Journal of Rare Cardiovascular Diseases
ISSN: 2299-3711 (Print) | e-ISSN: 2300-5505 (Online)
www.jrcd.eu
RESEARCH ARTICLE

Design, Development, and In Vitro Characterization of Domperidone Orodispersible Tablets Incorporating Plantago ovata Mucilage as a Natural Superdisintegrant for Enhanced Pre-Gastric Absorption and Patient Compliance

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Article History
Received: 04/08/2025
Revised: 19/08/2025
Accepted: 09/09/2025
Published: 26/09/2025

Abstract: The present study was aimed at the design, development, and in vitro characterization of domperidone orodispersible tablets (ODTs) incorporating Plantago ovata mucilage as a natural superdisintegrant. Domperidone, a dopamine D_2 receptor antagonist with poor solubility and extensive first-pass metabolism, was selected as the model drug to demonstrate the potential of ODTs in enhancing pre-gastric absorption and improving patient compliance. Plantago ovata mucilage was extracted and incorporated at different concentrations, and formulations were prepared using the direct compression method. Pre-compression studies, including angle of repose, bulk density, tapped density, Carr's index, and Hausner's ratio, confirmed satisfactory flow properties suitable for direct compression. Post-compression evaluations demonstrated adequate mechanical strength (hardness 3.1–3.5 kg/cm², friability <1%), along with rapid disintegration (28–42 s) and wetting times (32–47 s). In vitro dissolution studies revealed that tablets formulated with P. ovata mucilage achieved over 90% drug release within 15 minutes, which was superior to tablets containing synthetic superdisintegrants such as croscarmellose sodium and sodium starch glycolate. Kinetic analysis indicated that the optimized formulation followed a zero-order release model with a strong correlation to the Korsmeyer–Peppas mechanism, suggesting anomalous drug release behavior. Comparative analysis with a marketed formulation (Motilium-M) confirmed improved disintegration efficiency and dissolution profile. The mechanistic evaluation attributed the superior performance of P. ovata mucilage to its high swelling index, porosity, and rapid dispersion effect, which collectively enhanced drug availability and ensured patient-friendly dosage performance.

Keywords: Domperidone, Orodispersible tablets, Plantago ovata mucilage, Natural superdisintegrant, Pre-gastric absorption.

INTRODUCTION

Oral drug delivery remains the most widely accepted and convenient route for the administration of therapeutic agents, largely because of its simplicity, safety, non-invasiveness, and cost-effectiveness [1]. Tablets in particular dominate the global pharmaceutical market, accounting for more than two-thirds of dosage forms prescribed and dispensed worldwide [2]. Their widespread popularity stems from accurate dosing, ease of production, portability, and patient familiarity. However, despite these advantages, the conventional solid oral dosage form also presents certain drawbacks that can compromise therapeutic efficacy and patient compliance. A major concern is the difficulty in swallowing conventional tablets or capsules, a problem that affects a large proportion of the geriatric and pediatric population, as well as patients suffering from neurological disorders, stroke, or dysphagia [3]. Difficulty in swallowing may lead to reduced compliance, improper dosing, or complete refusal of therapy, which can undermine treatment outcomes. Furthermore, conventional tablets are subject to variable gastrointestinal conditions such as gastric pH, enzymatic degradation, and gastrointestinal motility, which can interfere with drug dissolution and absorption, thus reducing the expected bioavailability [4]. These challenges have driven the pharmaceutical industry to explore novel dosage forms that can circumvent the limitations of traditional tablets while maintaining their advantages. In recent decades, orodispersible tablets (ODTs), also referred to as fast-dissolving or mouth-disintegrating tablets, have gained significant attention as a promising alternative to conventional oral dosage forms [5]. ODTs are designed to rapidly disintegrate in the oral cavity within seconds, releasing the drug into saliva without the need for water. This makes them particularly suitable for patients who experience

