayan *et al.*[1] studied the effect of water deficiency circumstances on black cumin (*Nigella sativa* L.) and Ispaghula (*P. ovata* Forsk.) plants during two growing seasons in northeast Iran. The findings revealed that all water deficit protocols resulted in a reduced yield of Ispaghula seed favored to the monitoring, although black cumin demonstrated resistance to water deficit besides when irrigation was halted during seed development. When irrigation was discontinued during the flowering period, the poorest seed production was recorded and the major yield element affected was the quantity of seeds per plant. Formerly, in Iran, researchers studied the impact of compost manure, organic fertilizers and synthetic fertilizers on the mucilage proportion, swelling index, output and chemical contents of Ispaghula seeds. The application of fertilizers had a substantial influence on any of the features studied in that research, according to the findings. Vermin-composton output (992.50 kg/ha) and mucilage (19.65%) had a greater impact than the other procedures. Utmost swelling index (22.63 mmM^3), N (0.33) and K (0.39%) concentrations, protein (1.75%) and net carbohydrate content (4.40 mg/g) were found in animal dung.[8]

Biological sources. *Plantago psyllium* is the biological origin of *Plantago* (Family-

Plantaginaceae). This tree's dried mature seeds are what it is as we use it.

Morphological features. The seed is pinkish grey to brown in color. They have a dull, mucilaginous flavor. They don't have any distinguishing odor. This tree's leaves are sessile. Pseudo-petiole refers to a thin section of the leaf near the stem. Based on the variety, leaves can be wide or narrow in form. The leaves contain 3-5 parallel veins that diverge in the leaf's broader portion. This tree's inflorescence is carried on 5-40 cm stalks. The inflorescence might be a long spike or a tall, short cone. They have small blooms that are pollinated by the breeze. They have a small root with several branches that stand or squat. Stems lack holes that are the same length as or marginally higher than the leaves. The leaves are oval in form with wide veins and dentate edges and they have longer petioles.[9,10]

Chemical constituents. Flavonoids, alkaloids, phenols, phenolic derivatives and terpenoids found in *Plantago* have various significant medicinal function. It contains 6.5% tannin, anvrtyn, emulsions and aucubin, a glycoside.[11] They also have iridoid glycosides, fatty acids and polysaccharides.[12,13] Vitamin C having therapeutic effect is considered the principal component of *Plantago*.[14] It contains 2-6.5% mucilage, which is made up of four polysaccharides.[14] Diastase, heterozeid, coloring components and pectins are all present. They include greater than 1% salicylic acid and carboxylic acids. Zinc and potassium are found as minerals.[5] They also include saponin and silicic acid. In addition to plantenolic acid, this plant's seeds include glotinic components. Adenine, choline and aeocoeine are all components of siccinic acid. The chemical constituents of *P. ovata* are shown in table 1.

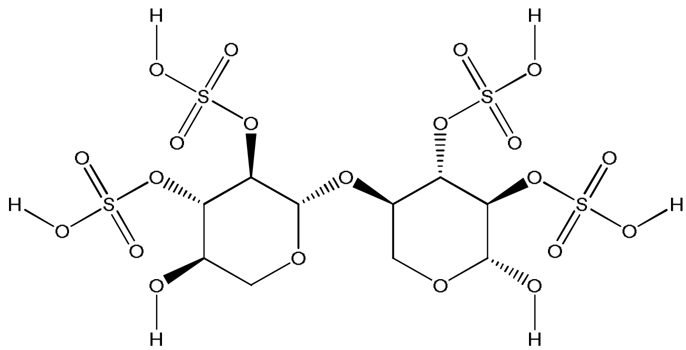
Table 1. Chemical constituents of Psyllium husk.

Contents	Name of compounds
Mucilage	Pentosan, aldobionic acid.[12]
Carbohydrate	D-xylose, L-arabinose, L-rhamnose, D-galacturonic acid.[3,4]
Soluble-insoluble sugars	Xylose, arabinose, galacturonic acid, galactose, mannose, glucose, rhamnose.[13]
Fatty oil	Linoleic acid, oleic acid, stearic acid, palmitic acid, lignoceric acid, linolenic acid.[12,13]
Amino acid	Valine, alanine, glycine, glutamic acid, cystine, lysine, leucine, tyrosine.[12]
Mineral	Calcium, magnesium, phosphorus, potassium, sodium, sulphar.[14]

