RESEARCH PAPER

Extraction, Physicochemical Characterization and Pharmaceutical Evaluation of Fruit-Derived Polysaccharides from Momordica dioica as a Natural Tablet Binder

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Abstract

Natural polysaccharides from plant sources are increasingly explored as pharmaceutical excipients due to their biocompatibility, biodegradability, and functional versatility. This study reports the extraction, characterization, and pharmaceutical evaluation of polysaccharides isolated from the fruit pulp of *Momordica dioica* Roxb. The polymer was obtained through aqueous extraction, alkaline purification, and acetone precipitation, yielding 1.6% of a white to cream-colored amorphous powder. The isolated polysaccharide exhibited a near-neutral pH (6.9) and moderate viscosity (85 cP), indicating suitability for oral dosage formulations.

FTIR analysis confirmed characteristic polysaccharide functional groups, including hydroxyl, aliphatic C–H, carboxylate, and glycosidic linkages, suggesting the presence of acidic pectic domains. DSC studies demonstrated thermal stability, with moisture loss occurring between 95–112 °C, a structural transition at 141.43 °C, and degradation onset at 237.10 °C. The polymer was evaluated as a natural binder (15% w/w) in placebo tablets prepared by wet granulation and compared with starch-based tablets. Tablets containing *M. dioica* polysaccharide showed satisfactory hardness (7.5 ± 0.10 kg/cm²), acceptable friability (0.92%), and significantly prolonged disintegration time (14.0 ± 0.20 min) compared with starch tablets (5.0 ± 0.10 min). Statistical analysis confirmed a highly significant difference in disintegration behavior ($p < 0.001$).

The extended disintegration profile is attributed to the gel-forming and water-retardant properties of the polysaccharide. These findings demonstrate the potential of *M. dioica*-derived polysaccharides as eco-friendly, plant-based binders for modified-release oral solid dosage formulations.

Keywords: *Momordica dioica*; natural polysaccharide; Pharmaceutical Excipient; Tablet Binder; sustained-release formulation; FTIR; DSC; wet Granulation; ANOVA

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1. Introduction

The growing demand for sustainable, biocompatible pharmaceutical excipients has directed considerable research attention toward naturally derived polysaccharides as functional alternatives to synthetic polymers. Plant-based polysaccharides offer inherent advantages including biodegradability, low toxicity, structural diversity, and a broad spectrum of physicochemical properties that can be exploited in solid dosage form design particularly as binders, disintegrants, film-formers, and matrix-forming

agents in controlled-release systems [1,2].*Momordica dioica* Roxb. ex Willd. (family Cucurbitaceae), commonly known as spiny gourd or teasel gourd, is a perennial dioecious climber widely distributed across tropical and subtropical regions of South Asia, Southeast Asia, and Africa. The plant holds a documented position in traditional Ayurvedic medicine, where various parts including the fruit, root, and leaf have been employed in the management of diabetes, inflammation, hepatic disorders, and skin ailments [3,4]. Phytochemical investigations have identified a diverse array of secondary metabolites in *M. dioica*, including cucurbitacins, triterpenoids, saponins, flavonoids, carotenoids, and carbohydrate polymers, with the fruit pulp being particularly rich in bioactive constituents [5,6].

Figure 1*: Momordica dioica* plant

Despite the well-documented ethnopharmacological relevance of *M. dioica*, the polysaccharide fraction of its fruit pulp remains largely unexplored from a pharmaceutical excipient perspective. Polysaccharides from related Cucurbitaceae species including *Momordica charantia*, *Cucurbita moschata*, and *Cucumis sativus* have been characterized as pectic heteropolysaccharides and xyloglucan-type hemicelluloses exhibiting favorable rheological, gelling, and immunomodulatory properties [7,8]. These structural and functional parallels provide a rational basis for investigating the analogous polysaccharide fraction of *M. dioica* fruit pulp as a candidate pharmaceutical excipient.

Conventional polysaccharide extraction from plant matrices presents well-recognized challenges, including co-isolation of proteins, phenolics, and lipids, partial degradation of thermolabile fractions during hot water extraction, and low selectivity of precipitation techniques [9]. In the present study, a sequential extraction protocol combining aqueous boiling, mild alkaline treatment with sodium hydroxide, and acetone precipitation was adopted to maximize polysaccharide recovery while minimizing contamination by non-carbohydrate impurities. The isolated polymer was subjected to comprehensive physicochemical characterization using viscometry, FTIR spectroscopy, and Differential Scanning Calorimetry (DSC) to establish its identity and thermal behavior. Subsequently, the excipient potential of the isolated *M. dioica* polysaccharide (MDP) was evaluated in placebo tablet formulations prepared by wet granulation, with conventional maize starch serving as a reference binder. Tablet characterization encompassed mechanical hardness, disintegration behavior, and batch uniformity assessment, with statistical validation performed using one-way Analysis of Variance (ANOVA).

The present investigation therefore aims to: (i) develop a reproducible and cost-effective method for isolating polysaccharides from the fruit pulp of Momordica dioica; (ii) characterize the isolated polymer using spectroscopic and thermal analytical techniques; and (iii) evaluate its performance as a natural binder in tablet formulations with particular reference to delayed disintegration behavior. Based on available literature evidence, limited studies have explored the pharmaceutical excipient potential of fruit-derived polysaccharides from this plant.

2. Materials and Methods

2.1 Plant Material and Sample Collection

Fresh fruits of *Momordica dioica* Roxb. ex Willd. were procured from a local agricultural market in Nashik, Maharashtra, India, during the peak harvesting season to ensure optimal pulp development and phytochemical content. Both mature and semi-mature fruits were selected on the basis of morphological criteria ovoid to ellipsoid shape, surface spines intact, color ranging from deep green (immature) to yellow-orange (mature), with firm, gelatinous pulp surrounding the seeds. Fruits exhibiting signs of microbial spoilage, physical damage, or over-ripening were excluded from the study. The plant species was authenticated by its characteristic morphological features: palmately lobed bright green leaves (5–10 cm), climbing tendrils, and heavily spine-coated fruits measuring 3–5 cm in length. The collected fruits were transported to the laboratory under hygienic conditions and processed within 24 hours of collection to minimize enzymatic degradation and oxidative deterioration of the polysaccharide fraction.

2.2 Chemicals and Instrumentations

All chemicals used in this study were of analytical reagent grade unless otherwise specified. Sodium hydroxide (0.25 N, NaOH) and acetone were obtained from Merck Life Sciences Pvt. Ltd., India. Lactose monohydrate, sodium starch glycolate, maize starch, sodium methylparaben, propylparaben, talc, and magnesium stearate were sourced from standard pharmaceutical suppliers and complied with the specifications of the Indian Pharmacopoeia (IP 2022) and/or British Pharmacopoeia (BP 2023). Distilled water was prepared in-house using a double-distillation assembly.