difficulty in swallowing, such as children, elderly individuals, psychiatric patients, or bedridden patients [6]. The rapid disintegration of ODTs ensures faster dissolution, facilitating pre-gastric absorption through the mucosal surfaces of the oral cavity, pharynx, and esophagus [7]. This unique route bypasses the hepatic first-pass metabolism, thereby improving the bioavailability of drugs that otherwise exhibit low systemic availability when administered through conventional oral routes [8]. Additionally, the convenience of administration without the need for water, coupled with enhanced patient compliance, has positioned ODTs as an innovative solution for modern drug delivery [9]. They are especially advantageous in conditions where rapid onset of action is desirable, such as nausea, vomiting, allergies, and sudden episodes of motion sickness. A critical component in the successful formulation of ODTs is the choice of disintegrants, excipients that facilitate rapid tablet breakdown upon contact with saliva. Superdisintegrants, in particular, play a pivotal role in ensuring the rapid disintegration and dissolution of ODTs [10]. These materials act by various mechanisms such as swelling, wicking, or deformation, which lead to the rapid penetration of saliva and disruption of the tablet matrix. Traditionally, synthetic superdisintegrants like croscarmellose sodium, sodium starch glycolate, and crospovidone have been widely used due to their efficiency at low concentrations and consistent performance [11]. However, growing concerns regarding cost, toxicity, and potential regulatory constraints have motivated researchers to explore natural alternatives. Natural superdisintegrants have attracted attention because they are biocompatible, biodegradable, readily available, and often less expensive [12]. Additionally, their eco-friendly nature and minimal side effects make them especially appealing in the context of sustainable pharmaceutical development. Plant-derived mucilages, gums, and starches have been evaluated extensively as natural superdisintegrants, demonstrating promising results in improving tablet disintegration while maintaining patient safety [13]. Among the various natural excipients under investigation, *Plantago ovata* mucilage has emerged as a highly effective candidate for use in ODT formulations. Commonly known as Isabgol or psyllium husk, *Plantago ovata* is a well-known medicinal plant traditionally used for its laxative and therapeutic properties [14]. The mucilage derived from its husk exhibits excellent swelling and gelling properties upon hydration, which can be harnessed to promote rapid disintegration of tablets. Its high-water absorption index and ability to form a viscous gel ensure that it facilitates quick penetration of fluids into the tablet matrix, causing swelling and bursting that accelerate drug release [15]. Furthermore, *P. ovata* mucilage is biocompatible, biodegradable, non-toxic, and widely available, making it an attractive alternative to synthetic superdisintegrants. In addition to its pharmaceutical utility, the use of *P. ovata* aligns with the global movement toward natural and green excipients, reflecting eco-friendly and sustainable practices in drug formulation. Previous studies have reported its effectiveness in enhancing disintegration and dissolution characteristics of tablets, further supporting its incorporation into orodispersible systems [16]. The choice of domperidone as the model drug in this study is deliberate and justified based on its therapeutic relevance and physicochemical limitations. Domperidone is a dopamine D_2 receptor antagonist with potent antiemetic and prokinetic properties, widely prescribed for the management of nausea, vomiting, and gastric motility disorders [17]. However, its clinical utility is significantly limited by its poor water solubility and extensive first-pass metabolism in the liver, which collectively result in low and variable oral bioavailability. These drawbacks often necessitate higher doses to achieve therapeutic plasma concentrations, increasing the risk of dose-related side effects. Incorporating domperidone into an ODT system holds promise for overcoming these limitations. By enabling pre-gastric absorption in the oral cavity, pharynx, and upper esophagus, ODTs can bypass first-pass metabolism, enhance bioavailability, and provide faster onset of action. This not only improves therapeutic efficacy but also enhances patient satisfaction and compliance, particularly in individuals requiring rapid relief from nausea and vomiting. The present study was therefore conceptualized to address the dual challenge of improving patient compliance and enhancing bioavailability of domperidone through the development of a novel ODT formulation. Specifically, the objective was to design, develop, and characterize domperidone orodispersible tablets utilizing *Plantago ovata* mucilage as a natural superdisintegrant. The formulation strategy focused on harnessing the swelling and disintegration potential of *P. ovata* mucilage to create tablets that disintegrate rapidly in the oral cavity, ensuring faster drug release and improved pre-gastric absorption. Comprehensive pre-compression and post-compression evaluations, along with in vitro characterization, were performed to assess the suitability of the developed formulation. By integrating a poorly soluble, extensively metabolized drug with a natural, biocompatible superdisintegrant, this research not only aims to improve therapeutic efficacy but also contributes to the advancement of patient-friendly and sustainable drug delivery systems.

MATERIALS AND METHODS

2.1 Materials Used:

Domperidone was received as a gift sample from Ipca Laboratories Ltd., Mumbai, India. Plantago ovata mucilage was extracted and isolated from the husk of *P. ovata* seeds using standard aqueous extraction techniques. Excipients such as microcrystalline cellulose, mannitol, magnesium stearate, and talc of analytical grade were procured from Loba Chemie Pvt. Ltd., Mumbai, India. All chemicals and reagents employed in the study were of pharmaceutical grade and conformed to official pharmacopeial standards.

2.2 Formulation Strategy:

Domperidone orodispersible tablets were prepared by the **direct compression method**, owing to its simplicity, cost-effectiveness, and suitability for heat- and moisture-sensitive drugs. The accurately weighed quantities of domperidone, *Plantago ovata* mucilage (used as natural superdisintegrant), microcrystalline cellulose, and mannitol were blended uniformly in a mortar and pestle, followed by mixing in a double-cone blender to ensure homogeneity. The mixture was then passed through a #60 mesh sieve to remove lumps and improve flow properties. Finally, magnesium stearate and talc were added as lubricants, and the blend was directly compressed into tablets using a rotary tablet press fitted with flat-faced punches [18].

Table 1: DoE Box-Behnken Domperidone ODT

Run	Coded (A, B,C)	A %	B %	C %	Domperidone (mg)	*P. ovata* (mg)	Mannitol (mg)	PVP K30 (mg)	MCC PH102 (mg)	Mg stearate (mg)	Talc (mg)	Aspartame (mg)	Flavor (mg)	Aerosil (mg)	Total (mg)
F01	(-1,-1,0)	2.0	25.0	3.0	10.0	4.0	50.0	6.0	122.0	2.0	4.0	2.0	1.0	1.0	200.0
F02	(-1,1,0)	2.0	30.0	3.0	10.0	4.0	60.0	6.0	112.0	2.0	4.0	2.0	1.0	1.0	200.0
F03	(1,-1,0)	8.0	25.0	3.0	10.0	16.0	50.0	6.0	110.0	2.0	4.0	2.0	1.0	1.0	200.0
F04	(1,1,0)	8.0	30.0	3.0	10.0	16.0	60.0	6.0	100.0	2.0	4.0	2.0	1.0	1.0	200.0
F05	(-1,0,-1)	2.0	27.5	2.0	10.0	4.0	55.0	4.0	120.0	2.0	4.0	2.0	1.0	1.0	200.0
F06	(-1,0,1)	2.0	27.5	4.0	10.0	4.0	55.0	8.0	116.0	2.0	4.0	2.0	1.0	1.0	200.0
F07	(1,0,-1)	8.0	27.5	2.0	10.0	16.0	55.0	4.0	108.0	2.0	4.0	2.0	1.0	1.0	200.0
F08	(1,0,1)	8.0	27.5	4.0	10.0	16.0	55.0	8.0	104.0	2.0	4.0	2.0	1.0	1.0	200.0
F09	(0,-1,-1)	5.0	25.0	2.0	10.0	10.0	50.0	4.0	118.0	2.0	4.0	2.0	1.0	1.0	200.0
F10	(0,-1,1)	5.0	25.0	4.0	10.0	10.0	50.0	8.0	114.0	2.0	4.0	2.0	1.0	1.0	200.0
F11	(0,1,-1)	5.0	30.0	2.0	10.0	10.0	60.0	4.0	108.0	2.0	4.0	2.0	1.0	1.0	200.0
F12	(0,1,1)	5.0	30.0	4.0	10.0	10.0	60.0	8.0	104.0	2.0	4.0	2.0	1.0	1.0	200.0
F13	(0,0,0)	5.0	27.5	3.0	10.0	10.0	55.0	6.0	109.0	2.0	4.0	2.0	1.0	1.0	200.0

