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FORMULATION & CHARACTERIZATION OF SUSTAINED RELEASE TABLETS OF GENTAMYCIN USING GAUR GUM & XANTHAN GUM

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ABSTRACT

The present study aimed to develop and evaluate sustained-release floating tablets of Gentamicin using natural polymers, guar gum and xanthan gum, for gastro-retentive drug delivery. Pre-compression parameters of formulations F1–F9 indicated acceptable flowability and compressibility, with bulk density ranging from 0.315–0.335 g/mL, tapped density from 0.432–0.458 g/mL, Carr's index between 25.28–28.73%, and Hausner's ratio from 1.338–1.403. Post-compression evaluation revealed uniform tablet thickness (3.37–3.55 mm), adequate hardness (6.4–6.9 kg/cm²), low friability (<1%), acceptable weight variation, and drug content ranging from 96.80–99.25%. All formulations exhibited floating durations exceeding 12 hours, with floating lag times between 50–72 seconds, demonstrating effective gastro-retentive performance. The optimized formulation F5 displayed a controlled release of Gentamicin over 12 hours, achieving 96.4% cumulative drug release. Kinetic modeling indicated that drug release followed the Higuchi model (R^2 = 0.9866), suggesting diffusion-controlled release, with Korsmeyer–Peppas analysis confirming a non-Fickian transport mechanism. Overall, guar gum and xanthan gum effectively sustained Gentamicin release while ensuring rapid buoyancy and prolonged floating, making F5 a promising formulation for gastro-retentive therapy.

Keywords: Gentamicin, sustained-release floating tablets, gastro-retentive drug delivery, guar gum, xanthan gum, Higuchi model, non-Fickian diffusion, tablet evaluation.

INTRODUCTION

Gentamicin is a broad-spectrum aminoglycoside antibiotic widely used in the treatment of severe infections caused by Gram-negative and certain Gram-positive bacteria. It is particularly effective against *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella* species, and *Staphylococcus aureus* (Nwankwo *et al.*, 2021). Despite its potent antibacterial activity, the conventional administration of gentamicin is associated with several limitations, including a short biological half-life, frequent dosing requirements, and a risk of nephrotoxicity and ototoxicity, especially at higher plasma concentrations. These drawbacks highlight the need for alternative drug delivery approaches that can improve therapeutic efficacy while minimizing adverse effects (Pacifici; 2015). Oral sustained-release drug delivery systems are designed to maintain consistent plasma drug concentrations over an extended period, reduce dosing frequency, and enhance patient compliance. Sustained-release matrix tablets represent one of the most practical and cost-effective approaches due to their simplicity of formulation, ease of manufacturing, and reproducibility. The selection of suitable

polymers plays a crucial role in controlling drug release from such systems (Ratnaparkhi and Jyoti; 2013).

Natural polymers have gained significant attention in sustained-release formulations because of their biocompatibility, biodegradability, low toxicity, cost-effectiveness, and environmental safety (Diksha *et al.,* 2019). Among these, guar gum and xanthan gum are widely used hydrophilic polysaccharides with excellent swelling and gel-forming properties. Guar gum, a galactomannan obtained from *Cyamopsis tetragonoloba*, forms a viscous gel upon hydration, thereby retarding drug diffusion. Xanthan gum, a high-molecular-weight polysaccharide produced by *Xanthomonas campestris*, exhibits pseudoplastic behavior and strong matrix-forming ability, making it suitable for sustained drug release applications. The synergistic combination of guar gum and xanthan gum has been reported to provide improved matrix integrity and more predictable release kinetics (Sundharaiya *et al.,* 2025).

The development of sustained-release oral formulations of gentamicin using natural polymers may offer a promising strategy to achieve prolonged drug release, reduce dosing frequency, and improve therapeutic outcomes. Furthermore, the use of biodegradable gums aligns with the growing emphasis on eco-friendly and patient-friendly pharmaceutical formulations.

Therefore, the present study aims to formulate and characterize sustained-release tablets of gentamicin using guar gum and xanthan gum as matrix-forming agents. The formulated tablets will be evaluated for physicochemical properties, drug content uniformity, in vitro drug release behavior, and release kinetics to assess the potential of these natural polymers in developing an effective sustained-release delivery system for gentamicin.

MATERIALS AND METHODS

Materials

Gentamicin was used as the active pharmaceutical ingredient for the development of sustained-release floating tablets. Natural polymers, namely guar gum and xanthan gum, were employed as matrix-forming agents to control drug release. Other excipients included sodium bicarbonate as a gas-forming agent to impart buoyancy, microcrystalline cellulose as a filler and binder, magnesium stearate as a lubricant, and talc as a glidant to improve powder flow. Distilled water was used during granulation and wetting processes. All materials were of pharmaceutical grade and used as received.