The instrumentation employed in this study included a Brookfield DV-E Viscometer (Brookfield Engineering Laboratories, USA) for viscosity measurement; a calibrated digital pH meter (Systronics Model 361, India); a hot air oven (Memmert, Germany) for drying; a single-punch tablet press equipped with 10 mm flat-faced punches for compression; a USP standard disintegration apparatus (Electrolab ED-2L, India); a Monsanto hardness tester; a Fourier-Transform Infrared (FTIR) spectrometer (PerkinElmer Spectrum Two, USA) for structural characterization; and a Differential Scanning Calorimeter (DSC 4000, PerkinElmer, USA) for thermal analysis.

2.3 Extraction and Isolation of Polysaccharide

The extraction procedure was carried out in a systematic, multi-step sequence designed to selectively isolate the polysaccharide fraction from the fruit pulp matrix while removing interfering non-polysaccharide components.

Pre-treatment and pulp preparation: Fresh *M. dioica* fruits were thoroughly washed under running tap water followed by rinsing with distilled water to eliminate surface contaminants. The outer exocarp was manually removed using a sterile stainless-steel knife, and the inner mesocarp (pulp) was carefully separated, avoiding inclusion of seeds and seed-associated mucilage. The pulp was weighed (50 g per batch) and subjected to further processing.

Alkaline pre-treatment: The weighed pulp was immersed in 0.25 N sodium hydroxide solution (500 mL) in a covered beaker and maintained at ambient temperature (25 ± 2°C) for 24 hours with intermittent stirring. This alkaline treatment serves to solubilize and remove lignin, phenolic compounds, proteins, and other non-polysaccharide constituents that would otherwise co-precipitate with the target polymer, thereby improving the purity of the final isolate [10]. Following alkaline treatment, the pulp was removed and thoroughly rinsed with distilled water until the washings were neutral to pH paper, confirming complete removal of residual alkali.

Aqueous extraction: The neutralized pulp was coarsely ground using a mortar and pestle and transferred to a 500 mL borosilicate glass beaker containing 100 mL of distilled water. The suspension was subjected to boiling under continuous stirring at 100°C for 60 minutes to ensure maximum solubilization of hydrophilic polysaccharides from the disrupted cell matrix. The resulting homogenate was cooled to room temperature and further homogenized using a mechanical homogenizer (3000 rpm, 5 minutes) to achieve a uniform dispersion and maximize polysaccharide release from residual intact cells. The homogenized suspension was allowed to macerate at room temperature for an additional 24 hours to permit complete hydration and diffusion of soluble polysaccharide chains into the aqueous phase.

Filtration and precipitation: The macerated suspension was passed through double-layered muslin cloth under moderate pressure to remove coarse particulate matter, yielding a clarified filtrate. To approximately 50 mL of the collected filtrate, 60 mL of cold acetone (4°C) was added dropwise with constant stirring. Acetone acts as a non-solvent for polysaccharides, reducing their solubility in the aqueous medium and inducing their precipitation as a cream-colored flocculent mass through a mechanism of dehydration and polymer chain aggregation [11]. The mixture was allowed to stand for 30 minutes to ensure complete precipitation.

Collection and drying: The precipitate was recovered by filtration through Whatman No. 1 filter paper under vacuum, transferred to a pre-weighed petri dish, and dried in a hot air oven at 40–50°C until a constant dry weight was achieved (approximately 18–24 hours). The dried product was gently pulverized using a mortar and pestle, passed through a 60-mesh sieve to obtain a uniform fine powder, and stored in a tightly sealed amber glass vial at room temperature (25 ± 2°C, relative humidity ≤ 45%) until further use.

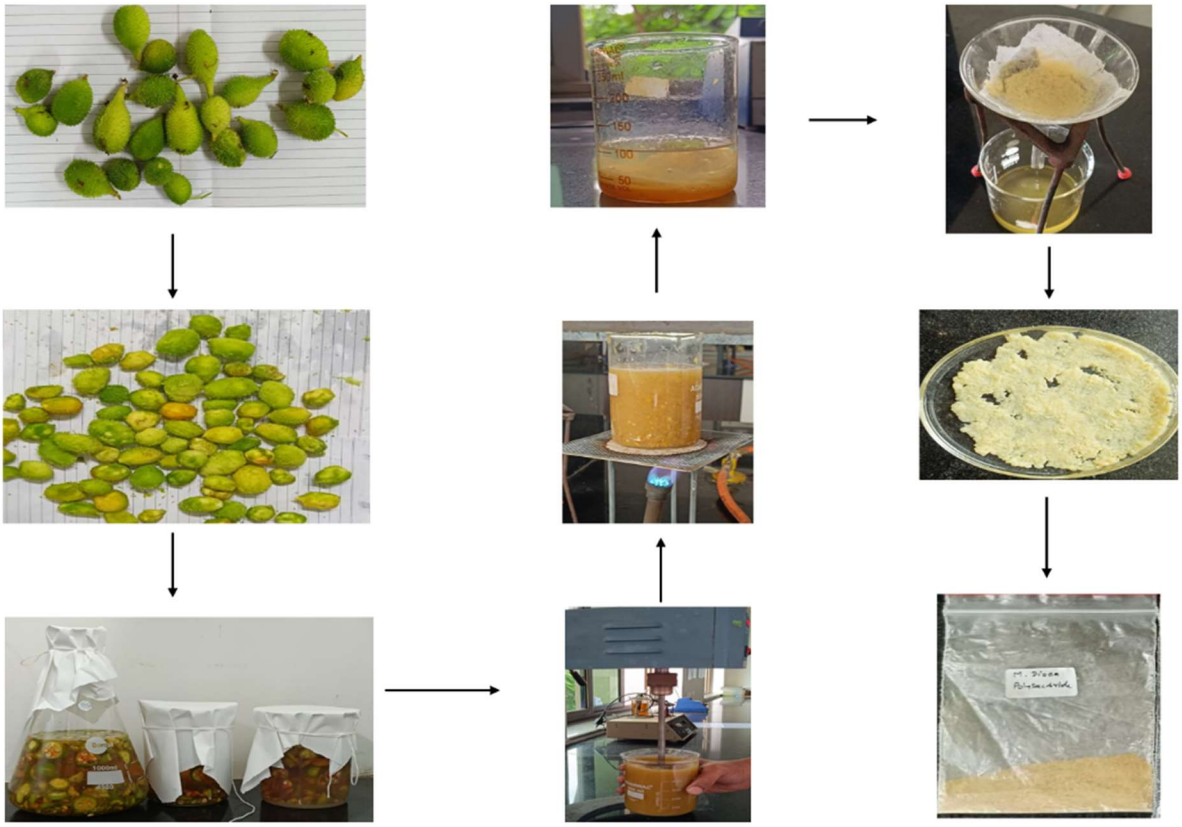

Figure 2. Experimental workflow for extraction, isolation and pharmaceutical evaluation of fruit-derived polysaccharide from

2.4 Physicochemical and Organoleptic Characterization of Isolated Polysaccharide

2.4.1 Organoleptic Properties

The isolated polysaccharide was evaluated for appearance (color and texture), physical state, odor, and taste by trained sensory evaluation in accordance with standard pharmacognostic procedures [12].