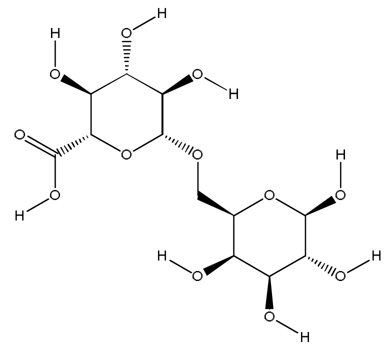
Psyllium husk includes a great percentage of hemicellulose, which consists of a xylan backbone coupled with arabinose, rhamnose and galacturonic acid portions (arabinoxylans).[13] *Plantago* species have a great effectiveness for producing a diverse range of secondary bioactive metabolites, including iridoids, phenols, polysaccharides, sterols, alkaloids and cumatines, which get use as the seed contains 35% soluble and 65% insoluble polysaccharides (cellulose, hemicellulose and lignin).[13] Because of its propensity to generate a gel in aqueous solution, psyllium is categorized as a mucilaginous fiber. This capacity stems from its function as the endosperm of the *P. ovata* seed, where it acts to hold on water and keep the seed from drying out.[15]

Seeds include a variety of bases, carbohydrates, sterols and protein. Psyllium seeds have more than 30% hydrocolloidal polysaccharide (mucilage) in the external seed coat, as well as fixed oils, tannins, aucubin glycosides (iridoid), sugars, sterols and proteins, which can be used to complement diet and as a medication to cure human ailments.[15] It is mostly made up of xylose, arabinose and galacturonic acid, with rhamnose and galactose thrown in for good measure.[9] Psyllium husk includes 6.83% protein, 0.94% ash and 84.98% total carbs. Osborne fractionation (based on solubility) provided 35.8% albumin, 23.9% globulin and 11.7% prolamin.[4]

a. Mucilage content. The mucilage from the seed husk is the functional portion. *Plantago* contains 2-6.5% mucilage. The mucilage has been split into two polysaccharide portions, pentosan and aldobionic acid (Figure 1). Cold water can solubilize one of them and produces D-xylose (46%), aldobiouronic acid (40%), L-arabinose (7%) and insoluble residue (2%); on the other hand, the other one is soluble in water at high temperature and forms an extremely viscous solution that forms a gel on reducing temperature and yields D-xylose (80%), L-arabinose (14%), aldobiouronic acid (0.3%) and a trace of D-galactose (2%), aldobionic acid produces galactouronic acid and rhamnose.[13]



Pentosan polysulfate

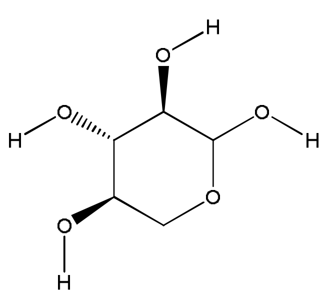


Aldobionic acid

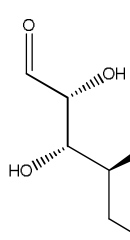
Figure 1. Chemical structures of mucilage contents.

It is believed that mucilage is accountable for the laxative activity since D-xylan polymers are not soluble in water. Compositional and methylation studies, as well as NMR spectroscopy, were used to investigate the physiologically active, gel-producing portion of the alkali-extractable polysaccharides of *P. ovata* Forsk seed husk (Ispaghula seed) and certain related incomplete hydrolysis yields. Resolving earlier scientists' contradicting assertions, the substance was discovered to be a neutral arabinoxylan (arabinose 22.6%, xylose 74%, molar basis; just traces of other sugars) with around 35% non-reducing terminal residues; extremely branched polysaccharide. The findings support a structure composed of a highly substituted principal chain of three tri-saccharide branches with the order L-Araf-a-(1-3)-D-Xylp-B (1-3)-L-Araf. The existence of this sequence is corroborated by methylation and NMR value, as well as the separation of the disaccharide 3-*O*-*β*-D-xylopyranosyl-L-arabinose as a result of incomplete acid hydrolysis of polysaccharide.[12]

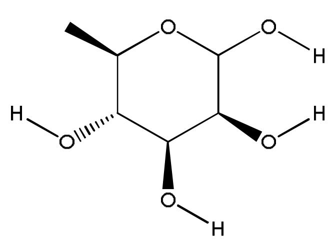
b. Total carbohydrates content. The primary polysaccharide is 14 heteroxylan, which is mostly made of (1,4) linked -D-xylose with side chains on C-3 or C-2 positions including arabinose and xylose in diverse patterns (Figure 2).[13] *Plantago* carbohydrate content has been found to be mostly D-xylose (63.6%), L-arabinose (20.4%), L-rhamnose (6.5%) and D-galacturonic acid (9.0%). Starch is found in the dehusked seed in rich amount.



