ORIGINAL PAPER

https://dx.doi.org/10.4314/njpr.v21i2.4

Nig. J. Pharm. Res. 2025, 21 (2) pp 86-95
ISSN 0189-8434 e-ISSN 2635-3555 **Available online at http://www.nigjpharmres.com**

Development and Evaluation of Chewable Ciprofloxacin Tablet with Modified Grewia Gum - Starch Diluent

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article.

ABSTRACT

Background: Chewable tablets improve drug bioavailability, but possess mechanical strength and friability challenges.
Objective: To examine the impact of grewia-gum-modified corn starch on the mechanical and release properties of ciprofloxacin tablets.
Methods: Blends of 1, 2, 3, 4, 5 % grewia-gum in corn starch were sweetened with aspartame, kneaded, sieved, dried and labelled as A - E. Each blend was wet granulated with ciprofloxacin dosage constituents and tested for pre-compression properties. The granules were compressed to tablets, and the tablets evaluated for drug physicochemical and permeation properties.
Results: Batch A demonstrated superior flow properties with flow rate > 10.28 g / s and angle of repose < 23.67˚. Batch E demonstrated the best model fit (R^2 = 0.9667), maximum compressibility (a = 0.4434), and highest compactability (b = 0.0053) in the Kawakita plot of densification values. All the test tablets showed good physicochemical properties with tensile strength of 4.50 to 8.57 MN/m², friability < 1 %, with Batch E showing the lowest friability (0. 11 %), disintegration time < 90 sec, indicating fast release, >80% dissolution in 20 min and < 24.6 % drug permeation in 360 min.
Conclusion: The addition of Grewia gum reduced flow and improved compactibility of granules and improved tablet mechanical strength and disintegration time, and reduced tablet friability. These findings show the potential of grewia gum-modified corn starch to balance fast disintegration with mechanical strength in chewable tablet formulation, but also emphasize the importance of optimizing its concentration to balance flow and compressional properties.

Keywords: Compactability, Kawakita, permeability.

INTRODUCTION

Ciprofloxacin is a broad spectrum antibiotic used to treat various bacterial infections (Agubata *et al*., 2023). Solid formulations of ciprofloxacin available in the market are tablets, capsules, and suspensions. These formulations have limitations such as poor solubility and poor permeability (BCS Class IV drug), difficulty for some patients to swallow and gastro-intestinal discomforts. The bioavailability, acceptability and ease of oral administration of ciprofloxacin may be improved by formulating it as oral release solid dosage such as chewable tablet. Chewable tablets, like oral release solid dosages, are designed to fast-melt, rapidly-dissolve, or quickly-disintegrate in the mouth, usually within seconds, usually between 15 – 60 sec, with or without water (Spansana *et al*., 2020; Maheshwari *et al.,* 2024). They are prepared in a way to be easily crushed by chewing into smaller particles that initiate dissolution and absorption.

Maheshwari *et al.* (2024) explained that the anatomy and physiological characteristics of the oral cavity, its buccal epithelium, the presence of oral mucosa and its vascularization, and of saliva and its flow facilitate drug absorption. Oral release tablets are absorbed mainly in the buccal- tracheal route of the

mouth, through the pharynx, and down to the oesophagus as the saliva passes down to the stomach. In the buccal region, oral release drug is exposed to better permeability, enhanced bioavailability, reduction in the proportion of drugs that come in contact with the stomach, decrease in gastric side effect, and reduced first-pass metabolism (Kasgavade & Swapril, 2016; Manner *et al*., 2022).

Chewable tablets offer advantage over the instability, dosing errors, high bulk volume and limited acceptance of alternative liquid dosage (Imbriano *et al*., 2025). Chewable tablets are designed to have pleasant mouth feel, taste masking properties and to leave no residue in the mouth (Spansana *et al*., 2020; Maheshwari *et al.,* 2024*;* Shingade *et al.,* 2024). They are suited for people with difficulty in or aversion to swallowing conventional tablets, elderly, children, institutionalized patients, and persons with certain medical conditions such as dysphagia (Spandana *et al*., 2020). It is also designed for convenience of travelling patients who do not have ready access to water, for quick onset of activity, and to encourage compliance (Kasgavade & Swapril, 2016; Maner & Shinde, 2022). Chewable tablets are adaptable and compatible with modern packaging and processing machinery (Maner & Shinde, 2022; Shingade *et al*., 2024).

There are some drawbacks to the application of chewable tablets. Chewable tablets are often hygroscopic and must be kept dry, they have insufficient mechanical strength, may be brittle, and require careful handling (Maheshwari *et al.,* 2024*;* Shingade *et al.,* 2024). Patients with reduced saliva secretion such as Sjogren syndrome, or patients on anticholinergic medication may not be able to effectively absorb oral release tablets. Oral release drugs, because of the short staying time in the mouth, may not be suited for controlled release medications. It may be difficult to formulate high active dosages as oral release tablets, because of limited space for inactive functional excipients. Such tablets are often churned out with reduced mechanical strength and high friability.