2.4.2 Percentage Yield

The percentage yield of the isolated polysaccharide was calculated gravimetrically using the following expression:

$$\% \textbf{ Yield} = \frac{\textbf{Weight of Dried Polysaccharide Obtained}}{\textbf{Weight of Fresh Fruit Pulp Processed}} \times \textbf{100}$$

2.4.3 pH Determination

The pH of the isolated polysaccharide was determined by preparing a 1% w/v aqueous dispersion in freshly boiled and cooled distilled water. The dispersion was continuously stirred for 2 hours to ensure complete hydration and homogeneity. Measurement was performed using a pre-calibrated digital pH meter (calibrated with standard buffer solutions at pH 4.0 and 7.0) at 25 ± 1°C. Triplicate readings were recorded and the mean value reported.

2.4.4 Viscosity Measurement

Viscosity of a 1% w/v aqueous dispersion of the isolated polysaccharide was determined using a Brookfield DV-E Viscometer at a controlled temperature of 25 ± 1°C. The sample was allowed to hydrate under magnetic stirring for 24 hours prior to measurement to ensure complete polymer chain uncoiling and equilibration. Measurement was performed using spindle No. 64 at a rotational speed of 100 rpm, and the viscosity value was expressed in centipoise (cP).

2.5 Structural Characterization by FTIR Spectroscopy

Fourier-Transform Infrared (FTIR) spectroscopy was performed to identify the characteristic functional groups and structural features of the isolated polysaccharide. Approximately 2 mg of the dried polymer was blended with 200 mg of anhydrous potassium bromide (KBr) and compressed into a transparent disc under hydraulic pressure (10 tons). The KBr pellet was scanned over a wavenumber range of 4000–400 cm^{-1} at a spectral resolution of 4 cm^{-1},

using 16 co-added scans to improve signal-to-noise ratio. A background spectrum of pure KBr was recorded and subtracted prior to sample analysis. The resulting spectrum was interpreted with reference to standard infrared absorption frequency tables [13] and published FTIR data for plant-derived polysaccharides from the Cucurbitaceae family.

2.6 Thermal Analysis by Differential Scanning Calorimetry (DSC)

DSC analysis was conducted to evaluate the thermal behavior, stability, and phase transitions of the *M. dioica* polysaccharide formulation. Accurately weighed samples (5–10 mg) were sealed in standard aluminum pans with a pinhole lid to allow vapor release, with an empty sealed pan serving as the reference. Samples were heated from 30°C to 300°C at a programmed heating rate of 10°C/min under a nitrogen gas purge (flow rate: 50 mL/min) to prevent oxidative degradation. Onset, peak, and endset temperatures, along with enthalpy values (mJ), were determined from the resulting thermogram using the instrument's integrated software (Pyris Software, PerkinElmer).

2.7 Formulation of Placebo Tablets by Wet Granulation

Table 1. Composition of 200 mg Placebo Tablets Prepared by Wet Granulation

Sr. No.	Ingredient	Function	F-MDP (mg/tablet)	F-Starch (mg/tablet)
1	Lactose monohydrate	Diluent / Filler	148.8	148.8
2	*Momordica dioica* polysaccharide	Binder (15% w/w)	30	—
3	Maize starch	Binder (15% w/w)	—	30
4	Sodium starch glycolate	Disintegrant (5% w/w)	10	10
5	Sodium methylparaben	Preservative	0.8	0.8
6	Propylparaben	Preservative	0.4	0.4
7	Talc	Glidant (4% w/w)	8	8
8	Magnesium stearate	Lubricant (1% w/w)	2	2
	Total tablet weight		200 mg	200 mg

2.7.1 Tablet Composition

Two placebo tablet formulations were prepared, each with a target tablet weight of 200 mg. Formulation F-MDP incorporated the isolated *M. dioica* polysaccharide (MDP) as the binder at a concentration of 15% w/w, while formulation F-Starch employed conventional maize starch at an equivalent concentration as the reference binder. All other excipients lactose monohydrate (filler), sodium starch glycolate (disintegrant, 5%), sodium methylparaben and propylparaben (preservatives), talc (glidant, 4%), and magnesium stearate (lubricant, 1%) were maintained at identical levels across both formulations to ensure a single-variable comparative study. The complete formulation composition is presented in **Table 1**.

2.7.2 Preparation of Binder Solution

A 5% w/v binder solution of the isolated Momordica dioica polysaccharide was prepared by dispersing 0.6 g of polymer in 12 mL of warm distilled water. The total quantity of binder corresponded to the required batch size of 20 tablets, each containing 30 mg binder (15% w/w of total tablet weight). The binder solution was used as the granulating fluid during wet granulation. The solution was allowed to cool to 40°C before use. For the F-Starch batch, an equivalent starch paste (5% w/v) was prepared by dispersing maize starch in cold water followed by heating to gelatinization (85–90°C) with constant stirring, then cooling to 40°C before application.

2.7.3 Wet Granulation Process

All solid excipients were accurately weighed on a calibrated analytical balance and individually passed through a 44-mesh (355 µm) sieve to break agglomerates and ensure uniform particle size distribution. The sieved powders were blended geometrically in a clean dry mortar for 5 minutes to achieve a homogeneous dry mix. The respective binder solution was added incrementally to the dry blend with continuous kneading until a cohesive, non-sticky, pliable wet mass of appropriate consistency was obtained. The endpoint of wet massing was determined by the formation of granules that retained their shape when compressed between the fingers without crumbling or sticking.

The wet mass was passed through a 22-mesh (710 µm) stainless steel sieve to produce uniform wet granules, which were spread in a thin layer on trays and dried in

a hot air oven at 40–45°C for 30–45 minutes. Dried granules were re-sieved through a 22-mesh screen to break any lumps formed during drying. Residual moisture content was verified to be below 3% by loss on drying (LOD) at 105°C. Talc and magnesium stearate were added to the dried granules and blended for 2 minutes to complete lubrication. The lubricated blend was compressed into tablets using a single-punch tablet press fitted with 10 mm round, flat-faced punches, with the compression force adjusted to yield tablets within the target hardness range of 4–8 kg/cm².

2.8 Characterization of Formulated Tablets

2.8.1 Hardness

Tablet crushing strength was determined using a Monsanto hardness tester. Three tablets from each formulation batch were individually tested, and results were expressed as mean ± standard deviation (SD) in kg/cm². An acceptable hardness range of 4–8 kg/cm² was used as the evaluation criterion in accordance with standard pharmaceutical quality control guidelines.

2.8.2 Disintegration Test

The disintegration time of tablets from both formulations (F-MDP and F-Starch) was determined using a USP standard disintegration apparatus (Electrolab ED-2L) at a temperature of 37 ± 0.5°C, using distilled water as the disintegration medium. Three tablets per batch were placed individually in the disintegration tubes and subjected to the standard up-and-down mechanical motion (30 cycles/min). The time at which no residue remained on the mesh screen was recorded as the disintegration endpoint. Results were reported as mean ± SD in minutes.

