REVIEW ARTICLE

Aspaghol (Plantago ovata Forssk.): A Scoping Review of Unani Concepts, Multi-Omics Profiling and Pharmacotherapeutics

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Abstract

Background: *Aspaghol* (Plantago ovata Forssk.) is a medicinal herb renowned for its extensive therapeutic application in the Unani System of Medicine (USM). While the seed husk is primarily recognized as a source of dietary fiber and bulk laxative, there is growing emphasis on its broader pharmacological profile, exhibited by various parts of this plant.

Aim: This review aims to integrate the medicinal applications of *Aspaghol* within USM, its multi-omics profiling, and a comprehensive evaluation of pharmacological actions.

Materials and Methods: Classical Unani literature was systematically examined alongside electronic databases, including PubMed and Google Scholar, for relevant studies available from January 2015 to February 2026. Unani terminology was standardized in accordance with WHO guidelines, while plant taxonomy was verified using the World Flora Online Plant List.

Results: In USM, Aspaghol is characterized as possessing cold and moist temperament. It is also utilized in managing conditions such as *Zaḥīr (*Dysentery), *Saḥj-o-Qurūḥ-i-Am'ā'* (intestinal abrasion), *Rabw* (bronchial asthma), *Sarsām* (meningitis), *Khafqān* (palpitation), *Niqris* (gout), and *Ḥummā al-Ḥādda* (acute fever), among others. Parallelly, evidence from recent meta-analyses establishes its efficacy in managing metabolic syndrome, specifically hyperglycemia, hypercholesterolemia, hypertension, and obesity. Concurrently, data from multi-omics studies have identified a rich array of bioactive phytoconstituents across different plant parts, including luteolin, kaempferol, and phenylethanoid glycosides, alongside the development of a reference genome to elucidate their molecular mechanisms.

Conclusion: *Aspaghol* remains a versatile drug for managing gastrointestinal and extra-gastrointestinal ailments. By synergizing Unani clinical wisdom with contemporary omics driven insights, this review establishes a robust molecular framework for validating these time-honored indications through a reverse pharmacology paradigm, potentially accelerating the transition from ancient empiricism to evidence-based medicine.

Keywords: *Aspaghol*; *Plantago ovata*; Psyllium husk; Unani medicine; Omics studies; Phytopharmacology

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Introduction

Aspaghol (*Plantago ovata* Forssk.), commonly known as psyllium, is an annual herbaceous medicinal plant belonging to the family Plantaginaceae.[1] Characterized by its distinctive texture and temperate distribution, it typically grows 30 to 45 cm tall with narrow lanceolate leaves and flowering shoots, as shown in Figure 1.[2] The therapeutic prominence of *Aspaghol* lies in its seeds, which are extensively utilized due to their unique properties. Specifically, the outer coat of the seed, the epidermis, known as husk, mainly contributes to its widespread therapeutic potential.[3] The medicinal utility of *Aspaghol* can also be explored within the Unani system of medicine, which is increasingly recognized as an integrative approach alongside conventional treatments due to its holistic perspective.[4]

In USM, *Aspaghol* (*P. ovata*) derives its name from the Persian term 'asp', meaning *horse*, and 'ghol', meaning *ear*, referring to the characteristic resemblance of the seed to a horse's ear.[5,6] Its profound therapeutic properties are meticulously detailed within the celebrated works of eminent Unani physicians, serving as a testament to its rich heritage. Distinguished luminaries, including *Avicenna* (980–1037 AD), *Ibn al-Bayṭār* (13th century AD), *Najmul Ghanī* (19th century AD), and *Kabīruddīn* (20th century AD), have extensively documented its classical Unani pharmacological actions, including *Mulayyin* (laxative), *Murattib* (moistening agent), and *Mubarrid* (cooling agent), etc., within their revered treatises.[6-9]

Beyond its historical use, the therapeutic significance of *Aspaghol* is further emphasized by its rigorous documentation in global pharmacopoeias and other regulatory bodies, reflecting an established safety profile. It is officially recognized by the United States Pharmacopoeia (USP), the European Medicines Agency (EMA), and the Canadian Natural Health Product Monograph.[10-12] Furthermore, it is also

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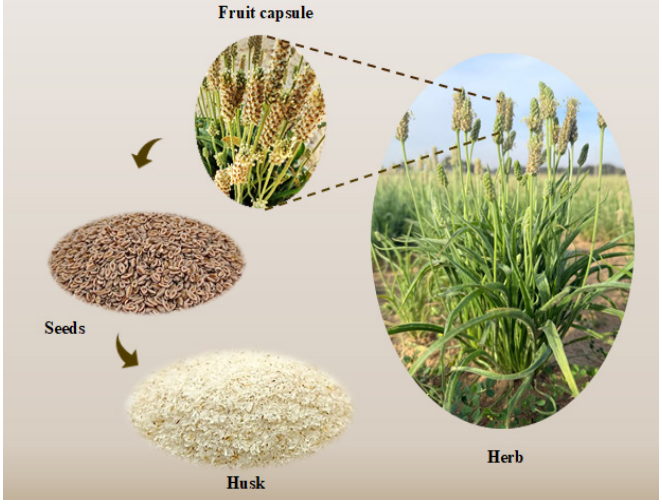


Figure 1: Morphology of *Aspaghol* (*Plantago ovata* Forssk.)

included in the British Herbal Pharmacopoeia (BHP), Indian Pharmacopoeia (IP), and the Unani Pharmacopoeia of India (UPI).[13-15] Notably, the U.S. Food and Drug Administration (FDA) recognizes its husk as a non-digestible dietary fiber, recommending a daily intake of ≥7 g to reduce the risk of coronary heart disease.[16]

The functional benefits of *Aspaghol* (*P. ovata*) are primarily attributed to its exceptionally high fiber content, which constitutes approximately 30% of the total seed weight, the highest reported within the genus *Plantago*.[17] The husk-derived mucilage is a highly branched, hydrophilic polysaccharide valued for its high viscosity, gelling capacity, and biocompatibility.[18-19] Beyond its established role as a bulk-forming laxative and dietary fiber supplement, it is widely employed across the nutraceutical, pharmaceutical, and other industrial sectors. Furthermore, recent advances in multi-omics profiling, including genomics, transcriptomics, and metabolomics, are unraveling its diverse pharmacological potential, as exhibited by different plant parts beyond the seed. Parallel evidence in managing metabolic dysregulations, gastrointestinal disorders, and cardiovascular risk factors has also been established. Complementing these findings, this review systematically integrates traditional Unani knowledge with contemporary evidence-based data to provide a holistic perspective of *Aspaghol* (*P. ovata*), delineating its potential for rational therapeutic development and clinical translation.

Methodology

A scoping review was undertaken to integrate the traditional Unani concepts, therapeutic applications, phytochemical composition, multi-omics evidence, and contemporary pharmacotherapeutic findings related to *Aspaghol* (*P. ovata* Forssk.). The process of review comprised two independent phases: (i) systematic examination of classical Unani literature and (ii) electronic retrieval and screening of contemporary scientific literature.

Classical Unani literature

A systematic manual search of major classical Unani texts was conducted to retrieve information concerning the *Mizaj* (temperament), actions, therapeutic applications of *Aspaghol*. Urdu translations of different compendia including *Al-Qānūn fi'l Ṭibb* by Avicenna (980–1037 AD), *Al-Ḥāwī fi'l Ṭibb* by Rhazes (10th century AD), *Al-Jāmi' li Mufradāt al-Adwiya wa'l-Aghdhiya* by *Ibn al-Bayṭār* (13th century AD), *Khazā'in al-Adwiya* by *Najmul Ghani* (19th century AD), *Muḥīṭ-i-A'ẓam* by *A'ẓam Khān* (19th century AD), and *Makhzanul Mufradat* by *Kabiruddin* (20th century AD) were consulted. Unani terminology was defined in accordance with the WHO International Standard Terminologies on Unani Medicine.