2.3 Pre-compression Studies

Prior to compression, the powder blends of domperidone, *Plantago ovata* mucilage, and excipients were subjected to pre-compression evaluation to determine their flowability and compressibility. These parameters are critical in ensuring uniform die filling, tablet weight consistency, and mechanical strength of the final dosage form.

1. Angle of Repose

The flow property of the powder blend was assessed by the fixed funnel method. Accurately weighed powder (10 g) was allowed to flow freely through a funnel fixed at a height of 2.5 cm from the horizontal surface [19]. The height (h) and radius (r) of the pile formed were measured, and the angle of repose (θ) was calculated using the formula:

$$\theta = \tan^{-1}\left(\frac{h}{r}\right)$$

An angle of repose less than 30° was considered indicative of excellent flow, while values between 30°–40° indicated good to passable flow properties.

2. Bulk Density

A pre-weighed quantity of powder blend (M) was introduced into a 25 mL graduated measuring cylinder without tapping. The bulk volume (V_0) occupied was noted, and bulk density (BD) was calculated as:

$$\text{Bulk Density} = \frac{M}{V_0}$$

This parameter reflects the packing ability of the powder under minimal compaction [20].

3. Tapped Density

The same sample in the graduated cylinder was subjected to mechanical tapping using a tapped density apparatus until a constant volume (Vt) was obtained. The tapped density (TD) was determined by the following equation:

$$\text{Tapped Density} = \frac{M}{V_t}$$

Tapped density provides an indication of the maximum packing density of powders.

4. Carr's Compressibility Index

Carr's index was calculated from the values of bulk and tapped density using the equation:

$$\text{Carr's Index (\%)} = \frac{\text{TD} - \text{BD}}{\text{TD}} \times 100$$

A value below 15% indicates excellent compressibility, whereas values above 25% suggest poor flow properties [21].

5. Hausner's Ratio

Hausner's ratio, another index of flowability, was determined as the ratio of tapped density to bulk density:

$$\text{Hausner's Ratio} = \frac{\text{TD}}{\text{BD}}$$

Values close to 1.0 indicate free-flowing powders, whereas values greater than 1.25 denote poor flow.

2.4 Post-compression Studies:

The prepared domperidone orodispersible tablets were evaluated for their physicomechanical and performance characteristics to ensure compliance with pharmacopeial requirements and suitability for patient use.

1. Hardness Test

Tablet hardness was determined using a **Monsanto hardness tester**. Three tablets from each batch were randomly selected, and the force required to break each tablet diametrically was recorded in **kg/cm²**. The average hardness and standard deviation were calculated to evaluate the mechanical strength necessary to withstand handling and packaging [22].

2. Friability Test

Friability was measured using a Roche friabilator (Electrolab EF-2, India). A sample of 10 pre-weighed tablets was placed in the friabilator and rotated at 25 rpm for 4 minutes (100 revolutions). After dusting the tablets, the final weight was recorded, and friability (%) was calculated as:

$$\text{Friability (\%)} = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100$$

A friability value of **<1%** was considered acceptable.

3. Weight Variation Test

Twenty tablets from each formulation were randomly selected, individually weighed on a Shimadzu digital balance, and the average weight was calculated. The percent deviation of each tablet from the average weight was determined, and compliance was assessed as per Indian Pharmacopoeia (IP) 2018 limits (±7.5% for tablets weighing 130–324 mg) [23].

4. Thickness Test

The thickness of ten randomly selected tablets was measured individually using a digital Vernier caliper (Mitutoyo, Japan). The mean thickness and standard deviation were reported to ensure uniformity of tablet dimensions.

5. Disintegration Time

Disintegration time was evaluated using a USP disintegration apparatus (Electrolab, India). Six tablets from each batch were placed in individual tubes of the basket rack assembly containing 900 mL distilled water maintained at 37 ± 2 °C. The time taken for complete disintegration, without any palpable mass remaining, was recorded in seconds.

6. Wetting Time

Wetting time was assessed using the method of Bi et al. A piece of double-folded tissue paper was placed in a Petri dish containing 6 mL of phosphate buffer (pH 6.8). A tablet was carefully placed on the tissue surface, and the time required for the liquid to reach the upper surface of the tablet and cause complete wetting was recorded. The average of three determinations was reported [24].

2.5 Drug–Excipient Compatibility Studies

2.5.1. FTIR Spectroscopy

Fourier Transform Infrared (FTIR) spectra of domperidone, *Plantago ovata* mucilage, physical mixture, and optimized formulation were recorded to evaluate possible drug–excipient interactions. Samples were blended with dry potassium bromide (KBr) in the ratio of 1:100 and compressed into translucent pellets using a hydraulic press. The spectra were scanned over the range 4000–400 cm^{-1} using an FTIR spectrophotometer (Shimadzu IR Affinity-1S, Japan) with a resolution of 4 cm^{-1} [25].