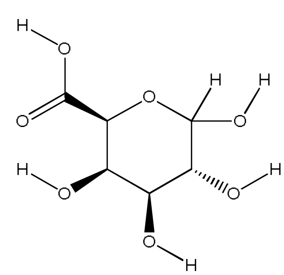
D-xylose



L-arabinose



L-rhamnose



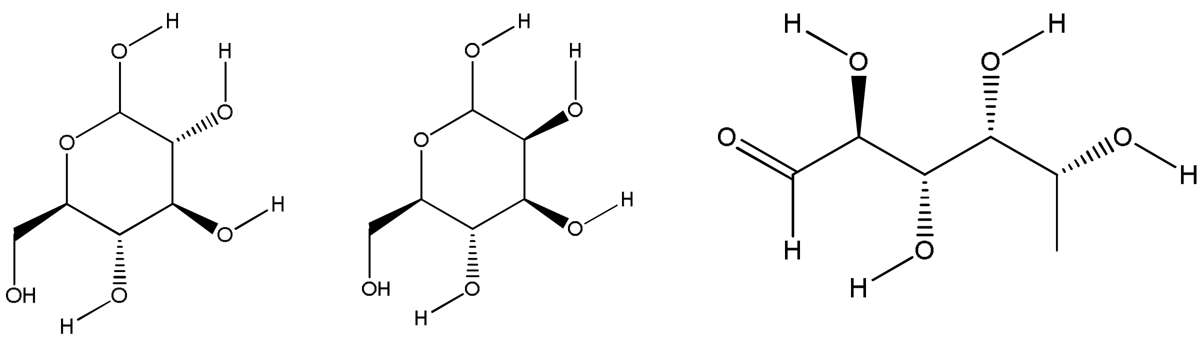
D-galacturonic acid

Figure 2. Carbohydrate contents.

Guo *et al.*[4] investigated that Psyllium husk arabinoxylan is an extremely branched polysaccharide composed mostly of xylose (74.6%) and arabinose (22.6%) on its sides, with xylose reinforcing the branches.

Arabinoxylans feature a heavily substituted 14 linked xylopyranose residue main chain. Moreover, arabinofuranose and xylopyranose residues or their small side chains are joined at various points in the principal chain of xylopyranose residues, resulting in a branching pattern.[3] The molar mass of arabinoxylans is 3,64,470 g/mol. It has a strong swelling efficiency in aqueous solution and its sugars, and it has three OH groups, which makes it much more useful. As a result, the molecule can produce tri-, di-, and mono-o-functionalized products in the form of carboxymethylated units while retaining around 35% of non-reducing terminal residues.

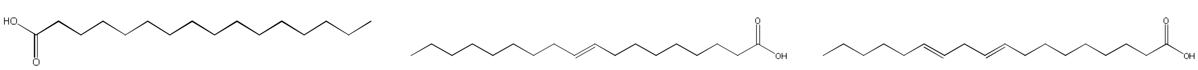
c. Soluble and non-soluble sugar contents. Xylose, arabinose, galacturonic acid, galactose, mannose, glucose and rhamnose (C6 sugars) are present in variable amounts (Figure 3).[11]



D-glucose D-mannose D-rhamnose

Figure 3. Soluble and non soluble sugar contents.

d. Fatty oil content. Over and above mucilage, *Plantago* seeds consist of a semi-drying brilliant yellow fatty oil (5%), trace levels of aucubin and tannin, as well as an active principle with acetylcholine-like activity (Figure 4). The oil contains 0.2% linolenic acid, 47.9% linoleic acid, 36.7% oleic acid, 3.7% palmitic acid, 6.9% stearic acid and 0.8% lignoceric acid.[12]



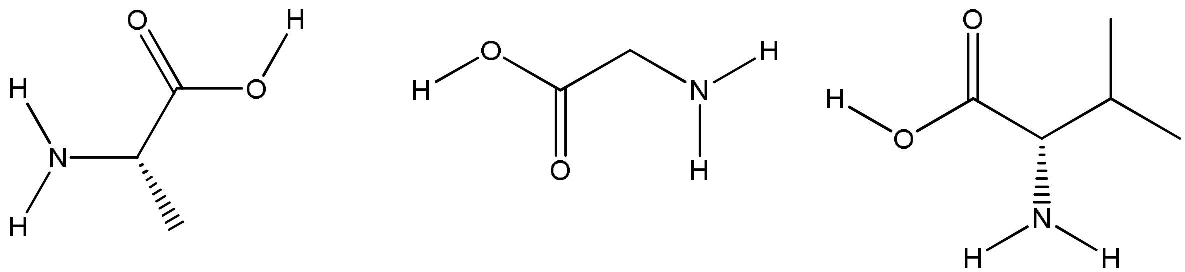
Palmitic acid Oleic acid Linoleic acid

Figure 4. Fatty oil content.