Electronic Literature Search

A comprehensive electronic search was conducted primarily in PubMed and Google Scholar, while additional relevant publications were identified through targeted searche of ScienceDirect and Semantic Scholar. The search covered publications from January 2015 to February 2026, and the search was conducted between July 2025 and February 2026. Keywords included *"Aspaghol," "Plantago. ovata," "psyllium husk," "seed mucilage," "omics," "genomics," "transcriptomics," "metabolomics," "clinical trials," "pharmacological activity,"* and *"regulatory status."* These terms were combined using Boolean operators (AND/OR), with relevant Medical Subject Headings (MeSH) and other controlled vocabulary where applicable. Appropriate truncation and phrase searching were also used to enhance precision of literature search. Botanical identity and nomenclature were verified using the World Flora Online Plant List (https://wfoplantlist.org/), while chemical structures were sourced from PubChem database.

Inclusion criteria

Studies were considered eligible when they met the following criteria:

- Studies investigating *P. ovata* Forssk. or its recognized medicinal materials, including seeds, seed husk, mucilage, leaves, aerial parts, roots, or other clearly identified plant parts.
- Scientific literature published from January 2015 to February 2026.
- Articles published in English language.
- Studies relevant to phytochemical composition, omics investigations, and pharmacological activities relevant to the medicinal use of *P. ovata*.
- Relevant *in-vitro* and *in-vivo* preclinical studies, along with meta-analyses evaluating clinical outcomes of *P. ovata*, were considered.

Exclusion criteria

Records were excluded when they met one or more of the following criteria:

- Studies involving plant species other than *P. ovata* or studies in which the identity of the investigated plant material could not be established.

- Publications outside the predefined period of January 2015 to February 2026.
- Articles published in languages other than English.
- Reports that could not be retrieved in full text after reasonable retrieval attempts.
- Articles focused exclusively on unrelated agricultural, ecological, taxonomic, or non-pharmacotherapeutic aspects of *P. ovata* without relevance to the predefined review objectives.

The review was conducted and reported in accordance with the Preferred Reporting items for Systematic Reviews and Meta-Analysis Extension for Scoping Review (PRISMA-ScR) guidelines. A systematic PRISMA-ScR flow diagram illustrating the literature identification, screening, eligibility assessment, and inclusion process in presented in Figure 2.

Results

The Unani Concepts

Vernacular names

Arabic: *Bazr Qatuna*; Persian: *Aspiyoos, Aspghol*; Urdu: *Aspaghol*; English: Spogel seeds; Gujarati: *Isapghol, Ghodajeeru*; Hindi: *Isubgol*.[5,6,20-25]

Mizaj (Temperament)

In USM, the concept of *Mizaj* (Temperament) serves as the foundational framework for understanding drug action, representing the unique qualitative profile that emerges from the interaction of a substance's primary elements.[26] When a drug is administered to the body, it undergoes a metabolic transformation triggered by *Ḥarārat Gharīziyya* (Innate heat) and *Akhlāṭ* (Humours), resulting in physiological shifts toward either heat, coldness, moisture, or dryness. These pharmacological effects are precisely measured through a four-degree potency scale: while the first-degree drugs slightly influence bodily conditions, fourth-degree substances are highly potent, capable of causing significant physiological disturbances or even fatal outcomes if not strictly regulated.[27,28]

In classical Unani literature, the drug *Aspaghol* is consistently described as possessing *Mizāj-i-Bārid wa Raṭb* (Cold and moist temperament), though the degree of these qualities varies slightly across sources. It is most commonly characterized as being cold in third degree and moist in second degree, while some descriptions denote it as cold in second degree and moderate in dry and wet properties or cold and moist in second degree.[5,7,8,15,21,29] In other accounts, it is regarded as cold and moist in the third degree or cold in the third degree with slight moistness.[5,6,22] Collectively, these descriptions indicate that *Aspaghol* possesses a predominantly cold and moist temperament, generally ranging between the second and third degree of intensity. A drug possessing variations in its potency is often attributed to different cultivation techniques and geographical habitats.

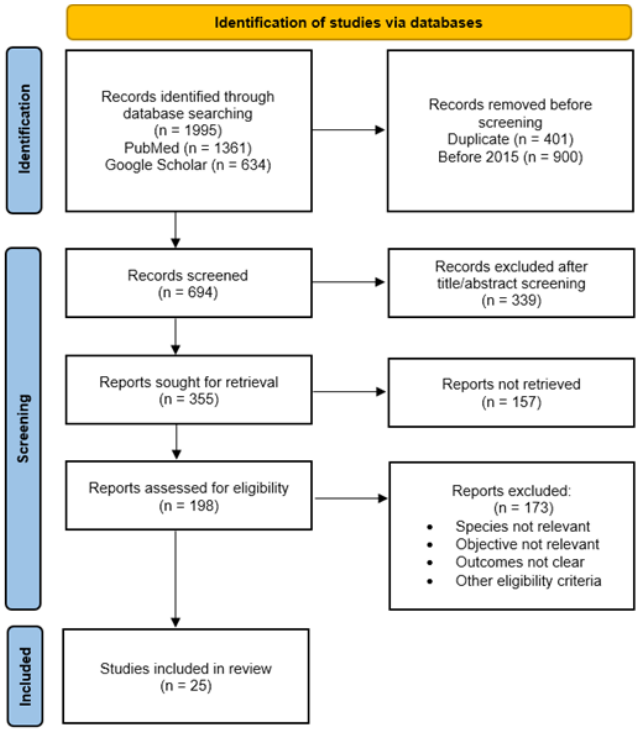


Figure 2: PRISMA flow diagram

Af'āl (Action)

The drug *Aspaghol* has been found to exhibit a diverse pharmacological profile. This includes *Mulayyin* (Laxative/softener: an agent which relieves constipation), *Mugharrī* (Glueing agent: mucilaginous drugs which produces stickiness), *Musakkin-i-Bukhār* (Febrifuge: an agent that lowers body heat), *Musakkin-i-Aṭash* (An agent which lowers thirst), *Muḥallil-i-Awrām-i-Ḥārra* (Resolvent: an agent which resolves acute inflammatory swellings), *Musakkin-i-Awrām-i-Ḥārra* (Soothing agent), *Mudirr-i-Bawl* (Diuretic: an agent that increases excretion of urine), *Munaqqī* (Cleanser: an agent that cleanses morbid matter from an organ), *Muraṭṭib* (Humidifying: an agent that generates moisture), *Qābiḍ* (Astringent: an agent that causes contraction of body tissues and lumen), *Mudammil-i- Qurūḥ* (Vulnerary: an agent that helps in process of wound healing and scar formation).[5-9,20-22]

Mawaq-e-Istemal (Therapeutic applications)

The drug's broad therapeutic profile is predominantly driven by the dense mucilaginous content found within its seed husk. The seeds release a substantial amount of mucilage after soaking in water, which, when consumed, imparts *Mulayyin* (Laxative), *Muraṭṭib* (Moistening), and *Mubarrid* (Cooling) effects. In contrast, seeds roasted in oily media such as *Roghan Gul* (Rose oil) or *Roghan Banafsha* (Violet oil) predominantly exhibit *Qābid* (Astringent) action instead. This apparent paradox is explained by the transformation of the *Muzliq* (Lubricating) property of the mucilage into a *Mugharrī* (Glueing or binding) property upon heating, thereby diminishing its laxative potential while enhancing its

astringent effect. The soothing action of the mucilage also renders it beneficial in the management of *Ishāl* (Diarrhea), particularly when it occurs as a secondary reaction following the administration of *Mushil* (Purgative) agents. Moreover, when the seeds are bruised or ground, they exhibit a distinctive *Muḥallil* (Resolvent or Anti-inflammatory) effect, which is attributed to the degree of inherent heat possessed by the dehusked seed.[5,6,21] A summary of the major clinical applications is detailed in Table 1.