2.9 Statistical Analysis

All data are expressed as mean ± standard deviation (SD) of triplicate determinations unless otherwise stated. To evaluate the statistical significance of differences in tablet disintegration time between formulations F-MDP and F-Starch, one-way Analysis of Variance (ANOVA) was performed using the disintegration time values from three independent trials per formulation. The F-statistic was calculated manually from the between-group (SSB) and within-group (SSW) sums of squares, with a significance threshold set at $\alpha = 0.05$. The calculated F-value was compared against the critical F-value (F-critical) obtained from standard F-distribution tables at the corresponding degrees of freedom. Intra-batch uniformity for tablet hardness was assessed by computing the coefficient of variation (CV%), with a CV below 5% considered indicative of acceptable batch homogeneity.

3. Results and Discussion

3.1 Organoleptic and Physicochemical Characterization of Isolated Polysaccharide

The polysaccharide isolated from the fruit pulp of *Momordica dioica* was obtained as a white to cream-colored, fine amorphous powder exhibiting no characteristic odor or taste. The absence of objectionable organoleptic properties is a prerequisite for pharmaceutical excipient acceptability, particularly in oral dosage forms where patient compliance and formulation palatability are important considerations [14]. The amorphous physical state of the isolated polymer is consistent with observations reported for polysaccharides isolated from related Cucurbitaceae species, including *Momordica charantia* and *Cucurbita moschata*, where the lack of long-range crystalline order is attributed to the heterogeneous, branched structural architecture of the polysaccharide chains [7,15]. A summary of the organoleptic and physicochemical parameters is presented in **Table 2**.

3.2 Percentage Yield

A gravimetric yield of **1.6 %** (w/w, based on fresh fruit pulp weight) was obtained from the aqueous extraction and acetone precipitation process. Quantitatively, 0.78 g of dry polysaccharide was recovered from 50 g of processed fruit pulp. Although the absolute yield appears modest, such values are characteristic of natural polysaccharide isolation from fresh plant matrices, where the target polymer constitutes only a minor fraction of the total dry matter alongside cellulose, hemicellulose, pectin, proteins, and inorganic salts embedded within a complex cell wall architecture [9]. Comparable yield values have been reported for polysaccharides isolated from *M. charantia* fruit by aqueous extraction (1.2–2.8 %) [16] and from *Cucurbita pepo* pulp (1.8 %) [17], supporting the reproducibility of the adopted protocol. The yield in polysaccharide extraction is known to be influenced by several interrelated factors, including the maturity stage of the fruit at the time of collection, the solid-to-solvent ratio employed during aqueous extraction, extraction temperature and duration, the concentration of the precipitating agent, and the efficiency of the pre-treatment step in removing competing non-polysaccharide macromolecules [9,11]. Optimization of these parameters through response surface methodology (RSM) or Box-Behnken design in future investigations may substantially improve the extraction yield without compromising the structural integrity of the isolated polymer.

3.3 pH of Aqueous Dispersion

The pH of a 1% w/v aqueous dispersion of the isolated *M. dioica* polysaccharide was determined to be **6.9**, indicating a near-neutral behavior in dilute aqueous solution. This value is well within the pH range of 6.0–7.5 considered compatible with the physiological conditions of the oral cavity, esophagus, and upper

gastrointestinal tract, thereby minimizing the risk of mucosal irritation or acid-catalyzed hydrolysis of glycosidic linkages during transit [18]. The near-neutral pH further confirms the effective neutralization of residual alkali following the 0.25 N NaOH pre-treatment step, indicating that the washing protocol adopted was adequate for complete removal of sodium hydroxide from the polymer matrix.

From a formulation perspective, a near-neutral polymer pH is advantageous for compatibility with a broad range of active pharmaceutical ingredients (APIs), particularly those that are pH-sensitive or susceptible to base-catalyzed degradation. The pH value of 6.9 observed in this study is comparable to values reported for mucilage's and polysaccharides isolated from other Cucurbitaceae fruits, including *Cucumis sativus* (pH 6.7) and *Lagenaria siceraria* (pH 6.8) [19], further establishing *M. dioica* polysaccharide within the physicochemical profile expected of this plant family.

3.4 Viscosity

The viscosity of the 1% w/v aqueous polysaccharide dispersion was measured at **85 cP** at 25 ± 1°C using a Brookfield DV-E Viscometer (spindle No. 64, 100 rpm). This moderate viscosity value reflects the capacity of the isolated polymer to form a structured, viscoelastic network upon hydration a property directly attributable to the intermolecular hydrogen bonding between hydroxyl-rich polysaccharide chains and surrounding water molecules, as well as chain entanglement at sufficiently high polymer concentrations [20].

In the context of tablet formulation, the viscosity of the binder solution is a critical determinant of granule quality. Binder solutions of excessively low viscosity fail to impart adequate cohesive strength to the granule bed, while those of very high viscosity result in over-wetting, extended drying times, and compromised disintegration behavior [21]. The viscosity of 85 cP observed for the 1% w/v MDP dispersion suggests a binder solution of moderate rheological character one that is expected to distribute uniformly within the powder bed during wet massing without inducing over-granulation. This is consistent with previously reported viscosity values for natural polysaccharide binders including okra mucilage (72–98 cP at 1% w/v) [22] and *Hibiscus rosa-sinensis* mucilage (80–95 cP at 1% w/v) [23], which have demonstrated satisfactory binder performance in wet granulation processes. Furthermore, the gel-forming propensity implied by the moderate viscosity profile provides a mechanistic basis for the prolonged disintegration behavior observed in F-MDP tablets (discussed in Section 3.7), wherein hydrated polysaccharide chains form a viscous diffusion barrier at the tablet surface that retards water ingress and delays disintegrant activation.

Table 2. Organoleptic and Physicochemical Properties of Isolated *Momordica dioica* Polysaccharide

Parameter	Observation / Value
Physical appearance	White to cream-colored fine powder
Physical nature	Amorphous
Odor	Odorless
Taste	Tasteless
pH (1% w/v aqueous dispersion)	6.9
Viscosity (1% w/v, 25°C, 100 rpm)	85 cP
Percentage yield (w/w)	1.6%

3.5 FTIR Spectroscopic Analysis

FTIR spectroscopy was employed to identify the principal functional groups and structural features of the isolated *M. dioica* polysaccharide, with assignments made by reference to established infrared absorption standards [13] and published spectral data for Cucurbitaceae-derived polysaccharides [7,8]. The complete spectral assignments are summarized in **Table 3**.

The most prominent absorption feature in the spectrum was a broad, intense band centered at **3699.1 cm^{-1}**, corresponding to O–H stretching vibrations of hydroxyl groups engaged in extensive intermolecular and intramolecular hydrogen bonding a hallmark of carbohydrate-rich macromolecules [13]. The breadth and intensity of this band are characteristic of polysaccharides bearing multiple free hydroxyl groups on each monosaccharide unit, consistent with the galactose, rhamnose, arabinose, and glucuronic acid residues commonly reported in Cucurbitaceae fruit polysaccharides [7].