At various phases of development, Ispaghula oil included primarily six fatty acids: myristic, palmitic, palmitoleic, oleic, linoleic and linolenic acids. Myristic, palmitic, palmitoleic and linolenic acid levels declined throughout seed development but oleic and linoleic acid levels rose during seed maturity.[13]

e. Amino acids. The seed contains valine, alanine, glycine, glutamic acid, cystine, lysine, leucine and tyrosine (Figure 5).[12]

Folkloric uses. It is utilized as an antimicrobial, anti-inflammatory, anti-toxic and antihistamine. It has expectorant and diuretic properties. They're also employed as styptic and demulcent. Its leaves are used as a treatment for bug bites and mild wounds. It can also be utilized as a syrup to treat coughs and bronchitis. Hypercholesterolemia is treated using them. They lower blood glucose levels. The presence of a significant amount of phenolic compounds contributes to its antioxidant properties (flavonoid, to be precise). The existence of phenolic chemicals confers to *Plantago* the ability to protect itself from UV radiation. *Plantago*'s phenolic character confers anti-mutagenic action, as phenolic substances reduce DNA damage in the availability of free radicals.[16-18]



Alanine Glycine Valine

Figure 5. Amino acid content of Ispaghula husk.

f. Mineral content. The mineral contents of *P. ovata* husk are presented in table 2.

Table 2. Mineral contents of *P. ovata* husk.

Name of minerals	Amount (µg/g)
Calcium (Ca)	1,500
Magnesium (Mg)	150
Phosphorous (P)	140
Potassium (K)	8,500
Sodium (Na)	640
Sulphur (S)	23

Biochemical properties of *P. Ovata*. *P. ovata*'s physical and chemical qualities have been studied in the past through a number of investigations. According to Fisher *et al.*[3] it contains 22.6% arabinose and 74.6% xylose, as well as a modest amount of other sugars.[5] Similarly, Psyllium gum's physicochemical characteristics were also examined by Guo *et al.*[4] Psyllium husk was extracted using hot water (80°C) and 0.5 M NaOH, 1.2 M NaOH and 2.0 M NaOH solutions, respectively to generate a variety of psyllium gum fractions. Water extractable (WE), 0.5 M alkali extractable (AES 0.5), 1.2 M alkali extractable (AES 1.2) and 2.0 M alkali extractable (AES 2.0) psyllium gum fractions were labeled. Furthermore, the alkali extracted solutions were neutralized with 0.5 M HCl and centrifuged to create a soluble fraction (AES 0.5) and a gel fraction (AEG 0.5). To investigate the chemical components of distinct fractions, monosaccharide and methylation analyses were performed. The monosaccharide analysis indicated that the WE, AEG, and AES fractions of psyllium gum had xylose and arabinose as main ingredients but uronic acid was discovered in the WE and AES 0.5 fractions but not in the AEG 0.5 fraction, which only contains minor neutral sugars. Methylation studies revealed that WE and AEG 0.5 mostly include linked D-xylopyranosyl residues in the key chain, with side chains composed of arabinose and xylose linked to the main chain through O-3 and/or O-2 linkage. Sarfraz *et al.*[5] investigated the nutritional content and trace element content of *P. ovata* and discovered that both the leaves and seeds include a bundle of crude fibers, proteins, lipids and carbs.[19] Besides, Singh *et al.*[7] thoroughly investigated the expansion and drug release processes from hydrogels, revealing that drug was liberated from the hydrogels by non-Fickian diffusion.[20] Furthermore, Singh *et al.*[7] investigated the characterization and expanding characteristic of pH sensitive psyllium and polyacrylamide-based hydrogels in order to build a novel controlled drug delivery system for the treatment of colon cancer.[21] The structural properties of polymeric hydrogels were investigated using FTIR, SEM and TGA techniques. Swelling repercussions were also thoroughly investigated, revealing that expanding action of polymer operates as a function of temperature and time. Expanding reaction of polymer and drug release from hydrogel may be adjusted by modifying any of the above elements.