Maḍarrat (Adverse effects) and their correctives

Excessive or improper use of *Aspaghol* is often associated with notable adverse outcomes. This includes *Muḍ'if A'ṣāb* (Nervine depressant), *Qaṭi' Ishtihā'* (Anorectic: an agent that lowers appetite), and *Muḍ'if A'ḍā' Ra'īsa* (Functional debilitative of vital organs). It is strictly contraindicated during *Ḥaml* (Pregnancy). Consuming crushed or bruised seeds in high doses (up to 30 g) can lead to fatal toxicity. Individuals with *Balghamī al-Mizāj* (Phlegmatic temperament), or those suffering from *Sū' al-Haḍm* (Indigestion/Dyspepsia) and a flatulent abdomen, must abstain from its use as symptoms may get aggravated. These adverse effects can be effectively ameliorated through the use of *Musleh* (Corrective agents). With *Asl* (Honey), primarily endowed with a *Mizāj-i-Ḥār Yābis* (Hot and dry temperament), serves as an ideal counterbalancing agent, neutralizing the excessive coldness and moisture. Additionally, *Sikanjabīn* (Oxymel: a mixture of honey and vinegar) and *Sattu* (Roasted wheat

Table 1: Therapeutic uses of *Aspaghol* as per Unani literature

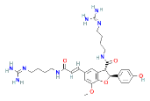
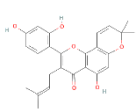
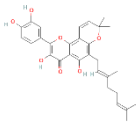
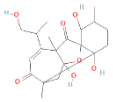
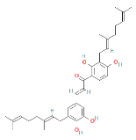
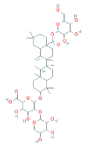
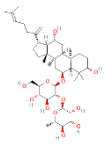
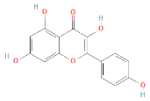
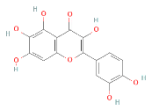
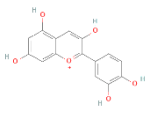
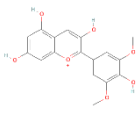
Organ system	*Therapeutic indications*	*Mode of Application / Administration*	*Ref.*
Dermatological disorders	*Ḥumra* (Erysipelas), *Jamra* (Carbuncle), *Namla* (Herpes)	Applied topically as poultice; prepared by mixing seeds with *Sirka* (Vinegar), and *Roghan Gul* (Rose oil).	5,6,20
	Skin lightening and complexion enhancement	Applied as scrub by rubbing bruised seeds over the body.	5,6,20
	Dry and split, hair strengthening and smoothness	Applied locally as mucilage blended with *Sirka* (Vinegar).	5,6,21
Gastrointestinal Disorders	*Bawāsīr Dāmiya* (Bleeding piles)	Administered orally as mucilage mixed with sugar.	5
	Waram-i-Mi'da (Gastritis), *Qūlanj* (Colitis), *Qabḍ* (Constipation)	Administered orally as mucilage mixed with *Roghan Badam* (Almond oil) or *Roghan Banafsha* (Violet oil).	5-7
	Zaḥīr (Dysentery), *Saḥj-o-Qurūḥ-i-Am'ā'* (Intestinal abrasions and ulcers)	Administered orally as mucilage or raw seeds roasted in *Roghan Gul* (Rose oil).	5,6,20
	Ishāl Safrāwī (Bilious diarrhea)	Administered orally as raw seeds roasted in *Roghan Gul* (Rose oil).	5,6
Respiratory Disorders	*Rabw* (Bronchial asthma)	Administered orally as raw seeds.	6
	Sual Yābis (Dry cough), *Khushoonat Ḥalaq wa Qasbat-ur-Riyah* (Dryness of throat and trachea)	Administered orally as mucilage mixed with *Roghan Badam* (Almond oil).	5,6,20,21
Nervous System Disorders	*Sarsām* (Meningitis)	Administered orally as mucilage mixed with *Julaab* (Rose syrup) or *Sikanjabeen* (Oxymel) and *Nabaat Safed* (Rock candy).	5,6
	Ṣudā' Ḥārr Sāda (Headache)	Applied topically as poultice over forehead; prepared by grounding seeds in *Sirka* (vinegar) mixed with *Roghan gul* (Rose oil) and *Roghan banafsha* (Violet oil).	5.7
Cardiovascular Ailments	*Khafaqān Ṣafrāwī* (Bilious palpitation)	Administered orally as mucilage mixed with *Arq Bedmushk* (Distillate of Musk geranium).	5,6
Musculoskeletal disorders	*Waja' al-Mafāsil Ḥār* (Acute Arthralgia), *Niqris* (Gout)	Applied topically as poultice; prepared by boiling seeds with rind of opium fruit.	5-7,21
Disease of Ear, Nose & Throat	*Ru'āf* (Epistaxis)	Applied topically as poultice over the temporal region; prepared by grounding seeds in *Sirka* (Vinegar).	6
	Waja' al-Udhun (Otalgia)	Instilled as ear drops; prepared by mixing mucilage with fresh onion juice.	6
Genitourinary disorders	*Qeela Mā'iya* (Hydrocele)	Applied topically as poultice over the scrotal region; prepared by grounding seeds in water.	5
	Sozish-e-Bawl (Burning micturition), *Mudirr-i-Bawl* (Diuretic), *Suzāk* (Gonorrhea)	Administered orally as mucilage mixed with sugar	6
Others	*'Aṭash Mufriṭ* (Excessive thirst)	Administered orally as mucilage mixed with *Roghan Badam* (Almond oil).	5,7
	Ḥummā al-Ḥādda (Acute fever)	Administered orally as mucilage.	5-7