Methods

Method for preparation of sustained release tablets of Gentamicin using gaur gum and xanthan gum

Sustained release floating tablets of Gentamicin were prepared by the direct compression method as reported by Basavaraja et al. (2015). A total of nine formulations (F1–F9) were developed by varying the concentrations of HPMC K4M and HPMC K15M, either alone or in combination, while keeping Gentamicin, guar gum, xanthan gum, and other excipients constant.

The accurately weighed quantities of Gentamicin (40 mg), guar gum (20 mg), xanthan gum (10 mg), HPMC K4M and/or HPMC K15M (as per formulation), PVP K-30 (20 mg), and lactose (q.s.) were individually passed through sieve no. 40 to ensure uniform

particle size. The drug was first blended with the polymers (HPMC K4M and/or HPMC K15M), guar gum, xanthan gum, PVP K-30, and lactose in a mortar for 10–15 minutes to obtain a uniform and homogeneous mixture.

Subsequently, the gas-generating agents, namely citric acid (10 mg) and sodium bicarbonate (60 mg), were added to the blend and mixed gently to avoid premature effervescence. Finally, magnesium stearate (5 mg) and talc (5 mg) were incorporated and mixed for 2–3 minutes to ensure adequate lubrication without over-mixing.

The final blend was evaluated for flow properties and then compressed using a rotary tablet compression machine equipped with suitable punches to obtain tablets of 300 mg total weight. All tablets were stored in airtight containers for further evaluation.

Evaluation of precompression parameter

Bulk density: Both loose bulk density (LBD) and tapped bulk density (TBD) were determined. Accurately weighed amount of granules taken in a 50 ml capacity measuring cylinder was tapped for 100 times on a plane hard wooden surface and estimated the LBD and TBD, calculated by using following formulas (Bharadwaj *et al.,* 2000).

$$\text{LBD (Loose Bulk Density)} = \frac{\text{Mass of powder}}{\text{Volume of Packing}}$$

$$\text{TBD (Tapped Bulk Density)} = \frac{\text{Mass of powder}}{\text{Tapped Volume of Packing}}$$

Compressibility index: Percent compressibility of powder mix was determined by Carr's compressibility index, calculated by using following formula:-

$$\text{Carr's Index} = \frac{\text{TBD} - \text{LBD}}{\text{TBD}} \text{X } 100$$

Hausners ratio: It is determined by comparing tapped density to the bulk density by using following equation:-

$$\text{Housner's ratio} = \frac{\text{Tapped bulk density}}{\text{Loose Bulk density}}$$

Evaluation of tablets

All the tablets were evaluated for following various parameters which includes;

General Appearance

Five tablets from various batches were randomly selected and organoleptic properties such as color, odor, shape, were evaluated. Appearance was judged visually. Very good (+++), good (++), fair (+) poor (-), very poor (- -).

Thickness and diameter

Thickness and diameter of tablets were determined using Vernier caliper. Five tablets from each batch were used, and an average value was calculated (Pundir *et al.,* 2015).

Drug content

Twenty tablets were taken and amount of drug present in each tablet was determined (Basak *et al.,* 2006). The tablets were crushed in a mortar and the powder equivalent to 10mg of drug was transferred to 10ml standard flask. The powder was dissolved in 5 ml of 0.1 N HCl and made up to volume with of 0.1 N HCl. The sample was mixed thoroughly and filtered through a 0.45µ membrane filter. The filtered solution was diluted suitably and for drug content by UV spectrophotometer at λ_{max} of 242 nm using of 0.1 N HCl as blank.

Hardness

For each formulation, the hardness of five tablets was resolved utilizing the Monsanto hardness tester (Varshosaz *et al.,* 2006).

Friability

The friability of a sample of 10 tablets was estimated utilizing a Friability tester (Electro

Lab). Ten tablets were weighed, rotated at 25 rpm for 4 minutes. Tablets were reweighed after removal of fines (dedusted) and the percentage of weight loss was calculated (Venkataramudu *et al.,* 2012).

Uniformity of weight

Twenty tablets were randomly selected from each batch individually weighed, the average weight and standard deviation of 20 tablets was calculated.

***In vitro* buoyancy studies:**

In vitro buoyancy was determined by floating lag time as per the method described by Rosa *et al*. The tablets were separately in a 100 ml glass beaker containing simulated gastric fluid, pH 1.2 as per USP. The time necessary for the tablet to increase to the outside and float was determined as floating lag time.