Two distinct absorption bands at **2976.4 cm^{-1}** and **2928.6 cm^{-1}** were attributed to the asymmetric and symmetric C–H stretching vibrations of methylene (–CH_2–) and methyl (–CH_3) groups, respectively, arising from the aliphatic carbon framework of the sugar ring backbone. These bands are universally present in polysaccharide FTIR spectra and serve as confirmatory markers of the carbohydrate nature of the isolated material [24].

A significant absorption band at **1655.0 cm^{-1}** was assigned to the asymmetric stretching vibration of carboxylate anions (COO^-) associated with uronic acid residues most probably galacturonic acid within the polysaccharide backbone. The presence of uronic acid functionality is of particular pharmaceutical relevance, as carboxylate-bearing polysaccharides exhibit pH-dependent swelling behavior that can be leveraged in colon-targeted and pH-responsive drug delivery systems [25]. The complementary symmetric stretching of the carboxylate group was confirmed by the absorption at **1435.4 cm^{-1}**, and together these two bands satisfy the diagnostic criteria for a free carboxylate salt rather than an esterified carbonyl, suggesting that the uronic acid residues are predominantly in their ionized (salt) form under the near-neutral extraction conditions employed.

The absorption region between **1222.0 and 1000 cm^{-1}** exhibited intense, complex overlapping bands attributable to C–O–C asymmetric stretching of glycosidic linkages and C–O stretching of the pyranose ring the most diagnostic spectral zone for confirming the polymeric carbohydrate identity of an unknown sample [13,24]. Finally, the band at **840.08 cm^{-1}** was assigned to C–H deformation vibrations of α-configured anomeric carbon atoms within pyranose sugar residues, consistent with α-glycosidic linkages suggestive of pectic acidic polysaccharide characteristics [26].

Taken together, the FTIR spectral profile conclusively confirms the polysaccharide identity of the isolated *M. dioica* polymer, with structural features hydroxyl groups, uronic acid carboxylates, glycosidic C–O–C linkages, and α-anomeric configurations consistent with an acidic heteropolysaccharide of the rhamnogalacturonan type, analogous to pectic polysaccharides previously characterized from *Momordica charantia* [16] and other Cucurbitaceae species [8, 26].

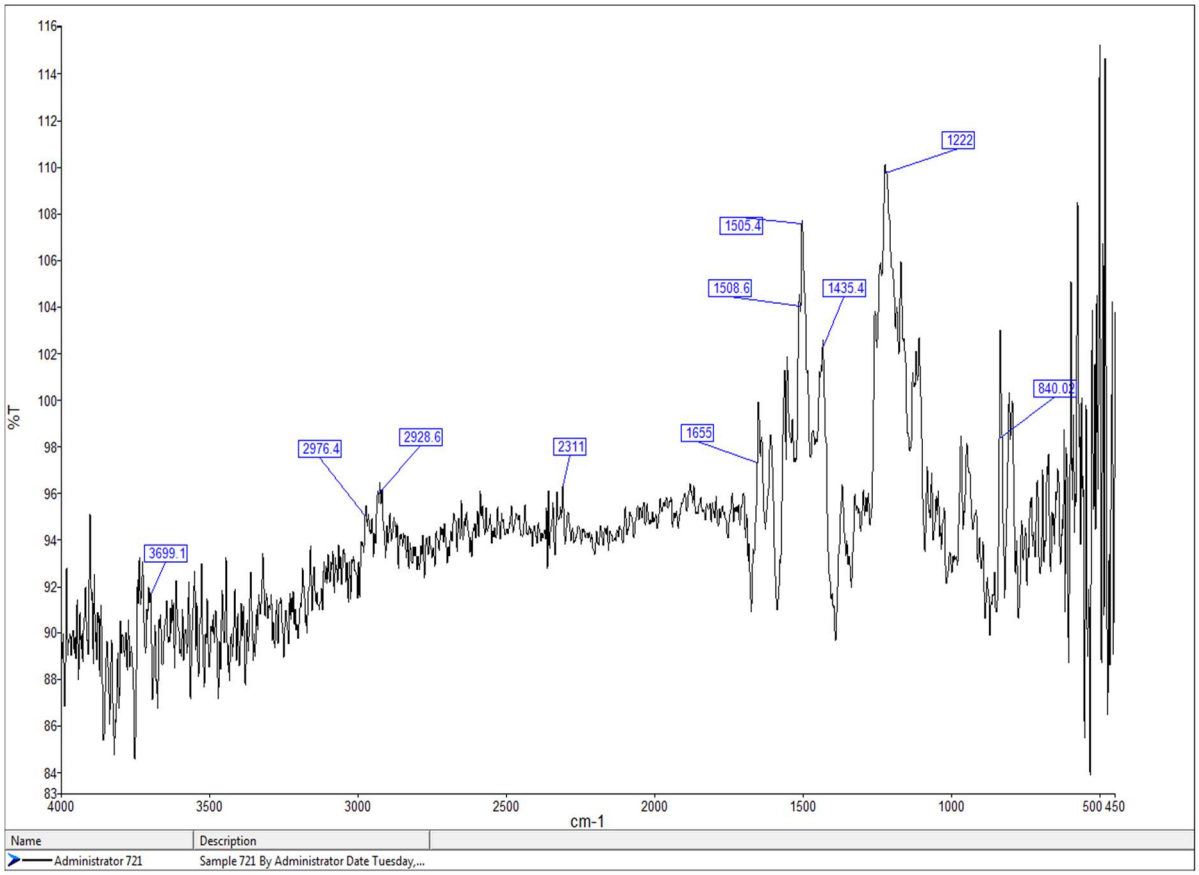

Figure 3. FTIR graph showing different peaks.