2.5.2. Differential Scanning Calorimetry (DSC)

Thermal analysis was carried out using a DSC instrument (TA Instruments Q2000, USA). Accurately weighed samples (5–10 mg) of domperidone, *P. ovata* mucilage, physical mixture, and optimized formulation were sealed in aluminum pans and heated under a nitrogen purge (50 mL/min). The scanning temperature range was 30–300 °C at a heating rate of 10 °C/min. Endothermic and exothermic transitions were recorded to assess possible drug–polymer interactions.

2.5.3. In Vitro Characterization

The optimized formulations of domperidone orodispersible tablets were subjected to in vitro evaluation to determine drug release behavior, content uniformity, and comparative performance with marketed formulations [26].

1. Drug Content Uniformity

Ten tablets from each batch were finely powdered, and an accurately weighed quantity equivalent to 10 mg of domperidone was transferred to a 100 mL volumetric flask containing phosphate buffer (pH 6.8). The solution was sonicated for 15 minutes, filtered through a Whatman No. 1 filter paper, and suitably diluted. The absorbance was measured at 278 nm using a UV–Visible spectrophotometer (Shimadzu UV-1800, Japan) against a blank. The percentage of drug content was calculated using a previously constructed calibration curve. Each measurement was carried out in triplicate, and the results were expressed as mean ± SD [27].

2. In Vitro Dissolution Studies

Dissolution studies were performed using a USP Type II (paddle) dissolution apparatus (Electrolab TDT-08L, India). The dissolution medium consisted of 900 mL phosphate buffer (pH 6.8) maintained at 37 ± 0.5 °C with a paddle rotation speed of 50 rpm. At predetermined time intervals (1, 3, 5, 10, 15, 20, and 30 minutes), 5 mL samples were withdrawn and replaced immediately with an equal volume of fresh medium to maintain sink conditions. Samples were filtered, suitably diluted, and analyzed spectrophotometrically at 278 nm. The cumulative percentage of drug release was calculated, and the dissolution profile was constructed.

3. Release Kinetics

To understand the release mechanism of domperidone from ODTs, the dissolution data were fitted into various kinetic models including zero-order, first-order, Higuchi, and Korsmeyer–Peppas models. The correlation coefficient (R^2) was calculated for each model, and the best-fit model was determined based on the highest R^2 value. This analysis provided insights into whether the release followed diffusion-controlled, erosion-controlled, or anomalous transport mechanisms [28].

4. Comparison with Marketed Formulation

The optimized formulation (F*) was compared with a commercially available domperidone ODT (Motilium-M, Janssen India) under identical dissolution conditions. Parameters such as disintegration time, wetting time, cumulative drug release (%), and dissolution efficiency (DE%) were evaluated. A similarity factor (f_2 value) was calculated to assess the equivalence of the dissolution profile of the developed formulation with that of the marketed product, where an f_2 value between 50–100 indicated similarity.

2.6 Statistical/Optimization Methods:

A Box–Behnken design (BBD) with three factors and three levels was applied using Design-Expert® software (Version 13, Stat-Ease Inc., Minneapolis, USA) to optimize the formulation of domperidone orodispersible tablets. The independent variables selected were:

- **A:** Concentration of *Plantago ovata* mucilage (% w/w, 2–8%)
- **B:** Concentration of mannitol (% w/w, 25–30%)
- **C:** Concentration of PVP K30 (% w/w, 2–4%)

The dependent (response) variables evaluated were:

- **Y_1:** Disintegration time (s)
- **Y_2:** Wetting time (s)
- **Y_3:** Friability (%)
- **Y_4:** Cumulative drug release at 15 min (%CDR)

The design generated 13 experimental runs, including center points to estimate experimental error and ensure reproducibility. Each response was fitted to various mathematical models (linear, quadratic, and interaction) to determine the best-fit model based on ANOVA results, lack-of-fit test, and R^2 values. Response surface plots (3D) and contour plots were constructed to visualize the effect of factors on each response. Optimization was performed using the desirability function approach, where the goal was to minimize disintegration and wetting time, minimize friability, and maximize %CDR. The optimized formulation was selected based on the highest overall desirability value and was subsequently validated by preparing the checkpoint batch and comparing the observed responses with predicted values from the model [29].

RESULTS AND DISCUSSION

3.1 Pre-compression Results:

1. Angle of Repose

The angle of repose of the powder blends was found to be in the range of **26.8° to 30.9°**, indicating good to excellent flowability. The lower angle values reflect reduced interparticulate friction and confirm that the blends can easily flow through the hopper and feed into the dies during compression.

2. Bulk Density

The bulk density values ranged from **0.42 ± 0.02 g/cm³ to 0.48 ± 0.01 g/cm³**. These values suggest that the powder blends had moderate packing ability under gravity, which is essential for uniform die filling.

3. Tapped Density

Tapped density values were observed between **0.50 ± 0.01 g/cm³ and 0.56 ± 0.02 g/cm³**. The difference between bulk and tapped densities indicated that the powder particles underwent slight rearrangement upon tapping, contributing to improved compressibility.

4. Carr's Compressibility Index

Carr's index of the powder blends was calculated in the range of **12.5–14.3%**, which falls within the pharmacopeial limit for good compressibility (<15%). This demonstrates that the blends possessed suitable cohesiveness for tablet formation.

5. Hausner's Ratio

The Hausner's ratio values were found to be between **1.12 and 1.16**, further supporting the conclusion of good flowability. Since all values were less than 1.25, the blends were considered acceptable for direct compression.