Table 2: Overview of multi-omics profiling in *P. ovata*

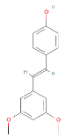
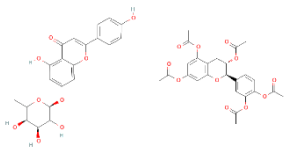
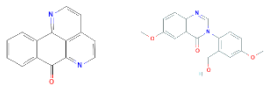
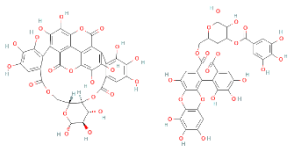
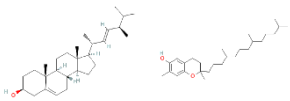
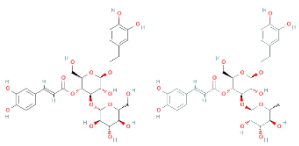
Study Type	*Parts Used*	*Extraction Technique*	*Analytical Method*	*Outcomes*	*Ref.*
Genomic study	Leaves	QIAGEN Genomic-tip anion-exchange chromatography	PacBio long-read sequencing + Hi-C scaffolding; transcript-assisted gene model annotation	Chromosome-level genome assembly (4 chromosomes); identified mucilage biosynthesis genes; established reference genome for functional and breeding studies.	39
	Leaves and ovules	Total RNA extraction using TRIzol reagent	qRT-PCR, UV–Vis Spectrophoto-metry	Five genes linked to arabinoxylan synthesis were identified and quantified at different stages of seed development	40
Transcriptomic study	Ovary	Total RNA extraction using TRIzol reagent	Illumina RNA-Seq (de novo assembly with Velvet & Oases), qRT-PCR	Generated 46,955 transcripts and identified genes related to mucilage biosynthesis, secondary metabolites, and antioxidants.	36
	Stem	Total RNA extraction using TRIzol reagent	RNA-Seq, cDNA cloning & sequencing, phylogenetic analysis	PoIRX10 and PoGT61 transcripts identified involved in synthesis of Xylan backbone synthesis and Xylan side-chain branching	41
Metabolomic study (Non-targeted)	Leaf	Ultrasonic-assisted extraction using 70% aqueous methanol	LC–MS	Flavonoids: Luteolin, quercetagetin, kaempferol, syringetin, limocitrin, catechin/epicatechin/pavetannin B2, helilupolone, dorsmanin,	1
				Anthocyanidin & Carotenoids: Cyanidin, malvidin, rhodopin/ OH-lycopene	
				Phytoalexin: Pterostilbene	
				food-flavoring agent : 2-phenylethanethiol,	
				Phenylpropanoid: Coriandrin	
	Seed			Alkaloid: Lunamarine, hordatine B	
				Flavonoid : Prorepensin, morusin/kuwanon B/cyclomulberrin, dorsmanin	
				Terpene: Cinncassiol C, ampeloside Bf2, prosapogenin, spinasaponin A, medicagenic acid	
				Triterpene saponin : cynarasaponin H,	
				Phytoalexin: Pterostilbene	
				Food-flavoring agent: 2-phenylethanethiol,	
				Phenylpropanoid: Coriandrin	
	Husk			Alkaloid: Pinidine,	
				Triterpene saponin: cynarasaponin H,	
				Triterpene: narasin B, ginsenoside Rg6, periandrin I	
				Others: Sarmentine, purmorphamine, tapentadol, zolmitriptan, withaperuvin.	
	Fruit capsule	Ultrasonic-assisted extraction using 70% aqueous methanol	LC–MS	Flavonoids: Apigenin 7-rhamnoside, kaempferol diacetylrhamnoside, Catechin pentaacetate, Myricetin tetramethyl ether. Alkaloid: Sampangine, Dictyoquinazol C Phenolic acid: Caffeoylquinic acid Phenylpropanoid: Syzyginin B Phytosterol: Brassicasterol Anthocyanin: Cyanidin coumaryl glucoside Ellagitannin: Punicalin	42
Metabolomic study (Targeted)	Roots	Methanolic extract	HPTLC	Phenylethanoid glycosides: Acteoside , Plantamajoside	43
	Seed	Solvent extraction using pet. ether	GC-MS	Identified 71 volatile constituents with key components including thymol, 2,4-decadienal, linoleic acid, and oleic acid	44

PacBio: Pacific Biosciences, Hi-C: High-throughput Chromosome Conformation Capture, qRT-PCR: quantitave Real Time-Polymerase Chain Reaction, UV-Vis: Ultraviolet–Visible, RNA: Ribonucleic Acid, cDNA: Complementary Deoxyribonucleic acid, PoIRX10: P. ovata Irregular Xylem 10, PoGT61: P. ovata Glycosyltransferase family 61, LC-MS: Liquid Chromatography-Mass Spectrometry, HPTLC: High-Performance Thin-Layer Chromatography, HPLC: High-Performance Liquid Chromatography, SEM: Scanning Electron Microscopy, GC-MS: Gas Chromatography-Mass Spectrometry, pet. ether: petroleum ether, d.w.: dry weight.

Table 3: Chemical structures of *P. ovata* phytoconstituents & their actions

Parts	*Compound class*	*Chemical structure*	*Pharmacological actions*	*Ref.*
Seed	Alkaloid	 Hordatine B	Anti-fungal	45
	Flavonoid	 Morusin  Dorsmanin	Anti-tumor	46,47
	Terpene	 Cinncassiol C  Prosapogenin	Immunomodulator, Anti-tumor, Anti-inflammatory	48,49
	triterpene saponin	 Cynarasaponin H	Anti-mutagenic	50
Husk	Alkaloid	 Pinidine	Anti-bacterial, Anti-fungal	51
	Triterpene	 Ginsenoside Rg6	Anti-inflammatory, Antibacterial, Antioxidant	52
Leaf	Flavonoids	 Luteolin  kaempferol	Anti-inflammation, Anti-allergy, Anticancer, Anti-oxidant, Anti-microbial, Cardioprotective, Antidiabetic, Anti-osteoporotic, Estrogen modulator, Anxiolytic, Analgesic	53,54
	Anthocyanidin & Carotenoids	 Cyanidin  Malvidin	Anti-oxidant, Anti-inflammatory, Anti-cancer, Anti-hypertensive, Cardioprotective, Neuroprotective	55-59

Cont...

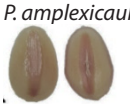
	Phytoalexin	 Pterostilbene	Anti-inflammatory, Anti-oxidant, Anti-cancer	60
Fruit capsule	Flavonoids:	 Apigenin 7-rhamnoside Catechin pentaacetate	Anti-cancer, Anti-proliferative, Proapoptotic, Anti-atherogenic, Anti-oxidant	61-63
	Alkaloid	 Sampangine Dictyoquinazol	Antifungal, Neuroprotective	64
	Tannin	 Punicalin Syzyginin B	Wound healing, Anti-inflammatory, Anti-cancer	65,66
	Lipid	 Brassicasterol βTocopherol	Anti-viral, Cardioprotective, Anti-cancer, Anti-melanogenic, Anti-oxidants	67-69
Root	Phenylethanoid glycosides	 Plantamajoside Acetoside	Anti-asthmatic, Hepatoprotective, Anti-aging, Neuroprotective, Anti-inflammatory, Anti-tumor, Anti-inflammatory, Diuretic, Wound-healing, Anti-oxidant, Anti-diabetic, Cardioprotective, Nephroprotective, Photoprotective	70,71

flour) are also recommended to enhance the tolerability of the drug.[5,6,8,20-22]

Phytochemistry & Multi-Omics Profiling

The traditional Unani applications of *Aspaghol* can be further contextualized through its distinctive phytochemical and molecular composition. The seeds of *Aspaghol* (*P. ovata)* represent a potent reservoir of bioactive compounds, featuring a macronutrient profile rich in complex carbohydrates, proteins, lipids, and a substantial proportion of dietary fiber.[30] The seeds serve as an excellent dietary source of minerals, characterized by an exceptionally high concentration of potassium (~687 mg/100g) alongside significant levels of calcium, sodium, and phosphorus, while also providing trace elements such as zinc, iron, and manganese. Although the leaves are less commonly utilized than the seeds, they contribute a significant level of crude proteins and higher total carbohydrates, but with lower fiber content.[31,32] The nutritional composition is further underscored by a robust array of water-soluble vitamins, dominated by niacin, pantothenic acid, and lipophilic antioxidants, including Vitamin E isomers and carotenoids such as lutein and lycopene.[31] Central to the functional utility of *P. ovata* is its seed husk-derived mucilage, a complex, multi-layered arabinoxylan polysaccharide. Its structure consists of a highly branched beta-(1,4)-linked D-xylose backbone substituted with arabinose side chains, which form a neutral inner core. While the middle layer provides the bulk and structural integrity, the highly hydrophilic outer layer is enriched with pectic polysaccharides, specifically galacturonic