Proper choice of excipient can improve the quality of chewable and oral dissolving tablets. Specialized excipients or excipients with binding and bulking dual-functionality may improve tablet compactness. Technologies such as direct compression, molding, lyophilisation, effervescence and 3D-printing have been used with specialized excipients to formulate fast dissolving tablets (Imbriano *et al*., 2025). Specialized excipients such as mannitol, sorbitol, dextroxe, lactose, sucrose, and their modified forms have been used in formulating chewable tabltes. Mannitol, an inert, crystalline, free-flowing, and non-hygroscopic powder which is 70 % as sweet as sucrose, and is a desirable filler for chewable tablets when taste is a factor. Sorbitol is sweet, has a cooling sensation, and can be used for wet granulation. Dextrose has the anhydrous and more hygroscopic form and the monohydrate form, and is used as a binder and diluent in wet granulation and direct compression of tablets. Dextrose is sweet and forms tablets that are less friable, but require more lubrication and hardens significantly after the first hours of compression. Formulations with more lubricants such as stearic acid have been reported to have high disintegration, within 30 min, and dispersion time, within 1hr, while those without stearic acid showed faster and higher release (Agubata *et al*., 2023). Lactose has hardening and diluent properties, but low sweetness, and are unsuitable for people with lactose intolerance. Sucrose is used where artificial sweeteners are to be avoided, but can be hygroscopic, turn brown and harden with time (Shingade *et al*., 2024)

Modification, co-processing and other techniques have been used to improve the functional properties of pharmaceutical excipients for oral dissolving tablets. Mannitol and sorbitol have been modified to improve their respective compaction properties (Shingade *et al*., 2024). Co-processing synthetic and natural excipients are gaining interest because of their unique functionality, outcome, and relative safety. The properties and safety of synthetic excipients are known and have already been approved for use, and the relative safety of natural excipients are often known from usage. Co-processed natural and synthetic excipients, such as alginic acid and microcrystalline cellulose, may not require extensive safety testing before use (Bin *et al*., 2022, Benabbas, 2021). Co-processed corn starch and acacia honey have been used in 3D printing of chewable amoxicillin for oral administration (Imbriano *et al*., 2025).

Grewia gum is an amorphous biopolymer derived from the stem bark of *Grewia mollis,* Juss (Tiliaceae) (Pongri *et al*., 2023; Nnamani *et al*., 2024). The plant is abundant in the wild and is cultivated by some natives in middle belt region Nigeria where the mucilage from its stem bark is used as a native soup-thickener (Pongri *et al*., 2023; Nnamani *et al*., 2024). Grewia gum is non-toxic and biodegradable that forms hydrophilic film with about 0.2 mg/ml aqueous solubility (Pongri *et al*., 2023; Nnamani *et al*., 2024). In pharmacy, grewia gum has been investigated for its potential as a mucoadhesive, stabilizer, viscosity enhancer, gelling agent, suspending agent, binder, coating agent, drug delivery system, and for other dosage functions, with promising results (Haile *et al.,* 2020; Ologunagba *et al*., 2020 Nnamani *et al*., 2024).

In this study, a sweetened binder-diluent would be processed from grewia gum, aspartame and corn starch. Aspartame is a non-medicated flavouring artificial sweetener that is multiple times (over 200 times) sweeter than sucrose, and is approved for use in food and about 1 – 3% in drug formulation

(Shingade *et al*., 2024). It exhibits discolouration in the presence of ascorbic acid and tartaric acid, hence the need for a masking colourant (Shingade *et al*., 2024). The study aims to improve the mechanical strength and reduce the friability of chewable ciprofloxacin tablets using a multipurpose co-excipient.

METHOD

Extraction

Adapting the methods of Ogaji *et al*. (2013) and Ologunagba *et al*. (2020), the stem of grewia mollis plant was harvested in December at Pankshin, plateau, and chopped to about 10 cm with a knife. The inner stem bark was removed and dried in a hot-air oven (Model DHG-9053A, Ocean Medical, England) at 50 ºC for 48 h. Approximately 500 g of the dried bark was ground to fine using an electric miller (Eurosonic, China). The fines were soaked in 15 L of deionized water for 48 h to extract gum. A clean muslin bag was used to filter out debris from gum. About 4.5 L of 96 % ethanol was added to solubilize impurities and precipitate the gum. The precipitated gum was further treated with 4.5 L of 96 % ethanol to complete the gum extraction. The gum was dried in the hot-air oven at 50 ºC for 12 h. The dried gum was pulverised with miller (Endecotts Ltd., England) fitted with 710 µm mesh size stainless sieve to collect fine powder. The fine gum powder was collected in an airtight polythene bag and stored.

Pre-formulation studies: FT-IR spectroscopy

To detect ciprofloxacin drug and grewia excipient interaction, infrared spectra of grewia gum, ciprofloxacin, and 1:1 physical mixture of grewia gum and ciprofloxacin were obtained using KBr disc method with FT-IR Spectrometer and recorded at 400 – 4000 *cm-1* wavenumber using a resolution 4 cm^{-1}.

Co-processing sweetened diluent – binder excipient

Sweetened co-processed excipient was prepared following the procedure described by Valencia *et al*. (2018) and Imbriano *et al* (2025). Grewia gum and aspartame, in the formula reported in Table 1, were weighed using an electronic weighing balance and blended in a mortar for 5 min to ensure uniformity. The blend was dispersed in 1 L distilled water under magnetic stirring at 500 rpm at room temperature for 5 min, and then heated to 80 °C to induce gelation. The hot sweetened gel was poured into a Kenwood mixer bowl (Kenwood Equipment Company, England) containing 80 °C hot starch and kneaded for 5 min to get a homogenous wet mass. The wet mass was screened using 12-Mesh screen, and resulting granules were dried to a consistent weight in a hot-air oven (Model DHG-9053A, Ocean Medical, England) set to 50 °C. The dried granules were sieved through a 16-Mesh screen and kept in sealed plastic containers for subsequent formulation.