Pharmaceutical properties of *P. ovata*

Mucilage. Several researchers have investigated the application of *P. ovata* mucilage as medicinal excipients. Mucilages are the most often utilized adjuvants in various pharmaceutical formulations because of their binding, dissolving, emulsifying, film forming, suspending and enhancing capabilities and they are achieving popularity owing to their vegetal origin and inexpensive cost.[5] Kulkarni *et al.*[8] investigated the binder characteristics of mucilages from *P. ovata* and *Trigonella foenum* graecum. The mucilages were produced using a general maceration procedure and then treated to granule and tablet production at various concentrations. The results revealed that *P. ovata* has similar binding qualities to starch and 8% to 9% concentration demonstrated strong adhesion properties in uncoated tablets. [22]

Disintegrant. Super disintegrants are compounds added to tablets to aid in the breakdown of condensed mass into particles, allowing for the release of active ingredients and medication dissolution when the tablet enters the fluid environment. Because of the swelling properties of its mucilage, *P. ovata* is employed as a super disintegrant. Appropriate media permeation is the most important step towards disintegration. When media enters the tablet, the disintegrant expands and a swelling pressure occurs, causing the tablet to disintegrate. Fast disintegrating tablets (FDTs) are a new form of tablet that disintegrates/disperses or dissolves in saliva and are utilized by pediatrics, geriatrics, bedridden, intellectually challenged people with dysphagia, as well as individuals suffering from nausea, allergies, coughing and motion sickness. Many investigations on the super-disintegrant characteristics of *P. ovata* in comparison to other organic and inorganic super-disintegrants for several FDTs have been conducted. To examine the impact of three natural super disintegrants (isolated mucilage of *P. ovata*, *Hibiscus rosa-sinensis* and *Aloe vera*) in various concentrations on lisinopril oral formulation and taste masked FDTs of lisinopril were made by direct compression technique. Because of its swelling characteristic, the lisinopril oral tablet with the highest proportion of *P. ovata* mucilage had faster disintegration time of 90.26 s and a higher dissolving rate than the other two disintegrants.[23] Likewise, in another work, fexofenadine FDTs were made utilizing *P. ovata* seed powder, husk powder and mucilage as a super disintegrant, with an emphasis on their disintegration characteristics. *P. ovata* was utilized as a disintegrant at a concentration of 5% w/w. The tablets produced with *P. ovata* mucilage demonstrated improved drug solubility and bioavailability, as determined by disintegration time, which was 31, 35 and 38 s for *P. ovata* mucilage, seed and husk powder respectively.[5] A research on granisetron HCl tablets compared the impacts of organic (*P. ovata*) and synthetic super-disintegrants in different quantities (gum karaya, agar, croscarmellose, crospovidone and Indion 234) super-disintegrants.[5] The experiment concluded that when granisetron tablets were formulated with a 5% *P. ovata* as a natural superdisintegrant, the disintegration time was 15 s and the drug release rate was 99.66% in 3 minutes, clearly demonstrating natural super-disintegrants as a stronger disintegrant and having excellent dissolution characteristic than frequently utilized synthetic super-disintegrants. Furthermore, carbamazepine FDTs were made to compare the effect of natural super-disintegrants (*P. ovata*) and synthetic super-disintegrants (croscarmellose and sodium starch glycolate) on the disintegration time of FDTs and it was discovered that FDTs consisting *P. ovata* mucilage had a concised disintegration time of 9 s than synthetic ones due to its swelling characteristic.[24] Previously, the effects of natural and synthetic super disintegrants at varied concentrations (2-9%) were tested in order to generate FDTs of readily soluble tramadol HCl and poorly soluble levofloxacin. For physicochemical properties, the mix of all formulations was examined. The results indicated that tramadol HCl formulations made with mucilage of *P. ovata* and *Hibiscus rosa-sinensis* had disintegration times of 71 and 72 s, respectively, whereas levofloxacin tablets had disintegration times of 72 and 75 s. As a result, it was concluded that the solubility of natural and synthetic super disintegrants had no influence on disintegration time and wetting efficiency.[25] The impact of organic (*P. ovata* mucilage) and chemical (sodium starch glycolate, croscarmellose sodium) super disintegrants on the disintegration time and drug release profile of aceclofenac sodium (NSAID) FDTs was also investigated.[26] The greatest swelling index revealed higher disintegration characteristics of *P. ovata* mucilage. Tablets manufactured with *P. ovata* disintegrated faster than tablets formulated with sodium starch glycolate and croscarmellose sodium. Similarly, famotidine FDTs were developed to evaluate the impacts of several natural and manufactured super disintegrants and reported that *P. ovata* husk powder outperformed maize starch in terms of flow characteristics, water retention and disintegration time. Psyllium husk powder performed better as a super disintegrant than maize starch at a 10% w/w concentration.[27]