Table 4: Comparative seed morphology of *Plantago* species

Species	*Shape*	*Color*	*Length*	*Width*	*Testa thick-ness*	*Inner side*	*Hilum*	*Seed coat pattern*
P. ovata 	Elliptic	Brown with white husk	2.12–2.8	1.25–1.6	Thick	Concave	Inside cavity	Scalariform
P. amplexicaulis 	Broadly elliptic	Yellow brown	5–6.1	2.3–3.2	Thin	Concave	On septum	Scalariform to reticulate
P. lanceolata 	Narrowly elliptic	Brown	1.9–2.3	0.94–1.2	Thick	Concave	In cavity	Scalariform to reticulate
P. afra 	Narrowly elliptic	Brown	1.96–2.96	0.69–0.96	Thick	Concave	In cavity	Scalariform to reticulate

Source: Mohsenzadeh et al. (2023), Turkish Journal of Botany, 47(1). Reproduced under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).

acid and rhamnose, to facilitate rapid hydration.[33-35] The major classes of secondary metabolites that underscore its therapeutic potential are flavonoids, polyphenols, tannins, phenylpropanoid glycosides, triterpenes, saponins, and sterols, etc.[36,37] The seeds specifically contain small amounts of aucubin (Iridoid glycosides) and an active principle exhibiting choline-like action.[38]

While classical Unani literature provides a therapeutic and pharmacological framework for understanding the drug, contemporary phytochemical investigations have revealed a diverse repertoire of polysaccharides, flavonoids, phenylpropanoid glycosides, terpenoids, sterols, and other bioactive constituents that may contribute to its biological effects.

The diverse repertoire of bioactive constituents identified in *P. ovata* has catalyzed extensive research, particularly through cutting-edge multi-omics profiling. Through the integration of genomic, transcriptomic, and metabolomic datasets, these studies provide a strategic analysis of various plant tissues to unravel the complex interplay between gene expression and its subsequent metabolic outcomes. Accordingly, the integration of genomic, transcriptomic, and metabolomic datasets offers a strategic approach to elucidating the complex relationship between biosynthetic pathways, phytochemical composition, and pharmacological activity, the key findings of which are summarized in Table 2, while their corresponding phytoconstituents are detailed in Table 3.

Adulterants

The therapeutic efficacy and overall quality of *P. ovata* are often compromised by the frequent use of adulterants and substitutes, which undermine the value of the high-quality mucilage found in the superficial layers of its seed coat.[72] Seeds of *P. ovata* are commonly mixed with those of allied species, including *P. amplexicaulis*, *P. lanceolata*, *P. afra*, and *P. asiatica*. Additionally, seeds from unrelated genus, such as *Salvia aegyptica*, are also utilized as substitutes.[73,74] The husk is sometimes adulterated with parched powdered rice.[75] This substitution presents a significant challenge because the seeds across the various *Plantago* species exhibit minimal morphological difference, making their distinction difficult. Precise identification is essential because significant variations in mucilage content and quality exist among these species. Driven by the immense therapeutic potential of *P. ovata*, the escalating market demand, and the challenge posed by allied species used as adulterants, establishing reliable identifying characteristics for seeds across the *Plantago* genus has become a critical necessity. The distinctive morphological features of some species based on scanning electron microscopy (SEM) has been summarized in Table 4. which aids in establishing phylogenetic relationships among these plants.[76-78]

Pharmacotherapeutics

Preclinical study

The bioactivity profiles of *P. ovata* extracts have been extensively studied. Key results from *in-vitro* and *in-vivo* studies are presented in Tables 5 and 6, respectively.

Clinical studies

The therapeutic versatility of drug *P. ovata* in managing various disorders is extensively documented; a comprehensive summary of these findings is provided in Table 7.

Discussion

Pharmacokinetics

The pharmacokinetics of *P. ovata* as shown in Figure 3, are characterized by a dual-action pathway. The primary

Table 5: *In-vitro* studies of *P. ovata*

Pharmacological Activity	*Part used*	*Extraction technique*	*Dose*	*Experimental Model Used*	*Standard Control*	*Outcome / Observation*	*Ref.*
Antimicrobial activity (*Bacillus subtilis, Candida albicans, P. glabrum, S. aureus, K. pneumoniae, S. typhi*)	Leaves	Supercritical Fluid Extraction (at 40 °C and 80 °C)	1000 µg/mL	Agar well diffusion method	Gentamycin	Extraction at 40°C showed potent activity against all organism except *P. glabrum*. MIC and MBC were 15.62 & 31.25 µg/mL respectively, and were significantly ↓ than those of 80°C extract.	79
Pancreatic Lipase Inhibition Assay				Enzyme inhibition assay	Orlistat	Extraction at 40 °C showed strong inhibition (IC_{50} = 17.21 µg/mL; 96.8% inhibition) significantly exceeding 80°C extract.	
Cytotoxicity assay				Cell lines: Caco-2 & WI38	Untreated cell line	Strong cytotoxicity against Caco2 cell line (IC_{50} = 109.47 µg/mL; 97.02% cytotoxicity) with & greater activity against WI38 cell line (IC_{50} = 218.25 ± 1.33 µg/mL), demonstrating greater potency than the 80°C extract.	
Antioxidant activity	Seed	Ethanolic extract	-	DPPH assay, H_2O_2, NO scavenging activity, and FRAP	Trolox, Quercetin	The extract demonstrated significant antioxidant activity across DPPH, H_2O_2, FRAP, and NO-scavenging assays ($p < 0.001$).	80
Antiviral activity	Husk	Chemically sulfated arabinoxylan fractions	up to 1000 µg/mL	Plaque reduction assay against HSV1 in Vero cells	Virus control (HSV1 infected Vero cells without extract)	Sulfated arabinoxylan fraction IS1-203 showed potent anti-HSV-1 activity (IC_{50} = 2.9 µg/mL; SI = 345) with no cytotoxicity up to 1000 µg/mL.	81
Antibacterial activity (*A. actinomycetemcomitans, P. gingivalis, P. intermedia, and F. nucleatum*)	Leaves and Seeds	Aqueous extract	0.2–100 µl/ml	Tube dilution method	-	*P. intermedia* was most sensitive (MIC = 0.4 µL/mL), whereas *A. actinomycetemcomitans* was most resistant (MIC = 50 µL/mL). *P. gingivalis* and *F. nucleatum* showed intermediate sensitivity with MIC values 0.8 µl/mL & 12.5 µl/mL respectively.	82
Anti-inflammatory Study			100 µl/ml	Zymography to assess MMP-2 & MMP-9 activity against inflamed tonsil tissue samples	Positive control: Tetracycline Negative control: no treatment	The extract moderately reduced MMP-2 and MMP-9 activity by approximately 30% and 40%, respectively, compared with 90% and 100% reduction by tetracycline.	
Antidiabetic activity	Husk	Aqueous extract	25, 50, 125 mg/mL,	Alpha-glucosidase inhibition assay	Acarbose	The highest α-glucosidase inhibition occurred at 125 mg/mL (92.75%), exceeding that of acarbose.	83

MIC: minimum inhibitory concentration, MBC: minimum bactericidal concentration, IC_{50}: half-maximal inhibitory concentration, SI: selectivity index, DPPH: 2,2-diphenyl-1-picrylhydrazyl, FRAP: ferric reducing antioxidant power, NO: nitric oxide, H_2O_2: hydrogen peroxide, MMP-2: matrix metalloproteinase-2, MMP-9: matrix metalloproteinase-9, HSV-1: herpes simplex virus type 1, Caco-2: human colorectal adenocarcinoma cell line, WI-38: human embryonic lung fibroblast cell line.