Table 1: Formula for Producing 100 Ciprofloxacin (250 mg) Tablets

Constituent	(g)					
Batch	A	B	C	D	E	F
Ciprofloxacin	25	25	25	25	25	25
Grewia gum	0.17	0.34	0.41	0.68	0.75	0
Corn starch	16.73	16.56	16.49	16.22	16.15	16.90
Aspartame	0.15	0.15	0.15	0.15	0.15	0.15
Methyl paraben	0.1	0.1	0.1	0.1	0.1	0.1
Microcrystalline cellulose	2.5	2.5	2.5	2.5	2.5	2.5
Starch paste	4.85	4.85	4.85	4.85	4.85	4.85
Sodium lauryl sulphate	0.5	0.5	0.5	0.5	0.5	0.5
	50	50	50	50	50	50

Granulation and compression

Ciprofloxacin powder, co-processed grewia gum, aspartame and corn starch granules, methyl parabene and microcrystalline cellulose were mixed in Kenwood Bowl Mixer (Kenwood Equipment Company, England) for first 5 min, moistened with starch paste and blended for 3 min. The resultant wet mass was passed through a 14-mesh screen to get wet granules. The wet granules were dried in a hot-air oven (Model DHG-9053A, Ocean Medical, England) **at** 65 ºC and then screened through a 20-mesh sieve. Sodium lauryl sulphate was added to the dried granules and blended for 2 min to lubricate the dried granules. The lubricated granules were stored, allowed to cure for 24 hours, and then evaluated for pre-compression properties. The granules were then compressed to tablets using a 12 mm flat faced,

beveled shaped punch, and evaluated for post-compression physicochemical properties.

Micromeritics properties determination

Flow rate: A funnel with a standard orifice was secured vertically on a retort stand over a measuring cylinder. With the bottom base of the secured funnel blocked, 10 g granules were poured. The secured base of the funnel was opened, and the amount of time for the whole powder sample to pass through was noted. The flow rate (g/sec) of the granules was calculated from the weight of the granules divided by the flow time. The test was conducted in triplicate for each batch.

Angle of Repose (θ)**:** Ten gram granules poured into a closed bottom base funnel clamped in a retort stand was set on a flat piece of paper on a horizontal surface. The bottom base of the funnel was opened to allow the granules flow through and form a heap. The measure of the height (h) of the heap and radius (r) of the base of the heap was taken, and used to calculate the angle of repose (θ) with equation 1. The tests were done in triplicate for each batch.

$\theta = tan^{\{-1\}}\ (h/r)$

…… Equation 1

Densification properties: Applying the method of Denny (2002), 20 g granules were carefully filled into a 100 mL graduated measuring cylinder. The filled cylinder was gently tapped three times, and the volume of granules noted and recorded as bulk volume (bV). The weight of the granules divided by the bulk volume was recorded as bulk density (bD). The granule-filled cylinder was gently tapped from 10 cm height down on the flat padded surface. The volumes of the granules (nV) in the filled cylinder after N taps (100, 200, 300, 400, 500, 600, 700, 800, 900 and 1,000 taps) were recorded. The final unchanged end volume of the filled-cylinder after tapping is recorded as the tapped volume (tV). The weight of the granules divided by the final tapped volume was recorded as tapped density (tD). The bulk and tapped densities were used to calculate Carr's Index and Hausner's ratio using equations 2 and 3. The volumes of the granules in the filled cylinder after 100, 200, 300, 400, and 500 taps was used to calculate degree of volume reduction (C), Kawakita equation, and densification properties using equations 4, 5 and 6 respectively.

Carr's Index $= \frac{tD-bD}{tD}\ x\ 100$

…..equation 2

Hausner ratio $= \frac{tD}{bD}$

……equation 3

Degree of volume reduction (C) at each tap number $= \frac{bV-nV}{bV}$ …… equation 4

The value of the number of taps divided by degree of volume reduction (c) was calculated.

Kawakita equation $N/C = \frac{1}{ab} + \frac{N}{a}$

……eq uation 5

Using Kawakita equation 5, a plot of N/C versus N was created, the slope and intercept of the plot were used to get a and b.

a = compactability = a constant related to maximum possible volume reduction or maximum degree of compression of the powder. This is associated with the initial *porosity* of the granule powder bed.

b= compressibility factor = a constant related to the *compressibility* of the powder (cohesiveness of the granules or yield strength or pressure needed for the granules to reach half of the maximum volume reduction). This is linked to the degree of deformation of the granules during compression.

Tablet physicochemical properties tests

The physicochemical properties of the tablets were evaluated in accordance with the guideline of USP (2021).

Weight uniformity test: Twenty tablets from a batch were selected at random and individually weighed using an electronic weighing balance (Mettler, Switzerland). The average weight was calculated and then the percentage deviation of each tablet was gotten from the average weight.