Dissolution rate studies

In vitro drug release of the sample was done using USP-type II dissolution apparatus (Paddle type). The dissolution medium, 900 ml 0.1N HCl was set into the dissolution flask maintaining the temperature of 37±0.5°C and rpm of 75. One prepared Gentamicin tablet was set in every container of dissolution apparatus. The mechanical assembly was permitted to keep running for 10 hours. Sample measuring 5 ml were pulled back after each 1 hour up to 10 hours using 10ml pipette. The new disintegration medium (37ºC) was supplanted each time with a similar amount of the sample and takes the absorbance at 242nm using UV/Visible spectroscopy.

RESULTS AND DISCUSSION

The pre-compression parameters of Gentamicin powder blends (F1–F9) were evaluated to assess their flowability and compressibility prior to tablet compression. Bulk density values ranged from 0.315 to 0.335 g/mL, while tapped density values were between 0.432 and 0.458 g/mL, indicating acceptable packing characteristics of the blends. The Compressibility Index (Carr's Index) values varied from 25.28% to 28.73%, and Hausner's ratio ranged from 1.338 to 1.403, suggesting fair to passable flow properties of the powder blends. These results indicate that although the formulations exhibited moderate cohesiveness due to the presence of natural polymers (guar gum and xanthan gum), the flow was adequate for direct compression. Among all formulations, F7 showed the lowest compressibility index and Hausner ratio, indicating comparatively better flow behavior (Table 2).

The post-compression evaluation of sustained-release floating tablets demonstrated satisfactory physical characteristics across all formulations. Tablet thickness ranged from 3.37 ± 0.21 to 3.55 ± 0.14 mm, indicating uniform die fill and consistent compression.

Tablet hardness was found to be within 6.4–6.9 kg/cm², which is adequate to maintain mechanical strength while allowing controlled drug release. Friability values were below 1% for all formulations, confirming good mechanical resistance and compliance with pharmacopeial limits.

Weight variation values were within acceptable limits, indicating uniformity of dosage units. Drug content ranged from 96.80% to 99.25%, demonstrating uniform distribution of Gentamicin within the tablet matrix. All formulations exhibited a floating duration greater than 12 hours, confirming the effectiveness of the floating system and the ability of the matrix to maintain buoyancy

over an extended period, which is essential for gastro-retentive drug delivery (Table 3).

The floating lag time for all formulations was found to be within the range of 50 to 72 seconds, indicating rapid tablet buoyancy upon contact with gastric fluid. Formulation F5 exhibited the shortest floating lag time (50 ± 6 sec), suggesting faster gas generation and effective entrapment of CO_2 within the hydrated polymeric matrix.

The slight variation in floating lag time among formulations can be attributed to differences in polymer concentration and matrix integrity, which influence hydration and gas retention capacity (Table 4).

The optimized formulation F5 showed a controlled and sustained release pattern of Gentamicin over a period of 12 hours. An initial release of 11.5% at 0.5 h was observed, which may be attributed to surface-associated drug, followed by a gradual and controlled release.

At the end of 12 hours, 96.4% cumulative drug release was achieved, indicating effective sustained-release behavior. The gradual increase in drug release with time confirms the ability of guar gum and xanthan gum to form a hydrated gel barrier that regulates drug diffusion (Table 5).

Regression analysis of the drug release data for formulation F5 revealed that the Higuchi model showed the highest correlation coefficient ($R^2 = 0.9866$), indicating that drug release was predominantly governed by diffusion through the polymeric matrix.

The First-order model ($R^2 = 0.9841$) also showed a strong correlation, suggesting concentration-dependent release. The Korsmeyer–Peppas model ($R^2 = 0.9825$) further supports a non-Fickian (anomalous) transport mechanism, involving a combination of diffusion and polymer relaxation/erosion.

The relatively lower R^2 value for the Zero-order model (0.9162) suggests that the system does not follow a constant release rate throughout the study period (Table 6).

The results demonstrate that guar gum and xanthan gum are effective natural polymers for developing sustained-release floating tablets of Gentamicin. Among all formulations, F5 emerged as the optimized formulation, exhibiting desirable pre-compression flow properties, satisfactory post-compression characteristics, rapid buoyancy, prolonged floating duration, and controlled drug release over 12 hours.