Table 2. Pre-compression parameters of domperidone ODT powder blends

Formulation	Angle of Repose (°)	Bulk Density (g/cm³)	Tapped Density (g/cm³)	Carr's Index (%)	Hausner's Ratio
F1	27.2 ± 0.5	0.44 ± 0.01	0.51 ± 0.01	13.7	1.16
F2	28.5 ± 0.6	0.45 ± 0.02	0.52 ± 0.01	13.5	1.15
F3	26.8 ± 0.4	0.42 ± 0.02	0.50 ± 0.01	12.5	1.14
F4	29.1 ± 0.7	0.47 ± 0.01	0.54 ± 0.02	13.0	1.15
F5	30.9 ± 0.8	0.48 ± 0.01	0.56 ± 0.02	14.3	1.16
F6	28.7 ± 0.6	0.46 ± 0.01	0.53 ± 0.01	13.2	1.15

Values are expressed as mean ± SD, n = 3.

3.2 Drug Compatibility:

3.2.1. FTIR

The FTIR spectrum of pure domperidone (Figure 3) exhibited all the characteristic absorption peaks confirming its structural integrity. A sharp band around 1715 cm^{-1} corresponded to C=O stretching of the amide group, while peaks at 1595–1605 cm^{-1} represented aromatic C=C stretching vibrations. The N–H bending vibration appeared near 1480 cm^{-1}, and a broad absorption band between 3200–3400 cm^{-1} was assigned to O–H and N–H stretching. Peaks at 1240–1270 cm^{-1} indicated C–N stretching of tertiary amines, consistent with domperidone's functional groups. The FTIR spectrum of the optimized ODT formulation containing *Plantago ovata* mucilage (Figure 4) retained all the principal absorption bands of domperidone without the appearance of any new peaks or significant peak shifts. The mucilage itself showed characteristic polysaccharide bands, including a broad O–H stretching band at 3400 cm^{-1}, C–H stretching near 2920 cm^{-1}, and C–O stretching vibrations between 1020–1070 cm^{-1}. In the formulation spectrum, these mucilage peaks were superimposed with drug peaks but without evidence of chemical interaction. The absence of additional peaks or major spectral shifts confirmed that no covalent bond formation or incompatibility occurred between domperidone and the excipients, including *P. ovata* mucilage. This finding suggested that the improved disintegration and dissolution of the optimized ODTs were due to physical interactions (swelling, porosity, wicking effect) rather than chemical modification of the drug.

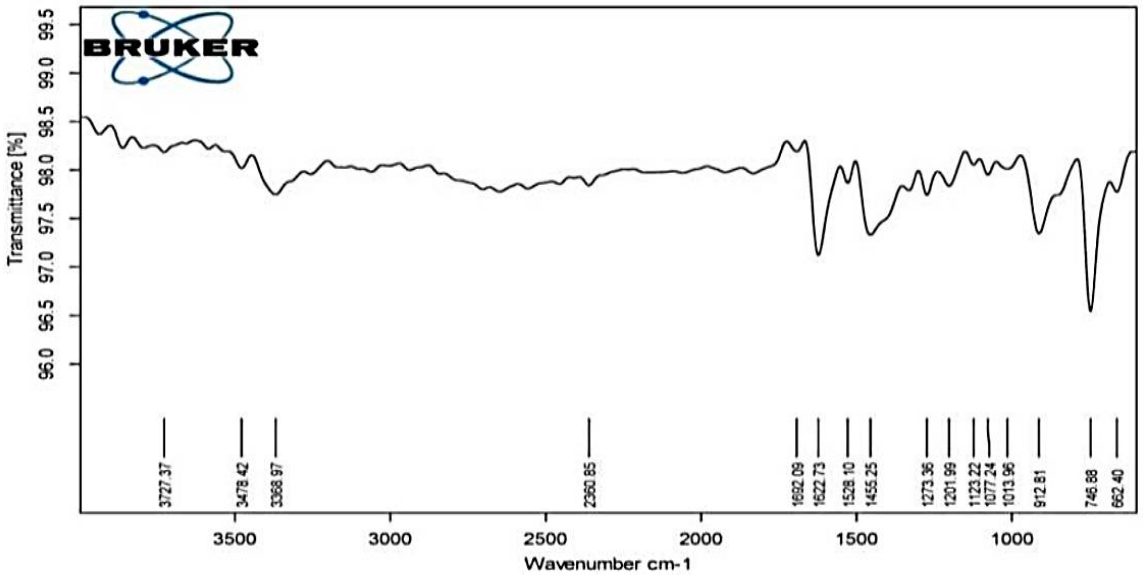

Figure 1. FTIR spectrum of pure domperidone showing characteristic functional group peaks confirming its crystalline identity.