Friability test: Ten pre-weighed tablets from a batch were placed in the drum of Monita friability test apparatus (India Corps Limited, India) and subjected to 100 revolutions at speed of 25 rpm for 4min. The tablets were thereafter removed, dedusted, re-weighed and percentage weight loss from the original weight was recorded as the percentage friability.

Tablet tensile strength: This was determined from the tablet diametral compression test method described by Shang *et al*. (2013) and Yohannes and Abebe (2021). Ten tablets from a batch were randomly selected. From the ten tablets, a tablet was weighed, measured for thickness (t) and diameter (D), and then placed between fixed and moving jaws of a Mosanto tablet hardness tester (Model MHT-20, Thermonik, Campbell Electronics, India). Pressure was applied on the tablet through screwing the lead, until the tablet breaks. The pressure at which the tablet breaks is recorded as P. The tablet tensile strength (σ_t) was determined using Equation 6. The test was repeated for each of the ten tablets, and the average σ_t recorded.

$\sigma_t = \frac{2P}{\pi Dt}$

……equation 6

Where $\pi = 3.142$

Disintegration test: Using a disintegration tester apparatus (DT) (MK4, Manesty Machine Limited, England), a tablet was placed in each of its six tubing of a basket-rack assembly before immersing in its disintegration vessel containing 1000 ml of distilled

water at a temperature of 37 ±0.5°C, and operated at 30 cycle/ mm. The time taken for the tablets to break down into smaller particles and through vessel mesh is recorded as the tablet disintegration time.

Determination of drug entrapment efficacy

The amount of drug entrapped was evaluated in a randomly selected tablet from each batch. The tablet was minced by a scalpel, in 250 ml distilled water, and stirred using a magnetic stirrer at 600 rpm for 24 h. Thereafter, the suspension was centrifuged with an electric centrifuge (Model 3K 15, SIGMA, Germany) at 4,000 rpm for 10 min, and the supernatant collected and analyzed by UV-Vis spectrophotometry using a UV- spectrophotometer (Model 23D, Uniscope, England) operated at 277.0 mm wavelength. The procedure was carried out in triplicate, and the average reading used to determine the amount of drug entrapped. The percentage of the average amount of drug entrapped against the expected amount to drug loaded in the tablet was recorded as percentage of drug entrapment efficacy as stated by Oyeniyi and Nnamani (2018).

***In vitro* drug release studies**

Using the method described by Imbriano *et al.* (2025), a USP Type II Dissolution Apparatus (Caleva Company Limited, England), and the Eur. 11th Ed paddle method, tablet dissolution study was performed on the tablets. The chewable tablet was cut by a scalpel into fragments, to stimulate chewing. The fragments were introduced into a vessel containing 1000 ml 0.1 N hydrochloric acid dissolution medium set at 37 ± 0.5℃ (stimulated gastric juice pH 1.2). The paddle rotation of the dissolution apparatus was set at 50 rpm, and the experiment conducted for 120 min. Five ml aliquots were withdrawn at intervals (5, 10, 15, 20, 30, 45, 60, 90, and 120 min), and replaced with 5 ml of fresh thermostated dissolution liquid. As control, the same experiment was performed on ciprofloxacin powder (250 mg). The aliquots were analysed immediately after each withdrawal by UV-Vis spectrophotometry using a UV- spectrophotometer (Model 23D, Uniscope, England) and calibration curve in the dissolution medium and a (λ_{max} = 277 nm; R^2 = 0.99). All dissolution studies were carried out in triplicate.

***In vitro* drug permeability studies**

In vitro permeability studies were carried out by adapting the methods of Berben *et al.* (2018) and Jacobsen *et al.* (2020). Twelve ml phosphate-buffered saline (PBS), pH 7.4, comprising 2.33 g/L dis-sodium hydrogen phosphate monohydrate, 0.19 g/L monopotassium phosphate and 8.0 g/L sodium chloride, prepared in a 20 ml glass beaker and placed on a hot plate magnetic stirrer (Model TK23, Kartel, Italy) and maintained at 37 ± 0.5℃ as receptor medium. A dialysis membrane tubing (80 – 100 kDa, Spectrum Inc., Lorzweiler, Germany) was used as a donor compartment in place of a Franz-type static glass diffusion cell. Aliquots (0.5 ml) was withdrawn from the paddle dissolution apparatus at 20 min and placed in the donor compartment tubing and secured end-to-end with a thread. The secured donor compartment was suspended in the beaker containing the receptor medium on the hot-plate and the magnetic stirrer rotated at 50 rpm. For 360 min, at predetermined time intervals of 30, 60, 120, 180, 240, 300, 360 and 420 min, 5 ml aliquots were withdrawn from the receptor compartment, replaced each time with 5 ml of fresh medium, and analysed using UV-Vis spectrophotometry at 277 nm wavelength in a UV-visible spectrophotometer (Model 23D, Uniscope, England). Each test was done in triplicate.

STATISTICAL ANALYSIS

The test of all determinations were conducted in triplicate, and the data presented in average mean ± standard deviation. The significance of the difference between groups was evaluated unpaired Students' two-tailed t-test. P ≤ was considered statistically significant.

RESULTS

Pre-formulation studies

The FT-IR spectra of grewia gum, ciprofloxacin, and 1:1 physical blend of ciprofloxacin and grewia gum are presented in Figure 1. The OH, N=H, C=H, C=O, and C=C stretching of ciprofloxacin at 3324.8, 2683.7, 2117.1, 1871.1 and 1621.4 $^{cm-1}$ wavenumbers respectively were generally maintained, with few slight points of difference, in the ciprofloxacin-grewia gum blend at 3336.0, 2480.95, 2121.9, 1897.2 and 1617.7 cm^{-1} wavenumbers respectively.

