Development and Evaluation of Tara Gum-Based Floating Clindamycin Tablets for Prolonged Gastric Retention and Sustained Drug Release

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ABSTRACT

Background: Gastroretentive floating drug delivery systems can prolong gastric residence and provide sustained drug release. Natural polymers such as Tara gum offer useful swelling and hydration properties for developing controlled-release matrix tablets.

Objective: This study aimed to develop and evaluate clindamycin floating tablets containing Tara gum as a natural release-retarding polymer in combination with hydroxypropyl methylcellulose K4M (HPMC K4M), and to investigate the influence of polymer composition on swelling, floating behavior, and drug release.

Methods: Eight formulations (F1–F8) were prepared by direct compression, each containing 300 mg clindamycin. HPMC K4M (70–84 mg) and Tara gum (80–66 mg) were varied across formulations, while Carbopol 934, sodium bicarbonate, tartaric acid, magnesium stearate, and talc were incorporated as formulation excipients. Pre- and post-compression parameters, drug content, in vitro drug release, swelling index, and floating characteristics were evaluated.

Results: Extracted Tara gum exhibited a swelling index of 18, bulk density of 0.42, tapped density of 0.59, Carr's index of 17.85%, Hausner's ratio of 1.12, angle of repose of 20.52°, and 20% yield. The formulations demonstrated satisfactory flow and tablet properties, with thickness of 3.91–3.96 mm, hardness of 6.5–7.3 kg/cm², drug content above 90%, and friability below 1%. Cumulative drug release at 6 h ranged from 74.3% to 94.2%. F6, containing 80 mg HPMC K4M and 70 mg Tara gum, showed the lowest drug release (74.3%), highest swelling index (265 ± 0.32 at 6 h), and approximately 6 h floating duration.

Conclusion: Tara gum effectively contributed to matrix swelling and sustained drug release. F6 was identified as the most promising formulation for prolonged in vitro release and floating behavior. Further optimization and in vivo gastroretention studies are warranted.

Keywords: Tara Gum; Clindamycin; Floating; Gastroretentive; Tablets; Sustained Release; Gastric Retention; Natural Polymer; In-Vitro Release; Direct Compression.

INTRODUCTION

Oral drug delivery remains one of the most widely used approaches for systemic administration because of its convenience, patient acceptability and ease of administration. However, conventional immediate-release dosage forms may exhibit limitations when prolonged drug exposure or controlled release is desirable. Rapid gastric emptying and gastrointestinal transit can shorten the residence time of an oral dosage form and may consequently limit the duration over which drug release occurs at a particular gastrointestinal site.

Gastroretentive drug delivery systems (GRDDS) have been developed to increase the residence time of pharmaceutical dosage forms within the stomach. Among the different gastroretentive approaches, floating drug delivery systems are particularly attractive because they are designed to maintain a density lower than gastric contents and consequently remain buoyant in the gastric environment. A successful floating system should possess adequate buoyancy, sufficient mechanical integrity, appropriate swelling characteristics and a controlled drug-release profile.

Clindamycin is a semisynthetic lincosamide antibiotic used for the treatment of infections caused by susceptible microorganisms. The uploaded research file describes the development of a floating tablet intended to provide prolonged drug release and improved oral administration characteristics. The study specifically investigated the use of a combination of synthetic and natural polymers, with Tara gum serving as the principal natural polymer.

Natural polymers are increasingly investigated in oral controlled-release formulations because many possess useful swelling and gel-forming properties. Tara gum is a galactomannan polysaccharide capable of hydration and swelling in aqueous environments. Such behavior can contribute to formation of a hydrated polymeric matrix around the dosage form, thereby increasing diffusion path length and slowing drug release. In a floating matrix tablet, polymer hydration and swelling may simultaneously contribute to maintenance of tablet integrity and gastric buoyancy. In the present formulation, HPMC K4M was combined with Tara gum to investigate the influence of polymer concentration on tablet performance. Sodium bicarbonate and tartaric acid were incorporated as gas-generating components, while Carbopol 934 and conventional tableting excipients were included in the formulation. The formulation design comprised eight batches, F1–F8, in which the quantities of HPMC K4M and Tara gum were systematically varied while the other major components were kept constant. The rationale of the present investigation was therefore to determine whether incorporation of Tara gum could modify the hydration, swelling, buoyancy and release characteristics of clindamycin floating tablets and identify a formulation capable of providing prolonged in vitro drug release.