Gelling agent. Several research have been undertaken, with the primary focus being on the usage of *P. ovata* as a gelling agent. Ispaghula, as per Jain *et al.*[22], might be used as a gelling agent in a variety of tissue culture procedures and microbiological culture media. They observed the development of bacteria such as *Aspergillus flavus*, *Rhizobium meliloti* and *Penicillium chrysogenumby* on Ispaghula rather than agar. Ispaghula jelled medium enhanced the development of both bacterial and fungal species, indicating that it has high gelling characteristics.[28] In addition, Sahay[23] expanded on the usage of *P. ovata* mucilage husk as an alternate jelling agent. He employed 4% w/v pulverized husk in conjunction with 0.5% w/v agar medium to enhance microbe growth, although he had previously eradicated unwanted qualities of psyllium-gelled media by giving UV treatment, oven sterilization and autoclaving.[5]

Suspending agent. Due to its mucilage-forming ability, many research have been done to examine the usage of *P. ovata* as a suspending agent. Mucilages from various plants, according to Sarfraz *et al.*[5], can be utilized to suspend molecules in thermodynamically unstable systems, avoiding particle sedimentation and promoting simple dispersion of settled granules to their viscous and colloidal character.[5] Furthermore, they tested Ispaghula mucilage powder as a suspending agent by preparing a suspension with a standard medicine, nimsulide and comparing the suspending capabilities of the mucilage powder to one of the marketed products. Several formulations were created and studied for 7 days to assess particle sedimentation and settling rate. All preparations demonstrated well shear thinning qualities of the suspension and particles were evenly distributed except the formation of any deposits, indicating the characteristic of Ispaghula mucilage powder as an efficient suspending agent in various oral formulations. Rao *et al.*[8] studied the rheological characteristics of psyllium seed husk as a suspending agent as well.[29] Various amounts of psyllium polysaccharide (PPS) mucilage were synthesized and a suspension was created utilizing the common medication paracetamol. The rheological characteristics of various suspensions were investigated and compared to the common suspending agent carboxymethyl cellulose. The results demonstrated that Psyllium polysaccharide (PPS) mucilage has significant potential for usage as a suspending agent in various preparations. Bashir *et al.*[24] recently extracted arabinoxylan from *P. ovata* seed husk by alkali extraction and compared its capabilities as a suspending agent with bentonite using a 1% zinc oxide solution. Arabinoxylan created a stable, extremely flocculated solution that met all particle size standards and microbiological qualities; hence, it was noted that arabinoxylan was used as an efficient suspending agent in ZnO suspension.[30]

Pharmacological properties of *P. ovata*

Wound healing activity. Singh *et al.*[28] investigated the wound curing efficacy of an ethanolic extract of *P. ovata* seeds.[31] In compared to typical *Aloe vera* ointment (10% w/w), the extract was utilized as an ointment (10% w/w in petroleum jelly base) to treat the wound in the minimal feasible period with little ache, suffering and scarring to the patients. Albino rats were used in that study and surgical intervention was used to create wounds under sterile settings. Acute dermal toxicity was tested and an effective dosage was chosen for wound curing. A lesion's curing is followed by wound contraction, which is defined by the organization of healthy skin next to the lesion to conceal the exposed region. The findings revealed that ethanolic extract considerably raised the % wound contraction, resulting in improved wound curing.

Anti-diarrheal and anti-constipation activity. Mehmood *et al*.[26] investigated the antidiarrheal and anti-constipating properties of *P. ovata*.[32] In this study, a crude extract of *P. ovata* at a concentration of 100-300 mg/kg exerted a laxative effect in mice via muscarinic and 5-HT receptor activation. While, at 500-1000 mg/kg dosage, extract demonstrated gut inhibitory (anti-secretory/anti-diarrheal) effect in mice via blocking calcium ion channels and activating the NO cyclic guanosine monophosphate pathway. Similarly, in Guinea pig ileum, a crude extract at 10 mg/mL stimulated the muscarinic serotonin receptors, resulting in an anti-constipating action. Similarly, 10 mg/ml crude extract stimulated the stomach accompanied by relaxation in isolated rabbit jejunum by activating muscarinic and serotonin receptors. Another randomized parallel double blind trial compared the feces softening effectiveness of psyllium hydrophilic mucilloid (5.1 mg bid) to docusate sodium (100 mg bid) and the psyllium enhanced the feces water content (up to 2.3%) and feces water weight (84 g/BH). The frequency of bowel movements was likewise much higher with psyllium compared with docusate. As a result, psyllium outperforms docusate in the cure of persistent constipation.[33]