bulk component, a high-molecular-weight polysaccharide (arabinoxylan), remains unabsorbed due to β-linkages that resist human digestive enzymes. This ensures the fiber reaches the colon in a highly viscous, polymerized form to exert its local osmotic effects.[11,96] While the bulk polysaccharide remains localized, specific minor fractions undergo systemic uptake. Acid-dependent hydrolysis in the stomach releases free arabinose, which is efficiently absorbed by the small intestinal epithelium via specific monosaccharide transporters such as Sodium-Glucose Co-Transporter-1 (SGLT-1).[97,98] The remaining bulk polysaccharide undergoes microbial fermentation in the colon to produce gases like

Table 6: Preclinical *in-vivo* studies of *P. ovata*

Pharmacological activity	*Part used*	*Extraction technique*	*Dose*	*Experimental Model Used*	*Control*	*Outcome/Observation*	*Ref.*
Metabolic and Hepatoprotective activity	Seed	Ethanolic extract	25%, 50%, 100%	Streptozocin induced DM in female Wistar albino rats	Metformin (100 mg/100 g b.w.), Trolox (20 mg/kg b.w.),	Dose-dependent ↓ TG, TyG index ($p<0.005$), TC ($p<0.001$), AST & ALT ($p<0.01$); ↓ body weight ($p<0.001$).	80
Hypoglycemic & Anti-PCOS activity				Letrozole induced PCOS in female Wistar albino rats		Dose-dependent ↓ blood glucose, HOMA-IR ($p<0.001$), LH & testosterone ($p<0.05$); ↑ estrogen ($p<0.001$).	
Antiulcerogenic activity	Seed	Ethanolic extract	400 mg/kg b.w.	Ethanol induced gastric ulcer adult Male Wistar rats	Omeprazole (20 mg/kg b.w.)	↑ gastric mucus & pH ($p\leq0.001$); ↓ gastric volume & ulcer index (~50%, $p<0.001$); gastroprotection 4.62%.	84
Hepatoprotective	Seed	Aqueous extract	100 mg/kg	Indomethacin-induced liver damage in Male Albino rats	5% sodium bicarbonate (5 ml/kg)	Preserved hepatic architecture with no inflammation or necrosis; normal central vein and portal areas.	85
Anti-inflammatory & Anti-oxidant activity	Husk	Aqueous extract	100, 200, 300 mg/kg	TNBS-induced Ulcerative Colitis in BALB/c mice	Normal control (untreated), Vehicle control (ethanol),	↓ DAI, colonic damage, NO, MPO & lipid peroxidation ($p<0.0001$); ↑ SOD & GSH.	86
Anti-obesity / Metabolic regulation activity	Husk	-	5g fiber in 95g of standard diet	Obese male Zucker rats	-	↓ body-weight gain, liver weight, SBP, TG, FFA, cholesterol, hyperinsulinemia, glucose & TNF-α; ↑ endothelial-dependent vasodilation.	87

DM: Diabetes mellitus, TC: Total cholesterol, TG: Triglycerides, TyG: Triglyceride-Glucose, ALT: Alanine aminotransferase, AST: Aspartate aminotransferase, HOMA-IR: Homeostatic model assessment for insulin resistance, LH, Luteinizing hormone, TNBS: Trinitro benzenesulfonic acid, DAI: Disease activity index, MPO: Myeloperoxidase, NO: Nitric oxide, SOD: Superoxide dismutase, GSH: Reduced glutathione; HOMA-IR: Homeostatic model assessment for insulin resistance, PCOS: Polycystic ovary syndrome, SBP: Systolic blood pressure, TNF-α: Tumor necrosis factor-alpha.