MATERIALS AND METHODS

Materials

Clindamycin was used as the model drug. HPMC K4M and Tara gum were used as matrix-forming polymers. Carbopol 934, sodium bicarbonate and tartaric acid were incorporated into the formulation, while magnesium stearate and talc were used as tableting excipients. The formulation composition was designed for a tablet weight of 600 mg.

Methods

Extraction and Characterization of Tara Gum

Tara gum was extracted from Tara seeds and purified before formulation development. The extracted material was evaluated for loss on drying, swelling index, solubility, bulk density, tapped density, Carr's compressibility index, Hausner's ratio, angle of repose and percentage yield.

Parameter	Result
Loss on drying	12%
Swelling index	18
Solubility	Soluble in cold and hot water; insoluble in ethanol
Bulk density	0.42
Tapped density	0.59
Carr's index	17.85%
Hausner's ratio	1.12
Angle of repose	20.52°
Percentage yield	20%

These values were reported in triplicate in the source study.

Organoleptic Evaluation

Clindamycin was evaluated for color, physical form, odor and taste. The reported sample was brownish, crystalline, odorless and bitter.

UV Spectroscopic Characterization

The maximum absorption wavelength of clindamycin in the study medium was reported as 229 nm.

Melting Point

The melting point of the drug was reported as 142°C, with an observed range of 141–143°C.

Calibration Curve

A calibration curve for clindamycin in 0.1 N HCl was prepared at 229 nm using concentrations ranging from 0 to 25 µg/mL. The corresponding absorbance values were 0, 0.127, 0.231, 0.327, 0.439 and 0.533 for 0, 5, 10, 15, 20 and 25 µg/mL, respectively.

Drug–Excipient Compatibility

FTIR analysis was performed to investigate possible interactions between clindamycin and the polymers. The study reported that the principal drug-associated spectral features were retained in the drug–polymer mixtures and that no major changes indicative of chemical interaction were observed.

Solubility Study

The solubility of clindamycin was investigated in different solvents. The drug was reported to be freely soluble in water, soluble in methanol, sparingly soluble in ethanol and very slightly soluble in chloroform.

Formulation Development

Eight floating tablet formulations, F1–F8, were prepared by direct compression. Each formulation contained 300 mg of clindamycin. HPMC K4M concentration was progressively increased from 70 to 84 mg, whereas Tara gum was decreased from 80 to 66 mg. Carbopol 934, sodium bicarbonate, tartaric acid, magnesium stearate and talc were maintained at 55, 45, 30, 10 and 10 mg, respectively. The total tablet weight was 600 mg.

Table 1. Composition of clindamycin floating tablet formulations

Ingredient (mg/tablet)	F1	F2	F3	F4	F5	F6	F7	F8
Clindamycin	300	300	300	300	300	300	300	300
HPMC K4M	70	72	74	76	78	80	82	84
Carbopol 934	55	55	55	55	55	55	55	55
Sodium bicarbonate	45	45	45	45	45	45	45	45
Tartaric acid	30	30	30	30	30	30	30	30
Tara gum	80	78	76	74	72	70	68	66
Magnesium stearate	10	10	10	10	10	10	10	10
Talc	10	10	10	10	10	10	10	10
Total weight	**600**	**600**	**600**	**600**	**600**	**600**	**600**	**600**

The formulation procedure involved sieving the ingredients through sieve no. 80, blending the polymers and gas-generating components, followed by addition of talc and magnesium stearate. The final blends were compressed using a rotary punch tablet machine.