Table 3. FTIR Spectral Assignments for Isolated *Momordica dioica* Polysaccharide

Observed Peak (cm^{-1})	Standard IR Range (cm^{-1})	Vibrational Assignment	Functional Group	Interpretation
3699.1	3700–3200	O–H stretching (H-bonded)	Hydroxyl (–OH)	Broad, intense band confirming hydrogen-bonded hydroxyl groups characteristic of polysaccharides
2976.4	2975–2850	C–H asymmetric stretching ($–CH_3$)	Aliphatic methyl groups	Aliphatic C–H vibration of sugar ring carbon framework
2928.6	2930–2850	C–H symmetric stretching ($–CH_2–$)	Methylene groups	Confirms aliphatic backbone of hexose/pentose sugar units
2311.0	2350–2300	Weak overtone / CO_2 interference	Atmospheric CO_2 or O–H overtone	Weak, low-intensity band; consistent with environmental CO_2 artifact
1655.0	1650–1600	COO^- asymmetric stretching	Carboxylate of uronic acid (galacturonic acid)	Confirms uronic acid presence; indicative of pectic-type acidic polysaccharide
1508.6 / 1505.4	1510–1490	Aromatic C=C / N–H bending	Phenolic content or amide II	Minor aromatic or amide contribution from residual protein/phenolic impurities

1435.4	1450–1380	COO^- symmetric stretching / C–H bending	Carboxylate of galacturonic acid / rhamnose	Complements 1655 cm^{-1} band; confirms free ionized carboxylate groups
1222.0	1260–1000	C–O–C asymmetric stretching	Glycosidic linkages and ether bonds	Most diagnostic polysaccharide region; confirms polymeric carbohydrate identity
840.08	900–800	C–H deformation (anomeric carbon)	α-anomeric configuration in pyranose rings	Confirms α-glycosidic linkages typical of suggestive of pectic acidic polysaccharide

3.6 Differential Scanning Calorimetry (DSC) Analysis

DSC analysis of the *M. dioica* polysaccharide formulation revealed a complex thermogram comprising multiple sequential thermal events across the 30–300°C temperature range, reflecting the heterogeneous composition and structural organization of the plant-derived polymer system as shown in **Table 4**.

The first thermal event, a shallow endothermic transition with onset at **95.08 °C** and peak at **104.82 °C** (ΔH = −0.35 mJ), is attributed to the evaporation of loosely associated surface moisture from the hygroscopic polysaccharide matrix. Polysaccharides, by virtue of their abundance of free hydroxyl groups, readily adsorb atmospheric moisture, and the removal of this physically adsorbed water at temperatures approaching 100°C is a well-established thermal signature of carbohydrate-rich materials [27]. The relatively low enthalpy requirement of this transition reflects the small quantity of loosely bound water present in the adequately dried sample.

The second endothermic transition, with onset at **107.45 °C** and peak at **109.44 °C** (ΔH = −1.32 mJ), is distinguished from the first by its higher enthalpy requirement and is assigned to the desorption of more tightly bound water molecules that are associated with specific hydrophilic sites notably the hydroxyl and carboxylate groups within the polysaccharide chain [27,28]. The higher energy input required for this second dehydration event reflects the stronger interaction energy between these water molecules and the polymer's polar functional groups, a characteristic commonly observed in pectin-type polysaccharides containing uronic acid residues [28].

The major endothermic event, centered at a peak temperature of **141.43 °C** (onset 137.01 °C, endset 146.18 °C, ΔH = −10.54 mJ), represents a significant structural transition within the polysaccharide system. The substantially higher enthalpy value associated with this transition, relative to the preceding moisture-loss events, is indicative of a phase transformation involving the disruption of organized intermolecular hydrogen bonding networks and partial thermal transition of semi-crystalline phytoconstituent domains within the complex plant-derived matrix. Comparable endothermic transitions in the range of 130–155 °C have been reported for pectins and pectic polysaccharides isolated from Cucurbitaceae species and have been attributed to the thermal transition of crystalline polysaccharide microdomains stabilized by chain–chain hydrogen bonding [29].

The most pharmaceutically significant observation in the DSC thermogram was the exothermic transition with onset at **237.10 °C**, peak at **240.66 °C**, and endset at **243.11 °C** (ΔH = +16.29 mJ), which is assigned to the onset of thermal degradation involving oxidative decomposition and chain scission of the polysaccharide backbone. The positive enthalpy value confirms the exothermic nature of this degradation process [30]. Critically, the degradation onset temperature of 237°C establishes a wide thermal safety margin for pharmaceutical processing, given that the maximum temperatures encountered during granulation (40–50 °C), fluidized bed drying (50–60 °C), and tablet compression are all substantially below this threshold. This confirms the suitability of *M. dioica* polysaccharide for incorporation into conventional solid dosage manufacturing processes without risk of thermal degradation or structural compromise.

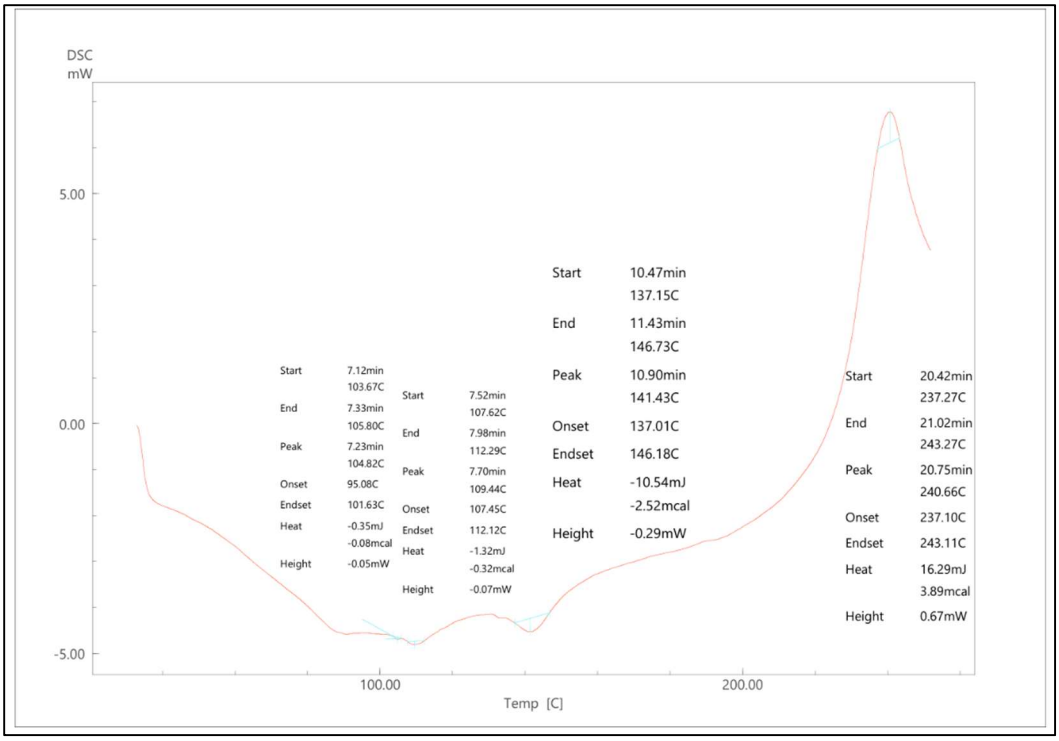

Figure 4: DSC thermograph.

Table 4. DSC Thermal Transitions of *Momordica dioica* Polysaccharide Formulation

Thermal Event	Onset (°C)	Peak (°C)	Endset (°C)	Enthalpy (mJ)	Nature	Interpretation
First transition	95.08	104.82	101.63	−0.35	Endothermic	Evaporation of loosely bound surface moisture
Second transition	107.45	109.44	112.12	−1.32	Endothermic	Desorption of tightly bound water from polar functional groups
Major transition	137.01	141.43	146.18	−10.54	Endothermic	Structural phase transition / thermal transition of semi-crystalline polysaccharide domains
Degradation onset	237.10	240.66	243.11	+16.29	Exothermic	Thermal degradation via oxidative decomposition and chain scission

3.7 Characterization of Formulated Tablets

3.7.1 Disintegration Time

The disintegration behavior of both formulations was assessed as the primary functional performance indicator, given the central hypothesis that *M. dioica* polysaccharide would significantly prolong tablet disintegration relative to conventional starch. The disintegration time data for F-MDP and F-Starch tablets are presented in **Table 5**.