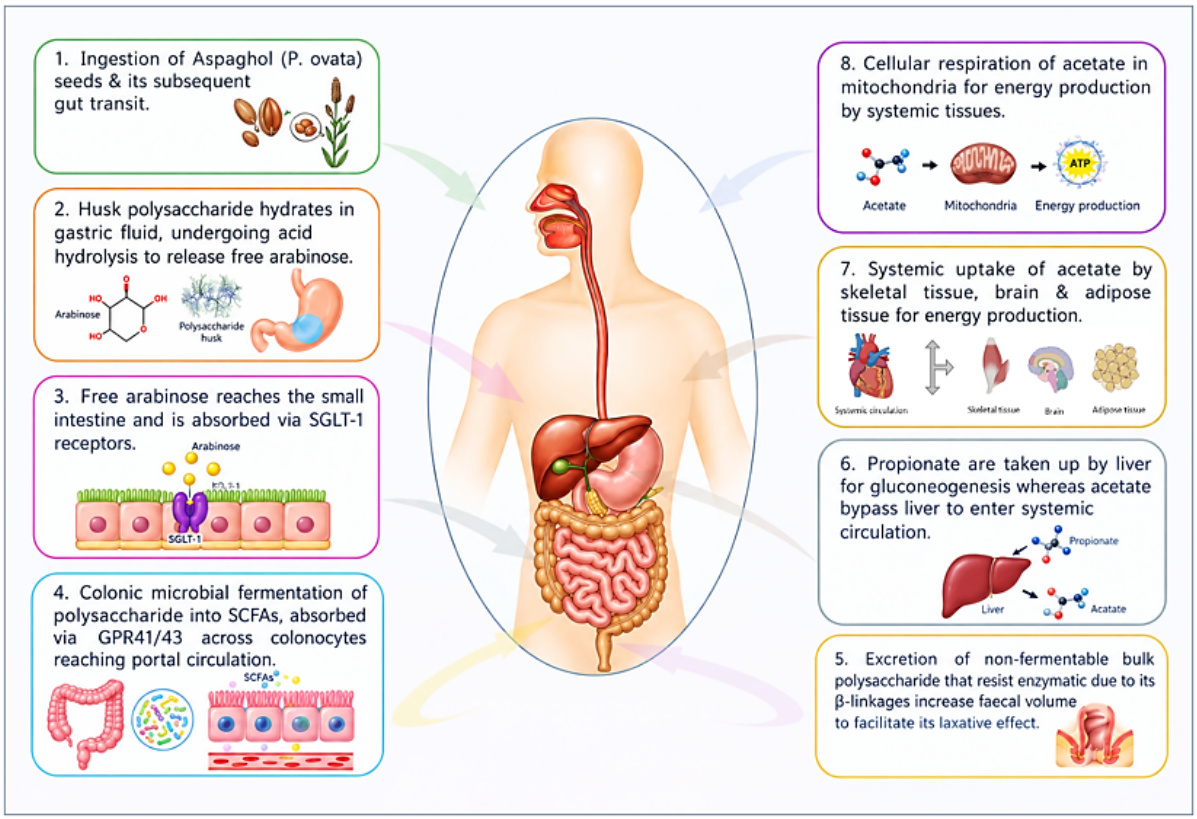


Figure 3: Pharmacokinetics of *Aspaghol* (*P. ovata*) mucilage

Table 7: Clinical studies of *P. ovata*

Clinical condition	*Study design*	*Sample size*	*Mode of administration*	*Duration dose*	*Outcome*	*Grade & Heterogeneity*	*Ref.*
Overweight & Obesity	SR MA	27 RCTs (n=352)	Oral psyllium husk/powder supplement	Dose: 0.002 to 25 g & Duration: 14 to 180 days	↑ body weight (WMD: 3.57; p<0.05); changes in WC (WMD: 0.72), BMI (WMD: –0.06) and WHR (WMD: –0.10) were non-significant (p>0.05).	Significant heterogeneity across outcomes	88
		6 RCTs (n= 354)	Oral administration of psyllium before meals	Mean duration: 4.8 months; Mean dose: 10.8 g/day	↓ body weight (MD: –2.1 kg), BMI (MD: –0.8 kg/m^2) and WC (MD: –2.2 cm); all p<0.001.	No significant heterogeneity; I^2=0% for all outcomes	89
Diabetes mellitus		19 RCTs (n=962)	Oral psyllium husk/powder supplement	Dose: 0.002 to 25 gm/day & Duration: <50 (NS) to >50 days (significant)	↓ FBS (WMD: –6.89; p<0.001), HbA1c (WMD: –0.75; p<0.001) and HOMA-IR (WMD: –1.17; p<0.05); insulin (WMD: -0.75 ; p > 0.05).	Significant heterogeneity; moderate-quality evidence for FBS, HbA1c & HOMA-IR; low-quality evidence for insulin	90
Hypertension		14 RCTs (n= 802)	Oral psyllium husk/powder supplement	Dose: m 7 to 25 g/day & Duration: 14 to 180 days.	↓ SBP (WMD: –2.24 mmHg; p<0.05); DBP showed no significant change (WMD: 0.04 mmHg; p>0.05).	Low, non-significant heterogeneity	91
Cardiovascular risk factors		61 RCTs (n=4100)	Oral psyllium husk/powder supplement	0.002 to 25 gm/day	↓ HOMA-IR (WMD: –1.17; p<0.05), HbA1c (WMD: –0.75; p<0.001), SBP (WMD: –2.24 mmHg; p<0.05), FBS (WMD: –6.89; p<0.001), TC (WMD: –9.05; p<0.05) and LDL-C (WMD: –8.55; p<0.0001). No significant change in BMI, DBP, WC, WHR, TG, HDL-C, CRP or TNF-α (p>0.05).	High grade heterogeneity for most outcomes; low grade heterogeneity for SBP & DBP	92
Metabolic syndrome		51 RCTs (n=2677)	Oral psyllium husk/powder supplementation	Median dose: 50 g/day & Median duration: 50 days	↓ FBS (WMD: –6.89; p<0.001) and SBP (WMD: –2.24 mmHg; p<0.05). No significant change in TG, HDL-C, DBP or WC (p>0.05).	Significant heterogeneity for FBS, HDL-C, TG & WC; low, non-significant heterogeneity for SBP & DBP	93
Hypolipidemic effect		28 RCTs (n=1924)	Oral administration of psyllium powder/baked fiber foods	Median dose: 10.2 g/day & Median duration: 8wk	↓ LDL-C (MD: –0.33 mmol/L; p<0.00001), non-HDL-C (MD: –0.39 mmol/L; p<0.00001) and apolipoprotein B (MD: –0.05 g/L; p<0.0001).	Moderate-quality evidence for LDL-C & non-HDL-C; high-quality evidence for apolipoprotein B	94
Irritable bowel syndrome		(14 RCTs n=906)	Oral supplementation of fibre (soluble & insoluble)	-	Soluble fibre improved IBS symptoms (RR: 0.83; NNT: 7; p=0.005); no significant benefit was observed with bran.	No significant heterogeneity between studies	95

SR MA: Systematic review & Meta analysis, RCT: Randomized Controlled Trial, n: sample size, WMD: Weighted Mean Difference, MD: Mean Difference, BMI: Body Mass Index, WC: Waist Circumference, WHR: Waist-to-Hip Ratio, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, FBS: Fasting Blood Sugar, HbA1c: Glycated Hemoglobin, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance, CRP: C-Reactive Protein, TC: Total Cholesterol, TG: Triglycerides, LDL-C: Low-Density Lipoprotein Cholesterol, HDL-C: High-Density Lipoprotein Cholesterol, TNF-alpha: Tumor Necrosis Factor-alpha.

carbon dioxide, hydrogen, methane and Short-Chain Fatty Acids (SCFAs), including acetate, propionate, butyrate and lactate. These SCFAs are absorbed across the colonic epithelium through passive diffusion (in their protonated form) or carrier-mediated active transport, notably facilitated by Monocarboxylate Transporters (MCT1/MCT4), and modulated by SCFA-sensing G-protein Coupled Receptors (GPR41/ GPR43/ GPR109a) before the metabolites enter the portal circulation.[99,100]

The absorbed fermentation products, primarily SCFAs, are distributed via the portal vein to the hepatic circulation, where differential first-pass clearance occurs.101 Colonocytes largely sequester butyrate as a primary energy source to maintain epithelial integrity. The liver clears propionate for gluconeogenesis, while acetate bypasses hepatic first-pass metabolism to be taken up by peripheral tissues, such as skeletal muscle, adipose tissue, and brain.100 In these peripheral tissues, acetate is activated by Acetyl-Coenzyme A Synthetase to Acetyl-CoA, which enters the Tricarboxylic acid cycle (TCA). This process yields Nicotinamide Adenine Dinucleotide (NADH) and Flavin Adenine Dinucleotide (FADH2) to drive the Electron Transport Chain (ETC) and oxidative phosphorylation for systemic Adenosine Triphosphate (ATP) generation.102 The majority of unmetabolized, non-fermented residue, which increases fecal mass and moisture to facilitate its therapeutic effect and is eliminated unchanged within a 12 to 24-hour window.[11]

Pharmacodynamics

The drug *P. ovata* exhibits a complex pharmacodynamic profile that addresses gastrointestinal, metabolic, and cardiovascular conditions through multifaceted biochemical pathways. At the enteric site, it exerts a dose-dependent dual regulatory effect. In small doses, gut-stimulatory effect is mediated by muscarinic and 5-hydroxytryptamine (5-HT_4) receptor activation, complementing its fiber-based laxative properties, while alongside its high dose intake provides gut-inhibitory activity through Ca^{2+} channel blockade and nitric oxide (NO)-cyclic guanosine monophosphate pathway activation, explaining its efficacy in diarrhea.[103] Recognized extensively for its role in correcting metabolic derangements, *P. ovata* significantly mitigates hyperglycemia through several synergistic mechanisms.[104] Its primary action stems from a potent gel-forming ability, which increases the viscosity of bolus contents and delays gastric emptying. This process slows the rate of carbohydrate digestion and glucose absorption within the small intestine, effectively blunting postprandial glucose spikes. Furthermore, the mucilage forms a protective coating along the gut lumen. This creates a mechanical barrier against digestive enzymes, hindering digestion and delaying the absorption of glucose molecules by the intestinal epithelium. [90,105]

The drug *P. ovata* also exerts its beneficial effects on metabolic syndrome through coordinated improvements in lipid metabolism, inflammation, and hormonal regulation. The fermentation-derived SCFAs activate hepatic adenosine monophosphate-activated protein kinase (AMPK), leading to inhibition of acetyl-CoA carboxylase and fatty acid synthase, which suppresses fatty acid synthesis while enhancing fatty acid oxidation and reducing hepatic triglyceride accumulation. It also decreases pro-inflammatory mediators, such as tumor necrosis factor-α (TNF-α), which in turn enhances adiponectin secretion and improves insulin sensitivity.[87,106] Its hypolipidemic actions are further supported by enhanced hepatic cholesterol excretion and improved plasma lipoprotein composition. In the liver, it increases cholesterol 7αhydroxylase activity, accelerating the conversion of cholesterol to bile acids, elevates 3-hydroxy-3-methylglutaryl-coenzyme A reductase (HMGCoA) activity, and suppresses cholesterol ester transfer protein activity, collectively producing a threefold increase in fecal bile acid excretion and reducing hepatic cholesteryl ester stores.[107-109] In circulation, it lowers plasma triglycerides and the Apolipoprotein B to Apolipoprotein AI ratio (Apo B: ApoAI) while increasing ApoAI and high-density lipoprotein (HDL) cholesterol, thereby improving major cardiovascular risk factors.[110]