Evaluation of Floating Tablets

Pre-compression Evaluation

The powder blends were evaluated for angle of repose, bulk density, tapped density, Carr's compressibility index and Hausner's ratio. The reported values indicated generally acceptable flow characteristics for tablet compression.

Table 2. Pre-compression properties of formulation blends

Formulation	Angle of repose (°)	Bulk density	Tapped density	Carr's index (%)	Hausner's ratio
F1	38.78 ± 0.06	0.51 ± 0.13	0.66 ± 0.05	15.52	1.15 ± 0.19
F2	30.35 ± 0.05	0.43 ± 0.01	0.45 ± 0.08	14.54	1.14 ± 0.18
F3	29.45 ± 0.12	0.31 ± 0.18	0.38 ± 0.10	16.12	1.17 ± 0.06
F4	27.35 ± 0.02	0.40 ± 0.05	0.42 ± 0.18	20.15	1.16 ± 0.12
F5	26.20 ± 0.22	0.44 ± 0.14	0.47 ± 0.14	18.16	1.18 ± 0.05
F6	24.30 ± 0.21	0.18 ± 0.05	0.20 ± 0.15	12.21	1.12 ± 0.10
F7	27.12 ± 0.15	0.32 ± 0.18	0.33 ± 0.12	16.45	1.16 ± 0.12
F8	26.41 ± 0.16	0.25 ± 0.20	0.26 ± 0.10	17.12	1.17 ± 0.19

The source reported that the powder blends possessed satisfactory flow properties for compression.

Post-compression Evaluation

The prepared tablets were evaluated for thickness, hardness, weight variation, friability, drug content, in vitro drug release, swelling index and floating behavior.

The tablets exhibited a thickness range of approximately 3.91–3.96 mm. Hardness was reported between 6.5 and 7.3 kg/cm², while friability remained below 1%. Drug content was reported to be greater than 90% across the formulations.

These results indicate that the direct-compression process produced tablets with acceptable mechanical properties and satisfactory drug-content uniformity.

In Vitro Drug Release Study

In vitro dissolution testing was performed using USP apparatus II with 900 mL dissolution medium, a paddle speed of 50 rpm and a temperature of 37 ± 0.5°C. Samples were withdrawn at predetermined intervals and analyzed spectrophotometrically at 229 nm.

Table 3. Cumulative percentage drug release from F1–F8

Time (h)	F1	F2	F3	F4	F5	F6	F7	F8
0.5	6.54	8.54	7.56	6.54	7.45	6.12	7.56	6.45
1	18.60	11.90	9.74	15.60	12.00	13.89	14.20	13.65
1.5	26.40	27.40	16.40	25.60	18.60	18.56	19.60	20.65
2	31.50	39.90	25.40	37.50	24.50	24.26	24.67	26.32
2.5	53.00	58.40	36.45	45.00	35.12	34.95	35.45	37.65
3	59.40	59.90	50.12	56.70	45.90	40.99	41.23	45.23
3.5	68.20	70.40	56.26	70.50	56.50	45.52	46.25	47.25
4	75.50	80.00	62.13	78.70	72.60	50.32	51.32	55.45
4.5	79.30	84.60	71.65	86.30	74.50	52.46	56.12	58.56

5	84.00	85.00	80.32	88.60	80.50	57.74	58.23	59.36
5.5	89.40	90.20	86.23	93.50	85.60	68.50	70.56	74.35
6	90.50	91.80	88.56	94.20	89.50	**74.30**	86.12	88.65

The dissolution profile demonstrated formulation-dependent release behavior. F6 showed the lowest cumulative drug release at 6 h (74.30%), whereas F4 showed the highest release (94.20%).

The slower release observed with F6 may be attributed to its relatively high total polymeric matrix content, consisting of 80 mg HPMC K4M and 70 mg Tara gum. Hydration and swelling of these polymers can produce a viscous barrier around the tablet and increase the diffusional resistance to drug molecules.