Tablets formulated with *M. dioica* polysaccharide (F-MDP) exhibited a mean disintegration time of **14.0 ± 0.20 minutes**, compared to **5.0 ± 0.10 minutes** for the starch-based reference formulation (F-Starch). The 2.8-fold prolongation in disintegration time observed for F-MDP tablets is a direct consequence of the physicochemical characteristics of the *M. dioica* polysaccharide specifically, its moderate viscosity, gel-forming capacity upon hydration, and the ability of the hydrated polymer chains to form a cohesive, water-retardant diffusion layer at the tablet surface. This gelatinous layer effectively impedes the ingress of the disintegration medium into the tablet core, thereby

delaying the activation of the sodium starch glycolate disintegrant and prolonging the time to complete tablet breakdown [31].

In contrast, maize starch a conventional binder with well-characterized rapid water absorption and swelling behavior promotes disintegration through capillary wicking of water along inter-granular channels and mechanical disruption of the tablet matrix upon rapid swelling of starch granules [32]. The absence of significant gel-layer formation in F-Starch tablets thus permits rapid and unimpeded water penetration, explaining the substantially shorter disintegration time of 5.0 minutes.

The disintegration time of 14 minutes observed for F-MDP tablets, while exceeding the conventional pharmacopoeial limit of 15 minutes for uncoated tablets, falls within a range that is clinically relevant for sustained or extended-release oral formulations, where a retarded disintegration profile is deliberately engineered to control drug release kinetics [33]. The behavior of *M. dioica* polysaccharide in this context is analogous to that of established natural hydrophilic matrix-forming polymers such as hydroxypropyl methylcellulose (HPMC) and xanthan gum, which are routinely employed as rate-retarding agents in sustained-release tablet formulations [34]. This positions *M. dioica* polysaccharide as a promising candidate for controlled-release applications, where its natural origin, biocompatibility, and retardant properties may offer advantages over semi-synthetic or fully synthetic alternatives. The delayed disintegration behavior observed in F-MDP tablets indicates the ability of the isolated polysaccharide to form a hydration-dependent diffusion barrier, suggesting its potential utility in modified-release oral tablet systems. However, further drug-loaded dissolution studies are necessary to validate this application.

Table 5. Disintegration Time Data for F-MDP and F-Starch Tablet Formulations

Trial	F-MDP (min)	F-Starch (min)
1	14.2	5.1
2	13.8	4.9
3	14.0	5.0
Mean ± SD	**14.0 ± 0.20**	**5.0 ± 0.10**

3.7.2 Tablet Hardness

The mean hardness of F-MDP tablets was determined to be **7.5 ± 0.10 kg/cm²** across three replicate determinations (individual values: 7.4, 7.5, and 7.6 kg/cm²), as presented in **Table 6**. This value falls comfortably within the pharmacopoeially accepted range of 4–8 kg/cm² for conventional uncoated tablets, confirming that the compressed tablets possess adequate mechanical resistance to withstand handling, packaging, transportation, and storage without friable fracture or surface erosion [35].

The satisfactory hardness achieved at the compression settings employed reflects the effective binding and cohesive properties of the *M. dioica* polysaccharide during wet granulation. The viscous binder solution, upon drying, forms a polymeric film coating around individual granule particles that acts as a solid-state adhesive, increasing the contact area and inter-particulate bonding strength during compression [21]. The consistent hardness values across the three trials further indicate that the granulation and compression process was well-controlled and reproducible, with minimal variation in granule size distribution, moisture content, and flow properties.

Table 6. Hardness Data for F-MDP Tablet Formulation

Trial	Hardness (kg/cm²)
1	7.4
2	7.5
3	7.6
Mean ± SD	**7.5 ± 0.10**
CV (%)	**1.33%**

3.7.3 Friability

Friability testing was performed to assess the mechanical resistance of F-MDP tablets to abrasion and attrition forces encountered during handling, packaging, and transportation. The test was conducted using a Roche friabilator in accordance with the procedure specified in the Indian Pharmacopoeia (IP 2022) and United States Pharmacopoeia (USP). Twenty pre-weighed tablets were placed in the friabilator drum and subjected to 100 revolutions at a rotation speed of 25 rpm. Following completion of the test, tablets were carefully dedusted, reweighed, and the percentage friability was calculated using the following expression:

$$\% \textbf{ Friability} = \frac{\textbf{(Initial weight − Final weight)}}{\textbf{Initial weight}} \times \textbf{100}$$

Table 7. Friability Data for F-MDP Tablet Formulation

Parameter	Value
Initial weight of tablets (g)	650mg
Final weight after friabilator (g)	644mg
Weight loss (g)	6mg
% Friability	**0.923%**
Pharmacopoeial acceptance limit	≤ 1.0%
Result	**Pass ✓**

The F-MDP tablets exhibited a percentage friability of **0.92%**, which is well within the pharmacopoeially accepted limit of not more than **1.0%** as specified by both the IP 2022 and USP [35] as shown in **Table 7**. This low friability value indicates that the tablets possess adequate resistance to mechanical wear and surface erosion under the abrasive conditions simulated by the friabilator, confirming the structural integrity and robustness of the compressed tablet matrix.

The satisfactory friability performance of F-MDP tablets is directly attributable to the strong inter-particulate binding capacity of the *M. dioica* polysaccharide. During wet granulation, the viscous polysaccharide binder solution uniformly coats and bridges individual powder particles, and upon drying forms a continuous solid-state polymeric film that significantly enhances granule strength and cohesiveness [21]. This film-forming behavior of the natural polysaccharide imparts sufficient bonding energy at particle contact points during compression, producing a mechanically robust tablet compact that resists surface attrition without crumbling or lamination. Comparable friability values have been reported for tablets formulated with natural polysaccharide binders of similar rheological character, including okra mucilage (0.65%) [22] and *Abelmoschus esculentus* seed mucilage (0.72%) [36], supporting the conclusion that *M. dioica* polysaccharide performs comparably to established natural binder systems in terms of imparting mechanical durability to tablet formulations.

3.8 Statistical Analysis: One-Way ANOVA

One-way ANOVA was performed to rigorously evaluate whether the observed difference in mean disintegration time between F-MDP (14.0 min) and F-Starch (5.0 min) was statistically significant or attributable to random experimental variation.

Null Hypothesis (H_0): The mean disintegration times of F-MDP and F-Starch formulations are not significantly different.

Alternate Hypothesis (H_1): The mean disintegration times of F-MDP and F-Starch formulations are significantly different.