Hypocholesterolemic activity. Sarfraz *et al.*[5] investigated the efficacy of Ispaghula husk (psyllium) as a dietary supplement in hypercholesterolemic individuals.[34] Similarly, a placebo-controlled double-blind study including 340 individuals aged 18 to 65 with light to severe hypercholesterolemia found that Ispaghula (7 g/day for 6 months) when combined with diet resulted in an 8.7% drop in LDL cholesterol level (4.1-0.42 mM/L). Total cholesterol levels were lowered by 7.7-8.9%. According to another study, psyllium binds with bile acids in the intestinal lumen & decreases blood cholesterol levels.[35] *P. ovata* has been shown to significantly lower total cholesterol and LDL cholesterol in rats[5,22] and in humans as well.[5,36] Furthermore, another research has revealed that consuming 5.1 g of psyllium husk twice each day for eight weeks results in a 3.5% drop in total cholesterol and a 5.1% deducting in LDL levels.[37]

Anti-inflammatory activity. When tested in HLA-B27 transgenic rats, psyllium was found to reduce inflammatory mediators associated with the intestinal inflammatory methods, such as NO, leukotriene B4 and TNF, suggesting its usage as an intestinal anti- inflammatory drug.[33,38]

Hypoglycemic activity. Siavash *et al.*[34] investigated whether psyllium successfully lowers plasma glucose levels in type 2 diabetes by decreasing gastrointestinal carbohydrate absorption.[29] It has been discovered that an aqueous extract of *P. ovata* husk subdues postprandial glucose in blood and slows small intestinal absorption except provoking sucrose influx into the large intestine, implying that *P. ovata* may be a vital source of active phytochemical components that could open up new avenues for diabetes treatment. Similarly, 5.1 g bid. of psyllium (*P. ovata* Forsk.), a natural soluble fiber supplement, has been studied as an adjuvant to dietary treatment in individuals with type II diabetes to lower glucose with great sufferance.[39] Former research has shown that psyllium dietary fibers have been widely utilized as pharmaceutical supplements and food additives in processed foods to aid in weight control with the goal of regulating glucose levels in diabetic patients and lowering blood lipid ranges in hyperlipidemias.[33]

Influence on autonomic gastrointestinal disorder. Psyllium husk can be utilized to treat

Parkinson's disease that is accompanied by autonomic GI dysfunction caused by anticholinergic medications. Levodopa was extracted and analyzed using HPLC from rabbit plasma samples that had been collected and centrifuged. In rabbits treated for 7-14 days, oral administration of levodopa and carbidopa (20:5 mg/kg), biperiden (100 g/kg), and Ispaghula husk at two distinct dosages of 100 and 400 mg/kg resulted in 50% greater AUC values and higher C_{max} values. As a consequence, when combined with levodopa/carbidopa, *P. ovata* husk improves the pharmacokinetics of levodopa and resulting in more stable plasma concentration, avoiding the 'wearing off' phenomena and delaying the beginning of dyskinesia.[38]

Table 3. Ispaghula husks' produced in Bangladesh by different pharmaceutical companies.