Swelling Behavior

Swelling is an important characteristic of hydrophilic matrix-based gastroretentive systems because hydration of the polymeric network can increase tablet dimensions, maintain matrix integrity and influence drug diffusion.

The source study reported progressively increasing swelling with increasing immersion time. F6 exhibited the highest swelling response among the investigated formulations, with a reported swelling index of 265 ± 0.32 at 6 h.

Table 4. Swelling index of floating tablet formulations

Time (h)	F1	F2	F3	F4	F5	F6	F7	F8
1	21 ± 0.50	18 ± 0.33	28 ± 0.34	21 ± 0.21	25 ± 0.66	36 ± 0.12	29 ± 0.12	30 ± 0.66
2	65 ± 0.50	75 ± 0.64	70 ± 0.56	69 ± 0.32	70 ± 0.32	164 ± 0.13	45 ± 0.65	65 ± 0.32
3	80 ± 0.56	120 ± 0.25	80 ± 0.65	130 ± 0.24	120 ± 0.45	212 ± 0.12	120 ± 0.25	90 ± 0.45
4	90 ± 0.60	135 ± 0.24	112 ± 0.33	165 ± 0.34	135 ± 0.12	235 ± 0.15	126 ± 0.23	120 ± 0.12
5	135 ± 0.30	145 ± 0.30	130 ± 0.66	177 ± 0.54	156 ± 0.21	255 ± 0.24	135 ± 0.34	135 ± 0.21
6	166 ± 0.20	165 ± 0.12	145 ± 0.55	185 ± 0.34	170 ± 0.33	**265 ± 0.32**	145 ± 0.15	165 ± 0.34

The markedly higher swelling response of F6 suggests that the combination of HPMC K4M and Tara gum produced a highly hydrated polymeric matrix. The source study attributed this behavior to a synergistic effect between the polymers.

Floating Behavior

The floating characteristics of the tablets were evaluated in 0.1 N HCl. Floating lag time was defined as the time required for a tablet to rise from the bottom of the vessel to the surface, whereas floating time represented the duration for which the tablet remained buoyant.

Sodium bicarbonate and tartaric acid were incorporated as gas-generating components. In an acidic aqueous environment, their reaction generates carbon dioxide, which becomes entrapped within the hydrated polymeric matrix and contributes to tablet buoyancy.

According to the reported findings, F6 demonstrated a total floating duration of approximately 6 h and exhibited the greatest swelling response among the formulations.

DISCUSSION

The present investigation demonstrates the potential utility of Tara gum as a natural polymer for development of a clindamycin floating matrix tablet. The formulation strategy was based on combining HPMC K4M with Tara gum to obtain a hydrated polymeric network capable of simultaneously influencing swelling, buoyancy and drug release.

The physicochemical characterization of the extracted Tara gum indicated satisfactory formulation-related properties. Its ability to swell in aqueous media is particularly relevant to matrix tablet development because polymer hydration can result in formation of a viscous gel layer. The observed swelling index of the extracted gum and its aqueous solubility support its suitability for further formulation investigation.

The pre-compression data demonstrated that the powder blends possessed generally satisfactory flow properties. F6 showed an angle of repose of 24.30°, Carr's index of 12.21% and Hausner's ratio of 1.12, indicating comparatively favorable flow characteristics among the tested formulations.

The post-compression evaluation further demonstrated acceptable tablet characteristics. The reported hardness range of 6.5–7.3 kg/cm² and friability below 1% indicate adequate mechanical strength for handling. Drug content was reported to exceed 90% in the tested formulations.

A clear formulation-dependent difference was observed in drug-release behavior. F6 provided the slowest release among the eight batches, with 74.30% cumulative drug release after 6 h. In contrast, F4 released 94.20% over the same period. This difference indicates that polymer concentration and polymer ratio exerted an important influence on release kinetics.