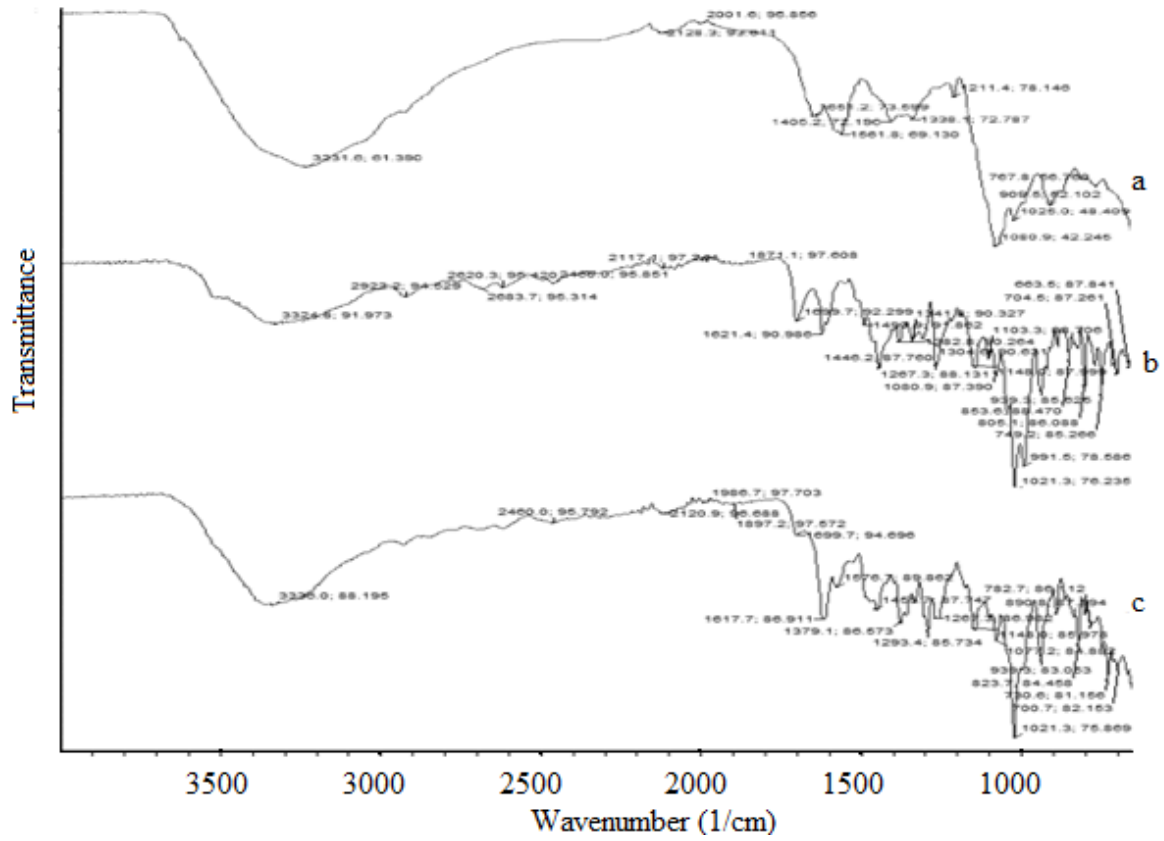

Figure 1: FT-IR Spectra of (a) *Grewia* Gum, (b) Ciprofloxacin and (c) Physical Mixture of *Grewia*-Ciprofloxacin Powders

Micromeritics properties

The micromeritics properties results of the granules (Table 2) showed granules flow rate > 6.19, Hausner ratio and % Carrs' indices ranges of 12.26 – 1.56 and 20.59 – 35.71, respectively. The densification result of Table 2 and extracted from slopes and intercepts of Figure 2, showed varying compressibility behaviour between batches. Batch E had the greatest model fit (R^2 = 0.9922), highest compressibility and cohesiveness (b = 0.0053), and average compactibility (a = 0.4433).

Table 2: Micromeritics and Densification Properties of Ciprofloxacin Granules

	Flow rate (g/s)	Θ (°)	Hausner Ratio	Carrs' Index	A	b	R^2
A	6.62±0.18	28.69±0.43	1.31	23.69	1.4286	0.0002	0.3427
B	6.28±0.21	23.67±0.12	1.35	25.71	0.8333	0.0005	0.4229
C	6.19±0.30	26.98±0.11	1.26	20.59	0.4348	0.0010	0.7525
D	6.58±0.65	27.49±0.13	1.28	21.62	0.3040	0.0036	0.9832
E	7.60±0.19	26.25±015	1.56	35.71	0.4434	0.0053	0.9922

a = compactability, b = yield strength which is a measure of compressibility and cohesiveness.