Beyond its metabolic benefits, *P. ovata* also demonstrates therapeutic potential in alleviating disorders of gut-brain interaction (DGBI) such as irritable bowel syndrome (IBS) through a multifaceted mechanism. The fermentation-derived SCFAs from polysaccharides act as key signaling molecules that enhance intestinal barrier integrity by inducing interleukin18 (IL18) secretion, stimulating the release of antimicrobial peptides, promoting mucin production by intestinal epithelial cells, and upregulating tight junction proteins, an essential action given that impaired barrier function is central to IBS pathogenesis.[111-113] SCFAs further modulate intestinal permeability and exert anti-inflammatory effects by influencing chemotaxis and epithelial cell proliferation while reducing pro-inflammatory mediators.[114,115] These combined actions strengthen the physical barrier against pathogens and contribute to symptom improvement in both constipation-predominant and diarrhea-predominant IBS. In addition, it has also shown therapeutic relevance in inflammatory bowel conditions such as ulcerative colitis (UC), which is attributed to increased production of butyric acid. Elevated butyrate levels correlate with reductions in pro-inflammatory mediators, including nitric oxide, leukotriene B4, and tumor necrosis factorα, following psyllium supplementation.[116]

Extending beyond its roles in IBS and ulcerative colitis, *P. ovata* also exhibits notable anticancer properties within the colon through multiple complementary pathways. Its protective effects on intestinal structure, together with reductions in pro-inflammatory mediators, help create a less carcinogenic mucosal environment. The ability of psyllium to shorten intestinal transit time further decreases luminal exposure to carcinogens, while its mucogel-forming capacity enables binding and neutralization of

carcinogenic compounds.[117] Additionally, inhibition of bacterial β-glucuronidase activity reduces the hydrolysis of glucuronide-conjugated carcinogens, limiting their reactivation in the colon. Further, elevated production of butyric acid during fermentation contributes further protection by suppressing epithelial cell proliferation and inducing apoptosis in the distal colon. Collectively, these mechanisms impede the transformation of normal colonocytes into malignant cells, underscoring the chemo-preventive potential of *P. ovata*.[118,119]

Safety & Tolerability

Commercial-grade psyllium husk powder poses a significant allergenic risk, affecting both consumers and workers in healthcare and pharmaceutical settings. Commonly reported adverse reactions include respiratory issues like allergic rhinitis and perennial asthma, along with severe, generalized responses such as anaphylaxis and various occupational allergies.[120-123] These reactions are primarily classified as Type 1 IgE-mediated hypersensitivity immune responses. The allergenicity is attributed to specific protein fractions originating from the seed's endosperm and embryo, which frequently contaminate the husk powder.[124] Given this considerable allergenic potential, the US FDA has implemented a stringent purity criterion, mandating that psyllium husk used in commercial products must contain a protein content of less than 3% to mitigate these associated health concerns.[125]

Potential Drug-Herb Interactions

The drug *P. ovata* exhibits a complex profile of drug-herb interactions, offering effects that range from beneficial associations to reduced bioavailability across various pharmaceutical classes. It demonstrates enhancing or beneficial effects when co-administered with drugs for metabolic and digestive support wherein it is known to improve outcomes by reducing cholesterol when combined with lipid-lowering drugs like cholestyramine, colestipol, and simvastatin.[126-128] It also contributes favorably to the therapeutic effect of metformin (oral hypoglycemic agent) by improving both efficacy and gastric tolerability.[129,130] Furthermore, it is beneficially associated with treating gastrointestinal conditions like IBS and UC with propantheline and mesalamine, respectively.[131,132] Conversely, a major concern is its reducing effect, where the husk decreases the absorption or bioavailability of several critical medications, notably the CNS drugs carbamazepine, the cardiac glycoside digoxin, and hormones such as levothyroxine, ethinylestradiol, and corticosteroids.[133-137] Tt is also important to note that studies found no significant interaction with certain drugs, including warfarin, mebeverine, and acetylsalicylic acid.[138-141] Because of its bulk-forming properties, *P. ovata* husk may delay the enteral absorption of concomitantly administered medications. Therefore, it should be taken at least half-to-one hour before or after the administration of other medicinal products.[11]

Pharmaceutical Applications

Psyllium mucilage is a highly versatile natural polymer, prized in pharmaceutical and food sciences for its exceptional swelling, gel-forming, and viscosity-modifying properties. Characterized by a high molecular weight of approximately 1780 kDa, this polysaccharide backbone provides the structural integrity necessary for its diverse functional roles.[142] As a conventional excipient, it serves a multi-functional role across various dosage forms. In solids, it functions as a hydrophilic matrix former, binder, and a critical component in gastroretentive systems; in semi-solids, it acts as a rheology modifier and stabilizer; and in liquid formulations, its characteristic pseudoplastic flow behavior ensures physical stability and the uniform distribution of active ingredients.[143-147] Furthermore, it is increasingly employed in modified-release formulations where its rapid hydration and subsequent gel layer formation act as a diffusion barrier, effectively regulating the release kinetics.[148]

In the field of Novel Drug Delivery Systems, psyllium is recognized as a superior biocompatible carrier for nanoparticles and a high-efficiency microencapsulating agent. It facilitates the creation of a protective matrix that resists degradation in the upper gastrointestinal tract, thereby enhancing the targeted delivery of labile compounds, such as curcumin, and significantly improving the viability of probiotics.[149-150] The functional utility of the mucilage is further augmented through chemical modification, wherein its thiol-functionalization enhances mucoadhesiveness for site-specific therapy, and the grafting by monomers enables the synthesis of crosslinked hydrogels optimized for colon-specific drug delivery.[151,152]

Beyond its role in delivery systems, psyllium mucilage serves as a functional food hydrocolloid, employed in the fabrication of biodegradable edible films and as an emulsion stabilizer by attenuating syneresis. Furthermore, it demonstrates clinical potential in cardiovascular health by binding and retaining dietary sodium.[153-155] Its grafting capabilities also extend to environmental and systemic detoxification, where it is used to develop efficient adsorbents for the removal of heavy metals from both aqueous environments and the human body.[156,157]

Conclusion and Prospects

This scoping review systematically maps the available evidence on *Aspaghol* (*Plantago ovata* Forssk.) across the Unani and scientific literature. Its longstanding traditional use in the management of bowel disorders along with other conditions is supported by substantial scientific evidence, particularly in relation to its mucilaginous properties and established pharmacological effects. Metabolomic profiling of seeds and its derived husk have further revealed diverse bioactive constituents, including alkaloids, flavonoids, phenylpropanoids, terpenoids, saponins, phytoalexins,

and volatile compounds. Integration of these identified constituents with their reported biological activities and molecular targets may provide a rational basis for relating traditional Unani indications to pharmacological evidence using reverse pharmacology framework. Furthermore, evidence from chemically modified seed mucilage with potential antiviral activity and favorable safety findings suggests its further exploration as an anti-viral agent, while highlighting opportunities for sustainable drug-delivery systems.

Declaration of competing interest

None to declare.

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