The performance of F6 can be rationalized by its composition. F6 contained 80 mg HPMC K4M and 70 mg Tara gum, representing a high combined polymer concentration. Upon hydration, these polymers can form an expanded and viscous matrix that increases the diffusion path for clindamycin. The greater swelling observed with F6 provides additional evidence of stronger matrix hydration. At 6 h, F6 showed a swelling index of 265 ± 0.32 compared with 166 ± 0.20, 165 ± 0.12 and 145 ± 0.55 for F1, F2 and F3, respectively.

The combination of polymer swelling and gas generation is particularly important for floating systems. Sodium bicarbonate and tartaric acid provide the gas-generating mechanism, while the hydrated polymeric matrix can help retain generated gas within the dosage form. This combination may facilitate maintenance of buoyancy while simultaneously controlling drug diffusion.

Overall, the results indicate that increasing the polymeric matrix strength did not simply affect drug release; it also altered swelling behavior and potentially the ability of the dosage form to remain buoyant. Thus, optimization of a gastroretentive system requires simultaneous consideration of release rate, swelling and floating performance rather than relying on a single response variable.

CONCLUSION

The present study successfully explored Tara gum as a natural polymer for the development of a gastroretentive floating tablet of clindamycin. Eight formulations were prepared by direct compression using different concentrations of HPMC K4M and Tara gum. The prepared formulations demonstrated acceptable pre-compression flow properties and satisfactory post-compression characteristics.

The incorporation of Tara gum significantly contributed to the swelling behavior of the matrix. Among the investigated formulations, F6, containing 80 mg HPMC K4M and 70 mg Tara gum, demonstrated the highest swelling response and the slowest drug-release profile, with 74.30% cumulative clindamycin release after 6 h. The source study also reported approximately 6 h of floating behavior for F6.

The findings suggest that a combination of natural and synthetic hydrophilic polymers can be used to modulate the performance of floating clindamycin tablets. Tara gum therefore represents a promising natural matrix-forming polymer for gastroretentive drug-delivery research.

However, the present conclusions are based primarily on in vitro formulation studies. Further work involving optimization by Design of Experiments, dissolution kinetic modeling, stability studies, in vitro–in vivo correlation and appropriate in vivo gastroretention/pharmacokinetic evaluation is required before claims regarding prolonged gastric residence, enhanced bioavailability or clinical benefit can be established.

Study Limitations and Future Perspectives

The present study provides useful preliminary evidence for the role of Tara gum in clindamycin floating tablets; however, several aspects should be addressed in future investigations.

First, the formulation was developed using a conventional trial-based approach. A Quality by Design (QbD) strategy incorporating polymer concentration, gas-generating agent concentration and compression parameters as critical formulation variables could provide a more robust optimization approach.

Second, dissolution data should be subjected to kinetic modeling using zero-order, first-order, Higuchi and Korsmeyer–Peppas models to identify the predominant release mechanism.

Third, the present work does not establish actual gastric retention in vivo. Therefore, radiographic, scintigraphic or other validated gastroretention approaches would be required to demonstrate prolonged gastric residence.

Fourth, pharmacokinetic studies should be conducted to determine whether the optimized floating system produces meaningful changes in drug exposure compared with an appropriate conventional formulation.

Finally, long-term stability testing under appropriate ICH conditions should be performed to establish the physical and chemical stability of the optimized formulation.

Overall Research Significance

The major contribution of this work is the investigation of Tara gum as a natural polymer in a clindamycin gastroretentive floating matrix system. Rather than relying exclusively on synthetic matrix-forming polymers, the formulation combines HPMC K4M with Tara gum to modulate hydration, swelling and drug release.

The experimental findings particularly highlight F6 as a promising formulation because its relatively high polymer content produced a pronounced swelling response and slower in vitro drug release.

The study therefore provides a foundation for further development of natural-polymer-based gastroretentive dosage forms and supports additional optimization and in vivo validation of Tara gum-containing floating tablets.

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