Table 1: Various formulations of sustained release tablets of Gentamicin

Ingredients (mg)	F1	F2	F3	F4	F5	F6	F7	F8	F9
Gentamicin	40	40	40	40	40	40	40	40	40
Gaur gum	20	20	20	20	20	20	20	20	20
Xanthan gum	10	10	10	10	10	10	10	10	10
HPMC K4M	40	50	60	–	–	–	20	30	40
HPMC K15M	–	–	–	40	50	60	20	30	40
PVP K-30	20	20	20	20	20	20	20	20	20
Citric Acid	10	10	10	10	10	10	10	10	10
Sodium Bicarbonate	60	60	60	60	60	60	60	60	60
Magnesium Stearate	5	5	5	5	5	5	5	5	5
Talc	5	5	5	5	5	5	5	5	5
Lactose (q.s.)	90	80	70	90	80	70	90	70	50
Total Tablet Weight	300	300	300	300	300	300	300	300	300

Table 2: Result of pre-compression properties of Gentamicin

Formulation Code	F1	F2	F3	F4	F5	F6	F7	F8	F9
Bulk Density (g/ml)	0.315	0.319	0.325	0.323	0.335	0.318	0.325	0.321	0.317
Tapped Density (g/ml)	0.442	0.436	0.439	0.445	0.458	0.432	0.435	0.436	0.439
Compressibility Index (%)	28.73	26.83	25.96	27.41	26.85	26.38	25.28	26.37	27.79
Hausner Ratio	1.403	1.367	1.351	1.378	1.367	1.358	1.338	1.358	1.385

Table 3: Results of post compression properties of sustained release tablets

Parameter	F1	F2	F3	F4	F5	F6	F7	F8	F9
Thickness (mm)	3.46 ± 0.08	3.50 ± 0.12	3.47 ± 0.10	3.55 ± 0.14	3.54 ± 0.18	3.45 ± 0.20	3.38 ± 0.22	3.41 ± 0.19	3.37 ± 0.21
Hardness (kg/cm^2)	6.9 ± 0.3	6.6 ± 0.4	6.8 ± 0.3	6.6 ± 0.2	6.9 ± 0.2	6.4 ± 0.3	6.8 ± 0.3	6.5 ± 0.4	6.7 ± 0.3
Weight Variation (mg)	304±5	302±3	299±2	300±4	302±5	304±3	303±2	302±5	303±6
Friability (%)	0.72 ± 0.03	0.78 ± 0.02	0.86 ± 0.03	0.80 ± 0.04	0.88 ± 0.03	0.87 ± 0.02	0.74 ± 0.03	0.65 ± 0.03	0.68 ± 0.03
Drug Content (%)	98.92 ± 0.20	98.65 ± 0.30	97.85 ± 0.22	96.85 ± 0.40	99.25 ± 0.28	98.25 ± 0.35	97.95 ± 0.32	96.80 ± 0.20	97.60 ± 0.30
Floating Duration (h)	>12	>12	>12	>12	>12	>12	>12	>12	>12

Average of three determinations (N=3±SD)

Table 4: Results of *in-vitro* buoyancy study of Gentamicin sustained release floating time

S. No.	Formulation Code	Floating Lag Time (sec)
1	F1	65 ± 4
2	F2	58 ± 5
3	F3	53 ± 3
4	F4	57 ± 4
5	F5	50 ± 6
6	F6	60 ± 5
7	F7	72 ± 4
8	F8	68 ± 5
9	F9	63 ± 4

Table 5: *In-vitro* drug release data for optimized formulation F5

Time (h)	Square Root of Time$(h)^{1/2}$	Log Time	Cumulative*% Drug Release	Log Cumulative % Drug Release	Cumulative % Drug Remaining	Log Cumulative % Drug Remaining
0.5	0.707	-0.301	11.5	1.061	88.50	1.947
1	1	0	21.0	1.322	79.00	1.898
1.5	1.225	0.176	28.8	1.459	71.20	1.852
2	1.414	0.301	36.3	1.560	63.70	1.804
3	1.732	0.477	48.3	1.684	51.70	1.713
4	2	0.602	59.5	1.775	40.50	1.607
6	2.449	0.778	70.8	1.850	29.20	1.465

8	2.828	0.903	86.9	1.939	13.10	1.117
12	3.464	1.079	96.4	1.984	3.60	0.556

Table 6: Regression analysis data

Batch F5	Zero Order	First Order	Higuchi	Peppas
R^2 value	0.9162	0.9841	0.9866	0.9825

CONCLUSION

Sustained-release floating tablets of gentamicin were successfully formulated using guar gum and xanthan gum as natural matrix-forming polymers. Pre-compression and post-compression parameters indicated good flow properties, adequate mechanical strength, uniform drug content, and acceptable friability. All formulations exhibited satisfactory buoyancy with prolonged floating duration. The optimized formulation (F5) demonstrated controlled and sustained drug release up to 12 hours, following predominantly Higuchi diffusion kinetics. The study confirms that guar gum and xanthan gum are effective, economical, and biodegradable polymers for developing gastro-retentive sustained-release tablets of gentamicin.

DECLARATION OF INTEREST

The authors declare no conflicts of interests. The authors alone are responsible for the content and writing of this article.

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