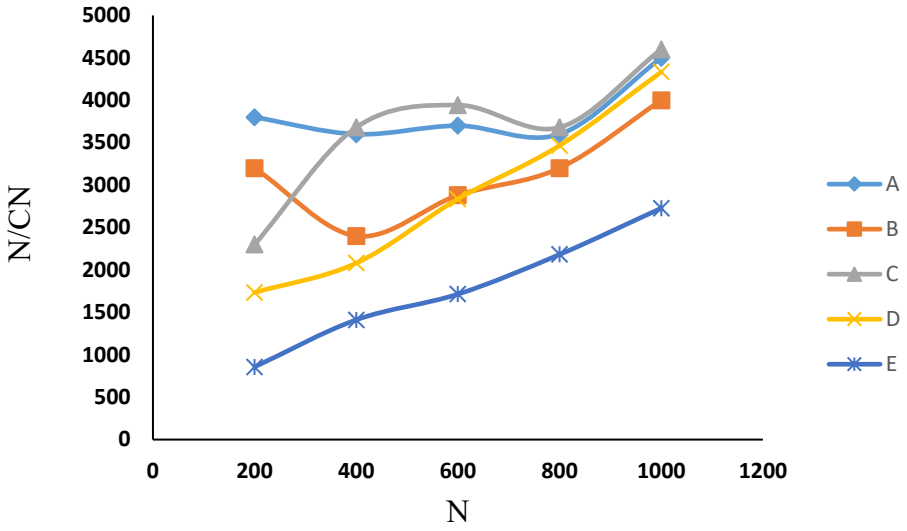

Figure 2: Kawakita's Densification Plot of Ciprofloxacin Granules

Tablet physicochemical and drug entrapment properties

Table 3 shows the tablet physicochemical properties, with thetables tensile strength > 4.5 MPa, percentage friability < 0.75 %, and tablet disintegration time of < 80.13 s. Batch E showed the highest tensile strength (8.47 MPa), lowest friability (0.11 %) and lowest disintegration time (46.34). The tablet drug entrapment of the batches were > 97.8 %

Table 3: Ciprofloxacin Tablet Physicochemical Properties

Batch	Tensile Strength (MPa)	Friability (%)	Disintegration time(s)	Drug Entrapment Efficacy (%)
A	5.12±3.21	0.75±0.09	80.13±9.56	98.7±1.12
B	6.79±2.68	0.76±0.04	68.26±6.28	98.6±0.79
C	6.46±1.74	0.54±0.02	64.34±3.48	102.9±2.13
D	7.52±4.12	0.35±0.11	62.18±25.03	97.8±0.87
E	8.47±2.46	0.11±0.03	46.34±1.47	101.4±2.16

***In vitro* drug release**

The drug release profiles of the different batches of ciprofloxacin are displayed in Figure 3. The results showed that the amount of ciprofloxacin released increased significantly ($p < 0.05$) with time for each batch. All the batches released more than 85 % ciprofloxacin within 15 min.

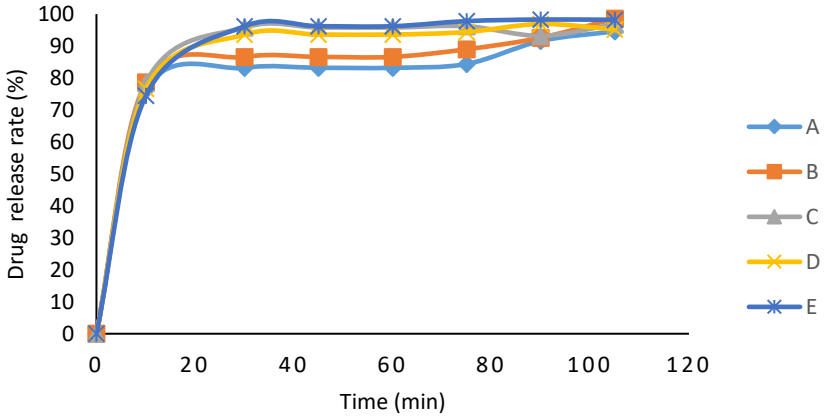

Figure 3: Drug Release Profile of Ciprofloxacin Tablets

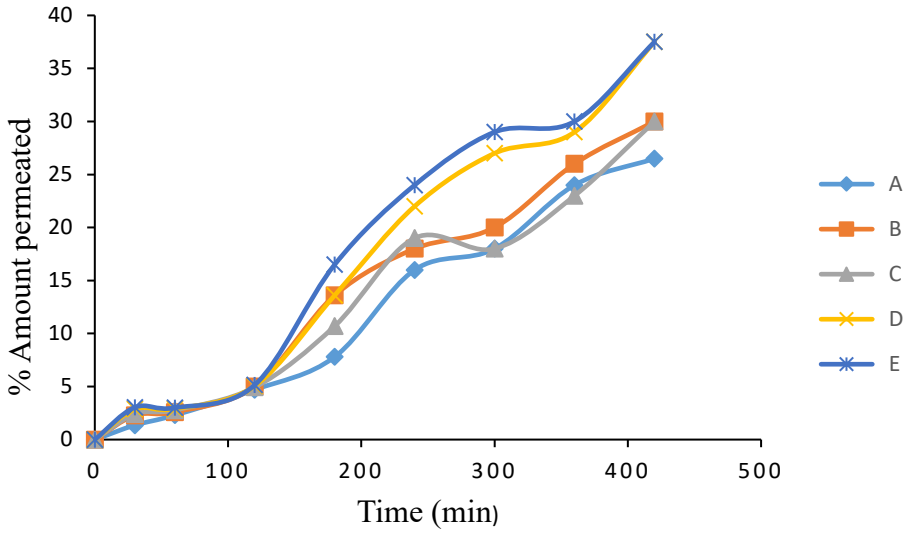

Figure 4: Ciprofloxacin Permeation Profiles from Formulated Tablets

***In vitro* drug permeability**

Figure 4 reports the percentage of the cumulative drug permeated over time for the ciprofloxacin batches formulations. After 420 min the drug permeation for all formulation was 26.5 - 37. 7 %, with control formulation having the least drug permeation of 26.5 %.