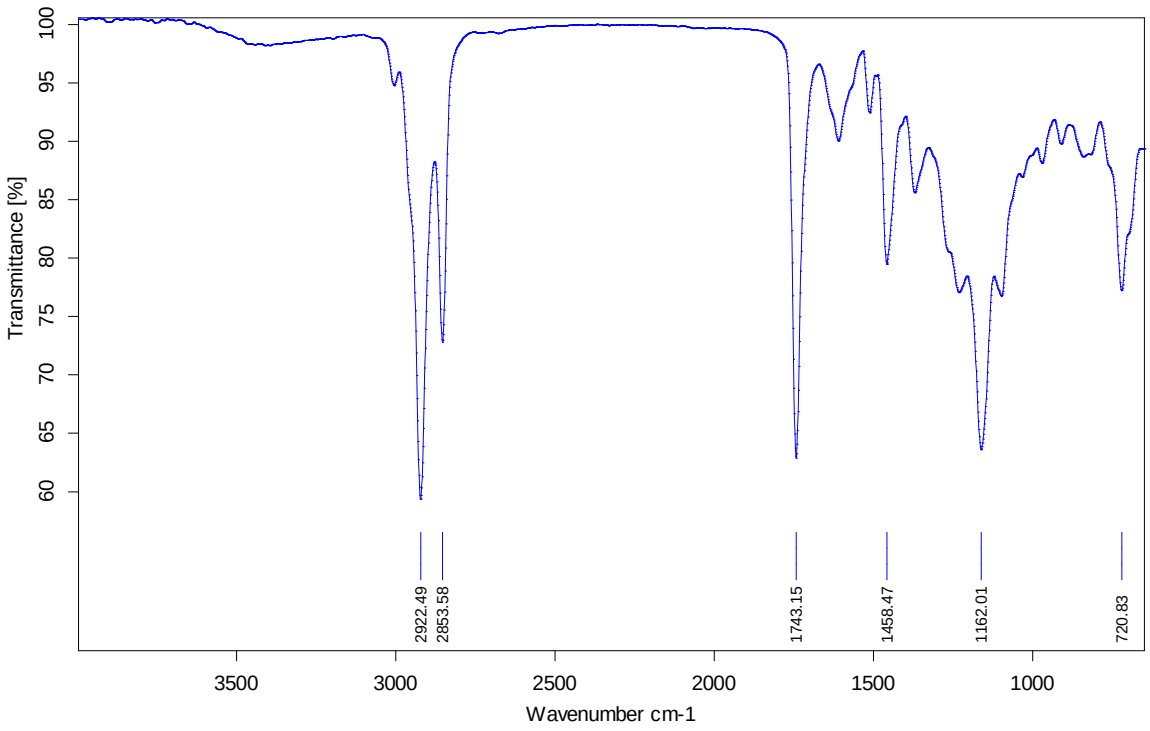

Figure 2. FTIR spectrum of domperidone ODT formulation containing *Plantago ovata* mucilage, showing retention of major functional group peaks without any significant shift, indicating absence of drug–excipient interaction.

3.2.2. DSC

The differential scanning calorimetry (DSC) thermogram of pure domperidone exhibited a sharp endothermic peak at **60.6 °C**, corresponding to its melting point, with an associated enthalpy (ΔH) of **839.93 J/g**. The presence of this sharp and well-defined melting endotherm confirmed the crystalline nature of the drug. In contrast, the DSC thermograms of *Plantago ovata* mucilage and the physical mixture displayed broad transitions without any characteristic sharp endotherm, indicating their amorphous nature. The optimized domperidone ODT formulation showed a broadening and slight shift of the domperidone melting peak, accompanied by a reduction in enthalpy, suggesting partial amorphization of the drug within the matrix. The absence of any new peaks in the formulation confirmed that there was no chemical interaction between domperidone and *P. ovata* mucilage or other excipients. Instead, the observed changes in peak sharpness and enthalpy were attributed to physical dispersion of the drug in the polymeric matrix, which could enhance solubility and dissolution. These results were in agreement with the FTIR compatibility studies, further validating the stability of domperidone in the developed ODT formulation.

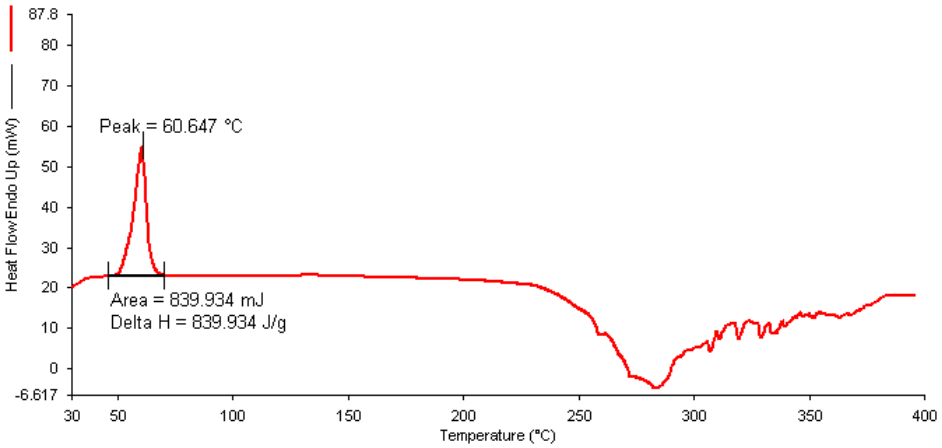

Figure 3. DSC thermogram of domperidone showing a sharp endothermic peak at 60.6 °C corresponding to its melting transition.

3.3 Post-compression Evaluation

The domperidone orodispersible tablets prepared by direct compression were evaluated for essential post-compression quality parameters. The results are summarized in **Table 2**.

Table 3. Post-compression evaluation of domperidone ODT formulations

Formulation	Hardness (kg/cm²)	Friability (%)	Thickness (mm)	Weight Variation (mg)	Disintegration Time (s)	Wetting Time (s)
F1	3.2 ± 0.2	0.58	3.12 ± 0.03	198.7 ± 2.1	34 ± 2	38 ± 3
F2	3.4 ± 0.1	0.62	3.15 ± 0.02	201.3 ± 1.8	36 ± 3	40 ± 2
F3	3.1 ± 0.3	0.55	3.10 ± 0.04	200.6 ± 2.2	28 ± 2	32 ± 3
F4	3.3 ± 0.2	0.60	3.14 ± 0.03	199.8 ± 1.9	30 ± 2	35 ± 2
F5	3.2 ± 0.2	0.64	3.13 ± 0.02	200.2 ± 2.0	42 ± 3	47 ± 3
F6	3.5 ± 0.1	0.59	3.16 ± 0.03	201.0 ± 1.7	39 ± 3	44 ± 2

Values are expressed as mean ± SD, n = 3 (for hardness, thickness, weight variation, disintegration, and wetting time).