The grand mean of all six disintegration time observations (three per formulation) was calculated as **9.5 minutes**. The between-group sum of squares (SSB = 121.50) vastly exceeded the within-group sum of squares (SSW = 0.10), yielding mean square values of MSB = 121.50 and MSW = 0.025, respectively. The resulting **F-calculated value of 4860.0** substantially exceeded the critical F-value of **7.71** at $\alpha = 0.05$ with degrees of freedom dfB = 1 and dfW = 4 ($F_{1,4}$), leading to unequivocal **rejection of the null hypothesis** ($p < 0.001$). The complete ANOVA table is presented in **Table 8**.

The extraordinarily high F-ratio obtained reflects not only the magnitude of the difference between group means ($\Delta = 9.0$ minutes) but also the remarkably low within-group variability (SSW = 0.10), which attests to the high precision and reproducibility of the disintegration measurements and the consistency of the tablet manufacturing process. These results provide compelling statistical evidence that the choice of binder natural *M. dioica* polysaccharide versus conventional maize starch exerts a highly significant and reproducible influence on tablet disintegration behavior.

Intra-batch uniformity of F-MDP tablet hardness was further assessed by computing the coefficient of variation (CV = SD/Mean × 100 = 0.10/7.5 × 100 = **1.33%**). Since this value is well below the threshold of 5% universally accepted as indicative of acceptable batch homogeneity in solid dosage manufacturing [35], it confirms that the *M. dioica* polysaccharide imparts consistent and reproducible binding performance across the tablet batch, with negligible variability in compressive strength between individual tablets. The complete statistical summary is provided in **Table 10**.

Collectively, the results of this study establish that the polysaccharide isolated from *Momordica dioica* fruit pulp fulfills the essential criteria for a pharmaceutical-grade natural binder: it is physiochemically stable, structurally well-defined by spectroscopic analysis, thermally robust up to 237°C, capable of producing mechanically strong and batch-uniform tablets, and exerts a statistically significant and reproducible

retardant effect on tablet disintegration a property of direct relevance to the design of controlled and sustained-release oral dosage forms.

Table 8. Raw Disintegration Time Data Used for ANOVA Calculation

Trial	F-MDP (min)	F-Starch (min)
1	14.2	5.1
2	13.8	4.9
3	14.0	5.0
Group Mean (x̄)	**14.0**	**5.0**
Grand Mean (x̄G)	**9.5**	**9.5**

Table 9. One-Way ANOVA Table — Disintegration Time Comparison (F-MDP vs. F-Starch)

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-calculated	F-critical (α = 0.05, df 1,4)	Significance
Between Groups (Formulations)	121.50	1	121.50	**4860.0**	7.71	p < 0.001 ✓
Within Groups (Error)	0.10	4	0.025	—	—	—
Total	**121.60**	**5**	—	—	—	—

Table 10. Complete Summary of Statistical Evaluation of All Tablet Characterization Parameters

Parameter	F-MDP (Mean ± SD)	F-Starch (Mean ± SD)	F-calculated	F-critical	p-value	Result
Disintegration time (min)	14.0 ± 0.20	5.0 ± 0.10	4860.0	7.71	< 0.001	Significant*
Hardness (kg/cm²) — F-MDP	7.5 ± 0.10	—	CV = 1.33%	< 5%	—	Uniform batch ✓
Friability (%) — F-MDP	0.92	—	—	≤ 1.0%	—	Pass ✓

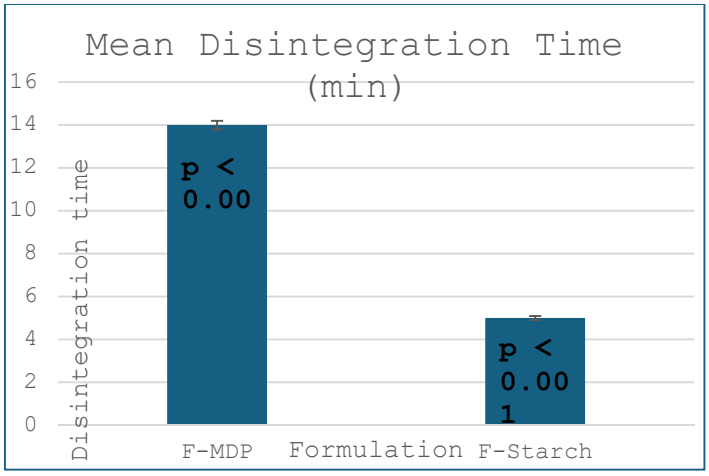

Figure 5: Anova Graph

4. Conclusion

The present study successfully demonstrated the extraction, isolation, physicochemical characterization, and pharmaceutical application of polysaccharides from the fruit pulp of *Momordica dioica* Roxb. ex Willd. The sequential extraction protocol yielded a predominantly amorphous polysaccharide powder (yield 1.6% w/w) with a near-neutral pH of 6.9 and moderate viscosity of 85 cP, confirming physicochemical compatibility with oral pharmaceutical formulations. FTIR spectroscopy confirmed the acidic heteropolysaccharide identity of the isolate through characteristic hydroxyl (3699.1 cm^{-1}), uronic acid carboxylate (1655.0 cm^{-1}), and glycosidic linkage bands (1222.0 cm^{-1}), consistent with a rhamnogalacturonan-type structure. DSC analysis confirmed a structural relaxation transition at 141.43°C and thermal degradation onset at 237°C, establishing adequate thermal stability for all standard pharmaceutical manufacturing processes.

Placebo tablets incorporating *M. dioica* polysaccharide as binder (F-MDP, 15% w/w) exhibited satisfactory hardness (7.5 ± 0.10 kg/cm^2), acceptable friability (0.92%), and excellent batch uniformity (CV = 1.33%). F-MDP tablets demonstrated a mean disintegration time of 14.0 ± 0.20 minutes — a 2.8-fold prolongation relative to starch-based reference tablets (5.0 ± 0.10 min) while remaining within the pharmacopoeial limit of 15 minutes for uncoated tablets. One-way ANOVA confirmed this difference to be highly statistically significant ($F_{1,4} = 4860.0$; $p < 0.001$). Based on the gel-forming behavior, retarded disintegration profile, and thermal stability demonstrated, it may be possible to employ *M. dioica* polysaccharide as a hydrophilic matrix former in controlled-release tablet formulations. However, as the present study employed placebo formulations, this remains a working hypothesis requiring systematic validation through drug-loaded in vitro release studies, release kinetics modeling, and in vivo pharmacokinetic evaluation.

In conclusion, *Momordica dioica* fruit polysaccharide represents a promising, biodegradable, and biocompatible natural excipient with reproducible binding performance and sustained-release-compatible disintegration behavior, warranting further investigation as a green alternative to synthetic excipients in controlled drug delivery systems. Future work should focus on complete structural elucidation by NMR and GC-MS, extraction yield optimization by response surface methodology, and comprehensive evaluation of drug-loaded matrix formulations.

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