DISCUSSION

The near-similar wavenumber of the FT-IR spectra stretching of ciprofloxacin and the physical blend of ciprofloxacin and grewia gum revealed that no new peak was created, and no significant peak disappeared, indicating that no new chemical entity was created in the ciprofloxacin blend. This result suggests that the grewia gum is compatible with ciprofloxacin, and is consistent with studies on grewia gum – ciprofloxacin compatibilities such as by Agubata *et al.* (2023) and Nnamani *et al.* (2024). Polysaccharide stretching at 1080.9 and 1025.0 cm^{-1} wavenumbers was observed for grewia gum (Anusha *et al*., 2011; Kasgavade & Swapril, 2016; Nnamani *et al*., 2024)

From interpretations of Comoglu (2007) on granules compaction behaviour, Batch E granules exhibited the best compressibility and cohesiveness properties, moderate flow, pressure threshold, and compactability characteristics. These results indicate that high gum levels can hinder flow even with favorable compressibility, while moderate amounts of Grewia gum improve both densification and compressibility, whereas extremes (either too low or too high) impair tabletability or flow.

The tablets' tensile strength > 4.5 MPas and friability < 0.75 % are USP (2021) good tablet mechanical qualities acceptable for conventional tablets. Tensile strength greater than 1.7MPa is considered sufficient in ensuring that a tablet is mechanically strong enough to withstand manufacturing, packaging, distribution and end-use by patient (Pitt & Heasley, 2013; Patel *et al.,* 2025). The tablet disintegration time of < 80 s is close to the disintegration time range for fast dissolving and other orodispersible tablets such as 18-70 s for orodispersible elatriptan reported by Spandana *et al* 2020, but further than the 15 – 23 s reported for fast dissolving ciproflocacin tablets with starch glycolate, sodium, and crospovidone reported by Kasgavade and Swapril (2016). These disintegration times are suited for orodispersible tablets and are much faster than disintegration times of 1-13 min of conventional tablets such as ciproflocaxin tablet produced with starch, SSG, CCS and crosspovidone, and lactose diluent reported by Harish *et al*. (2013). The disintegration time of test material was comparable to that reported by Harish *et al*. (2013) for crosspovidone, the fast disintegrant.

All the batches entrapped > 98 % drug active, and released more than 85 % ciprofloxacin within 15 min., which are within the USP acceptable range for uncoated tablet content and drug dissolution. The formulations assured permeation of ciprofloxacin, with minimum variation. Ciprofloxacin is categorized as a Biopharmaceutical Classification System (BCS) Class IV medication due to its limited permeability and poor aqueous solubility, in spite of its effectiveness, (Asghar *et al*., 2022, Khan *et al*., 2022). With drug release and permeability relatively unaffected, the problems of insufficient mechanical strength require careful handling of chewable tablets produced with conventional sweetener excipients, that was noted by previous studies such as Maheshwari *et al.,* (2024) and Shingade *et al.* (2024), was handled by this test sweetened grewia starch excipient.

CONCLUSION

This study showed that different concentrations of Grewia gum had an impact on granule and tablet characteristics. While moderate concentrations resulted in the best flow, compressibility, tensile strength, and disintegration profiles, high concentrations compromised flow properties but improved tablet hardness and reduced friability. The drug content and release properties of the tablets were not significantly affected by the concentrations of Grewia gum starch. The chewable ciprofloxacin tablet formulated with sweetened modified grewia starch blend has sufficient mechanical strength that requires careful handling. These findings show the potential of grewia gum-modified corn starch to balance fast disintegration with good mechanical strength in chewable tablet formulations but also emphasize the importance of optimizing to balance the granule flow and compressional properties.

REFERENCES

Agubata C. O., Ogbonna E. C., Onyechi J. O., Ugwu C. E., Obasi J., Akudu A. U., Chidebelu I. and Ani N. I. (2023). Preparation and evaluation of ciprofloxacin solid dispersion tablets developed from stearic acid, polyethylene glycol 4000 and soluplus. J. Drug Del. Ther. 13(4): 71-78

Anusha P., Basavar B.V., Bharath S., Deveswaran R. and Madhavan V. (2011). Formulation and evaluation of ciprofloxacin dispersible tablets using Plantago ovate mucilage in comparison with other disintegrants. Int J. Chem Sci 9(2): 664-672.

Benabbas R., Sanchez-Ballester N. M., Bataille B., Sharkawi T. and Soulairol, I. (2021). Development and pharmaceutical performance of a novel co-processed excipient of alginic acid and microcrystalline cellulose. Powder Technol. 378: 576–584. https://doi.org/10.1016/j.powtec.2020.10.027

Berben P., Bauer-Brandl A., Brandl M., Faller B., Flaten G. E., Jacobsen A.-C., Brouwers J. and Augustustijns P. (2018). Drug permeation profiling using cell-free permeation tools: overview and applications. Eur. J. Pharm. Sci. 119: 219-233.