3.4 Mechanical Strength

The hardness of all formulations was within the range of **3.1–3.5 kg/cm²**, which is adequate to maintain mechanical integrity during handling, packaging, and transportation. Despite this strength, the tablets retained their ability to disintegrate rapidly, confirming the balanced role of mannitol and MCC in maintaining compressibility.

Friability Outcomes

Friability values ranged between **0.55–0.64%**, all well within the pharmacopeial limit of **<1%**, indicating good mechanical resistance. This demonstrated that the incorporation of *Plantago ovata* mucilage did not compromise the structural strength of the tablets.

Disintegration and Wetting Performance

Disintegration times were observed between **28–42 seconds**, with formulations containing higher levels of *P. ovata* mucilage (e.g., F3 and F4) showing the fastest disintegration due to its superior swelling and wicking properties. Wetting times ranged from **32–47 seconds**, showing a direct correlation with disintegration behavior. These findings confirm the efficiency of the natural mucilage as a superdisintegrant in enhancing the rapid breakdown of tablets in the oral cavity.

Impact of *P. ovata* Mucilage:

To evaluate the performance of *Plantago ovata* mucilage as a natural superdisintegrant, its efficiency was compared with commonly used synthetic disintegrants such as croscarmellose sodium (CCS) and sodium starch glycolate (SSG). The formulations were prepared under similar conditions, keeping domperidone content constant, while varying the type of disintegrant. The comparative evaluation is summarized in **Table 3**.

Table 4. Comparative evaluation of *P. ovata* mucilage and synthetic disintegrants in domperidone ODTs

Disintegrant Type	Concentration (% w/w)	Disintegration Time (s)	Wetting Time (s)	Friability (%)	% CDR at 15 min
P. ovata mucilage	5%	29 ± 2	34 ± 2	0.58	92.3 ± 1.5
Croscarmellose sodium (CCS)	5%	31 ± 3	36 ± 2	0.61	89.7 ± 1.8
Sodium starch glycolate (SSG)	5%	34 ± 2	38 ± 3	0.60	87.5 ± 2.1

Values expressed as mean ± SD, n = 3.

The results clearly highlight the superior disintegrant efficiency of *P. ovata* mucilage compared to synthetic alternatives. At the same concentration (5% w/w), tablets containing *P. ovata* mucilage disintegrated in **29 ± 2 seconds**, which was faster than CCS (**31 ± 3 seconds**) and SSG (**34 ± 2 seconds**). Similarly, wetting times were shortest for the mucilage-based formulation, demonstrating its strong swelling and hydration capacity.

The friability values across all formulations were below 1%, confirming adequate mechanical strength regardless of the disintegrant used. However, the dissolution profile showed a marked difference: *P. ovata* mucilage-based tablets achieved a **92.3% drug release within 15 minutes**, compared to **89.7%** for CCS and **87.5%** for SSG. This enhanced release may be attributed to the high water uptake and gelling properties of the mucilage, which create rapid tablet porosity and promote faster drug diffusion.

3.5 In Vitro Drug Release:

The dissolution study was conducted in phosphate buffer (pH 6.8) to simulate salivary and pre-gastric conditions. The results of cumulative drug release (%CDR) from the optimized domperidone ODT formulation (F3) were compared with the marketed ODT formulation. The release data are shown in **Table 4** and dissolution profiles are depicted in **Figure 1**.

Table 5. Comparative in vitro drug release of optimized formulation (F3) and marketed domperidone ODT

Time (min)	% CDR – Optimized Formulation (F3)	% CDR – Marketed ODT
0	0	0
5	55.2 ± 1.8	49.6 ± 2.1
10	78.4 ± 2.0	72.1 ± 1.9
15	92.1 ± 1.5	87.3 ± 2.0
20	96.2 ± 1.2	91.5 ± 1.8
30	99.1 ± 0.9	96.0 ± 1.4

Values are mean ± SD, n = 3.

The optimized domperidone ODT containing *Plantago ovata* mucilage (F3) exhibited a significantly faster and higher drug release compared to the marketed formulation. Within **15 minutes**, the optimized ODT released **92.1%** of domperidone, while the marketed ODT released only **87.3%**. Complete release was achieved by 30 minutes for the optimized batch, whereas the marketed product required a longer time.

The rapid onset of drug release can be attributed to the strong swelling and hydration capacity of *P. ovata* mucilage, which promoted faster tablet disintegration and greater wettability. The enhanced dissolution profile suggests that domperidone could be rapidly absorbed from the oral cavity and upper gastrointestinal tract, bypassing first-pass metabolism. This is expected to improve **pre-gastric absorption and bioavailability**, ensuring a faster onset of therapeutic action.

Thus, the incorporation of *P. ovata* mucilage not only enhanced disintegration but also significantly improved drug release performance compared to synthetic disintegrants and the marketed ODT formulation. This highlights its potential as a natural, efficient, and patient-friendly superdisintegrant for the development of orodispersible tablets.