Company	Brand name	Pack size	Indications	Side effects
Popular Pharmaceuticals Ltd.	Laxgel	120 gm container	Constipation, raised levels of cholesterol, hemorrhoids or piles, irritable bowel syndrome (IBS), reduces blood glucose level	Flatulence, abdominal distension, gastro-intestinal obstruction
Radiant Nutraceuticals Ltd.	Radigel	3.5 gm sachet	Constipation, raised levels of cholesterol, hemorrhoids or piles, irritable bowel syndrome (IBS), reduces blood glucose level	Flatulence, abdominal distension, gastro-intestinal obstruction
Aristopharma Ltd.	Fibosyl	120 gm container	Constipation, raised levels of cholesterol, hemorrhoids or piles, irritable bowel syndrome(IBS), reduces blood glucose level	Flatulence, abdominal distension, gastro-intestinal obstruction
Square Pharmaceuticals Ltd.	Ispergul	3.5 gm sachet	Constipation, ulcerative colitis, hemorrhoids, hyperlipidemia	Flatulence
Incepta Pharmaceuticals Ltd.	Fiberlax	130 gm container	Constipation, chronic constipation, pregnancy induced constipation	Intestinal obstruction, fecal impaction
The ACME Laboratories Ltd.	Fecilax	100 gm container	Constipation, piles or hemorrhoids, bowel regulation, bedridden patients	Allergic reactions, loss of electrolytes
The Ibn Sina Natural Medicine	Ispaghula	4 gm sachet	Constipation, IBS, piles, hyperlipidemia	Intestinal obstruction, Fecal impaction
Hamdard Laboratories Bangladesh	Ispaghol	3.5 gm Sachet	Constipation, ulcer, dysentery, piles	Intestinal obstruction, fecal impaction
Universal Food Ltd.	Tasty Ispaghula Husk	2 gm sachet	Constipation, ulcer, piles	Intestinal obstruction, fecal impaction
Shezan International Ltd.	Pure Isobgul Bhushi	20 gm sachet	Piles, diarrhea, dysentery, diabetes, colon cancer, IBS, weight loss	Flatulence, abdominal distension, gastro-intestinal obstruction
Drug International Ltd.	Laxadil-EP	3.5 gm sachet	Constipation, irritable bowel syndrome (IBS), hemorrhoids or piles, reducing blood cholesterol and glucose	Flatulence, abdominal distension, gastro-intestinal obstruction
Sajeeb	Sajeeb Pure Psyllium Husk	25 gm sachet	Chronic constipation such as piles, fissures and fistulas.	Stomach cramping, allergic reactions

Treatment of metabolic disorders. In a study, obese Zucker rats were fed a diet containing 3.5% *P. ovata* husk for 25 weeks. The outcomes showed that this diet prevents numerous metabolic abnormalities such as obesity, dyslipidemia, hypertension and endothelial dysfunction and leads to lower body weight gain, decreased endothelium dependent relaxation I and react to acetylcholine and *P. ovata* ingestion reduces plasma concentrations of adiponectin and TNF–α.[39,40] Furthermore, a six-month research using psyllium fiber supplementation effectively decreased both systolic and diastolic blood pressure in hypertensive people with obesity.[41] Furthermore, lowering serum LDL cholesterol levels by limiting saturated fat intake is a well-established method of lowering the risk of cardiovascular disease (CVD). Epidemiological studies have suggested that a diet high in water soluble fibers like psyllium efficiently decreases blood LDL cholesterol levels while having no effect on HDL cholesterol or triacylglycerol concentrations, hence lowering the risk of CVD.[42]

Other pharmacological actions. *P. ovata* seeds' water soluble polysaccharide had a substantial and significant influence on the physiology of keratinocytes and fibroblasts.[18] Furthermore, *P. ovata* has cytotoxic properties, implying that it might be used to treat several forms of cancer.[43] Furthermore, *P. ovata* has antimicrobial properties. Bokaeian *et al*.[41] investigated the antibacterial activity of *P. ovata* seed extract-derived silver nanoparticles against antibiotic-resistant *Staphylococcus aureus*. The findings demonstrated that silver nanoparticles derived from *P. ovata* seed extract has antibacterial activity against *S. aureus* resistant to cefixime, trimethoprim-sulfamethoxazole and penicillin.

Market preparations of Ispaghula in Bangladesh. In Bangladesh many pharmaceutical companies manufacture Ispaghula husk in different pack size with different indications. These are summarized in table 3.

CONCLUSION

P. ovata has effective pharmaceutical characteristics such as superdisintegrant, binder, gelling agent, suspending agent and can be extensively applied in the formulation of FDTs, suspensions, oral gels and it also has spiffy pharmacological characteristics such as wound curing, anti-diarrheal, anti-constipation, hypocholesterolemic and hypoglycemic characteris-tics. Because of the aforementioned citable characteristics, *P. ovata* can be utilized in the development of novel drug delivery systems employing commencing techniques and can be formulated into a protective, fruitful and cost-effective drug devoid of the adverse events followed by synthetic drugs for the cure of a variety of diseases.

Authors' contribution

MSA has conceived the original idea. KS, MRT, SA, SF and TA extensively consulted the literatures. KS, FA, MSA prepared the initial manuscript and arranged the reference section. JAC, AAC and SK critically reviewed the overall activities. MSA supervised the whole activity. All the authors read the review article meticulously and agreed to submit the article.

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Conflict of interest

There is no conflict of interest according to the authors.

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