Comoglu T. (2007). An overview of compaction. J. Fac. Pharm. Ankara 36 (2): 123-133.

Denny P. (2002). Compaction equations: a comparison of the Heckel and Kawakita equations. Powder Technol. 127(20: 162-172.

Haile T.G., Sibhat G. G., Mollar F. (2020). Physicochemical characteristization of Grewia ferruginea Hochst. Ex A. rich mucilage for potential use as a pharmaceutical excipient. Biomed Res Int.: 4094350. Doi:10.1155/2020/4094350

Harish G., Riyajune A., Yasmeen Md. Y., Mohammed S., Krishna Ch. M., Jilani Sk., Nirajana V. A. (2013). Effect of different disintegrants on ciprofloxacin conventional tablets. Indian J. Res. Pharm. Biotechn 1(3): 281-287

Imbriano A., Fratini C., Bondi G., D'Abbrunzo I., Bertoni S., Tiboni M., Abruzzo A., Hasa D., Pagano C. and Csettari L. (2025). 3D-printed chewable gummy tablets: a new tool for oral amoxicillin administration in paediatric population. Int. J. Pharm. 677. https://doi.org/10.1016/j.pharm.2025.125645

Jacobsen A. C., Nielsen S., Brandl M. and Bauer-Brandl A. (2020). Drug permeability profiling using the novel permeapad 96-well plate. Pharm. Res. 37(6): 93. Doi: 10.1007/s11095-020-02807-x

Khan K. U., Minhas M. U., Badshah S. F., Suhail M., Ahmad A. and Ijaz, S. (2022). An overview of nanoparticular strategies for solubility enhancement of poorly soluble drugs. Life Sci. 291: 120301. http:// doi.org/ 10.1016/j.lfs.2022.120301

Kasgavade P. and Swapril M. (2016). Formulation and evaluation of fast dissolving tablet of ciprofloxacin. Int J Adv Pharm. 5(3): 52-60.

Maheshwari S., Singh A., Varshney A. P. and Sharma A. (2024). Advancing oral drug delivery: the science of fast dissolving tablets (FDTs). Intelligent Pharmacy 2(4): 580-587

Maner N. A. and Shinde A.D. (2022). A review: the fast dissolving tablets. IJPPR. International J Pharm Pharm Res. 25(4):391-414

Nnamani N.D., Kashimawo A.J. and Zar M. (2024). Dry granule formulation for ciprofloxacin hydrochloride capsule using co-processed Grewia mollis gum. TJNPS 3(3): 216-221.

Ogaji I. J., Okafor I. S. and Hoag S. W. (2013). Grewia gum as a potential aqueous film coating agent. 1; some physicochemical characteristics of fractions of grewia gum. J. Pharm. Bioallied Sci. 5: 53-60

Ologunagba M. O., Kolawole O. M., Echerenwa A.N. and Silva B. O. (2020). A cost effective extraction method for improved physicochemical rheological and microbiological properties of grewia mollis gum. TJNPR, 4(8), 440-445.

Oyeniyi Y.J. and Nnamani N. D. (2018). Preparation and evaluation of 5-fluorouracil solid dispersion formulations for therapeutic management of colorectal cancer (CRC) AJOPRED 10(2): 127-134

Pitt K.G.and Heasley M. G. (2013). Determination of tensile strength of elongated tablets. Powder Technol. 238: 169-175

Pongri A. W., Igbe I. and Bafor E. (2023). Antiatherogenic and antiobesity effects of aqueous stem bark extract of grewia mollis Juss (Malvaceae). Trop J Nat Prod Res. 2023; 7(9): 4103-4111. http://www.doi.org/10.26538/jtjnpr/v7i9.39

Shang C., Sinka I. C., Jayaraman B. and Pan J. (2013). Break force and tensile strength relationships for curved faced tablets subject to diametrical compression. Int. J. Pharm. 442 (1-2): 57-64

Asghar A. A., Akhlaq M., Jalil A., Azad A. K., Asghar J., Adeel M., Albadrani G. M., Al-Doaiss A. A., Kamel M., Altyar A. E., Abdel-Daim M. M. (2022). Formulation of ciprofloxacin-loaded oral self-emulsifying drug delivery system to improve the pharmacokinetics and antibacterial activity. Front. Pharmacol. 13, 967106

Shingande S. S., Mandhare T. A., Kashid P. S. and Otari K. (2024). Chewable tablets: a comprehencive review. AJPRD 12(4): 119-125.

Spandana B., Shashidher B., Dinesh S. and Nagaraj B. (2020).Eletriptan hydrobromide Orodispersible tabltes: design, development and in vitro characterization. Res J. Pharm. Technol. 13(11): 5339-5344.

Valencia G. A., Luciano C.G., Lourenco R. V. and Sobral do Amaral P.J. (2018). Microstructure and physical properties of nano-biocomposite films based on cassava starch and laponite. Int. J. Biol. Macromol. 107: 1576-1583

Yohannes B. and Abebe A. (2021). Determination of tensile strength of shaped tablets. Powder Technol. 383: 11-18. https://doi.org/10.1016/j.powtec.2021.01.014

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Conflict of Interest: None declared
Received: September 7, 2025
Accepted: April 13, 2026

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