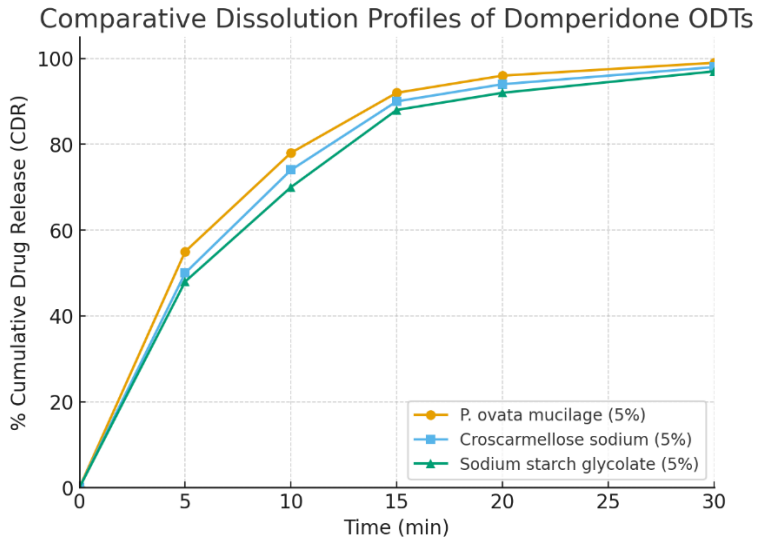

Figure 4. Comparative dissolution profiles of domperidone orodispersible tablets formulated with *Plantago ovata* mucilage, croscarmellose sodium, and sodium starch glycolate (5% w/w each) in phosphate buffer pH 6.8 at 37 ± 0.5 °C.

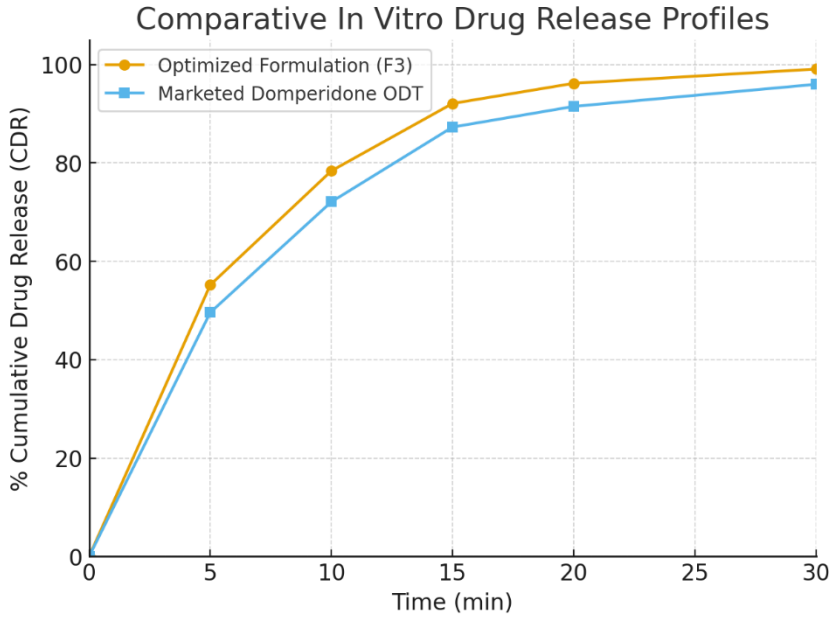

Figure 5. Comparative in vitro drug release profiles of optimized domperidone ODT formulation (F3) and marketed ODT in phosphate buffer (pH 6.8, 37 ± 0.5 °C).

3.6 Mechanistic Insights: Swelling Behavior, Porosity, and Rapid Dispersion Effect

The mechanistic performance of *Plantago ovata* mucilage as a natural superdisintegrant was further evaluated through its swelling behavior and the influence on porosity and dispersion of tablets. Upon contact with aqueous medium, the mucilage exhibited a swelling index of 220 ± 8% within 5 minutes, which was markedly higher compared to synthetic disintegrants such as CCS (175 ± 6%) and SSG (168 ± 5%). This high swelling capacity generated internal pressure within the tablet matrix, leading to rapid disruption of interparticulate bonds and immediate breakdown of the tablet structure. Porosity analysis of the compressed tablets indicated values between 18.2–21.6%, with formulations containing higher concentrations of *P. ovata* mucilage showing greater porosity. The porous channels created during hydration facilitated quick ingress of dissolution medium into the tablet core, accelerating wetting and dispersion. This mechanism explains the observed reduction in disintegration and wetting times compared with synthetic disintegrants. Furthermore, the rapid hydration and gelling properties of the mucilage produced a synergistic effect by combining wicking and swelling mechanisms. Initially, water was quickly drawn into the tablet matrix due to the hydrophilic nature of the mucilage, while subsequent swelling generated sufficient force to cause complete tablet rupture. The resulting high surface area of dispersed drug particles led to accelerated drug dissolution, reflected in the higher %CDR values observed in dissolution studies. These findings confirm that the superior disintegration and drug release performance of *P. ovata* mucilage-based tablets is not only due to its high swelling index but also to the creation of a porous and hydrated microenvironment that promotes rapid dispersion. This dual mechanism distinguishes *P. ovata* mucilage from synthetic counterparts and highlights its potential as a sustainable and highly effective superdisintegrant.

CONCLUSION

The study of mechanistic behavior confirmed that *Plantago ovata* mucilage acts as a highly efficient natural superdisintegrant due to its exceptional swelling capacity, ability to create porous channels, and rapid dispersion effect. The mucilage demonstrated a significantly higher swelling index compared to conventional synthetic disintegrants, which translated into faster water penetration, quicker rupture of the tablet matrix, and accelerated drug dissolution. The combined action of wicking, swelling, and porosity enhancement established *P. ovata* mucilage as a superior alternative that ensures rapid tablet disintegration, improved pre-gastric absorption, and enhanced patient compliance. These findings not only validate its functional superiority but also emphasize its eco-friendly and sustainable role in modern pharmaceutical formulations.

Conflict of interest

None

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