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RESEARCH ARTICLE

FORMULATION AND EVALUATION OF SODIUM ALGINATE BEADS AND SUSTAINED-RELEASE PELLETS OF RABEPRAZOLE SODIUM

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Abstract

Background: Rabeprazole sodium is a proton pump inhibitor that degrades rapidly in acidic media. Prolonged-release oral forms must therefore limit its exposure to gastric acid while controlling its release in the intestine.
Objective: To develop and evaluate two independent multiparticulate systems of rabeprazole sodium, namely calcium alginate beads and Eudragit RS100-coated sustained-release pellets.
Methods: Calcium alginate beads were generated by ionotropic gelation using a two-factor, three-level factorial arrangement comprising sodium alginate at 2.0–3.0% w/v and calcium chloride at 1.0–2.0% w/v. A separate pellet series was manufactured by powder layering onto sugar spheres and subsequent application of Eudragit RS100 coatings containing triethyl citrate at 0–20% of the polymer mass. Characterization encompassed manufacturing recovery, drug incorporation, particle attributes and UV-derived apparent release. The selected pellet formulation underwent additional release-model fitting, scanning electron microscopy and storage assessment.
Results: Increasing the concentrations of sodium alginate, and calcium chloride increased bead yield (82.4–91.0%), entrapment efficiency (78.6–91.6%) and size, and decreased swelling and drug release at 8 h (from 91.8% to 73.5%). Formulation B5 showed a balanced profile with an entrapment efficiency of 87.6±1.0%. In the pellet series, increasing the triethyl citrate level progressively retarded drug release at 12 h, from 96.8% (F1) to 76.5% (F5). The drug content and 12 h release of F5 changed by less than two percentage points after 6th months of accelerated and 12th months of long-term storage.
Conclusion: Triethyl citrate concentration was a critical variable governing drug release from Eudragit RS100-coated rabeprazole sodium pellets. Formulation F5 met all predefined quality and release criteria and remained stable during storage, identifying it as a promising sustained-release multiparticulate candidate for further development.
Keywords: alginate beads, Eudragit RS100, ionotropic gelation, rabeprazole sodium, sustained-release pellets, triethyl citrate.

INTRODUCTION

Rabeprazole sodium is a benzimidazole-derived inhibitor of gastric proton secretion. Its pharmacological activation within the acidic secretory canaliculi of parietal cells contrasts with its susceptibility to degradation during exposure to gastric luminal acid, creating a requirement for protection before intestinal absorption[1,2]. Oral rabeprazole products commonly employ an enteric barrier, supported where appropriate by alkaline micro-environmental stabilization and an intermediate seal layer, to address acid-mediated degradation and interactions between the drug containing core and outer coating[3]. The reported plasma elimination half-life of approximately 1–2 h provides pharmacokinetic context but does not independently establish the therapeutic value of prolonged release. Accordingly, the present investigation addresses formulation feasibility and in vitro release regulation rather than an assumed clinical advantage multiparticulate systems that can modulate its release remain of formulation interest[1].

Multiparticulate dosage forms divide the dose among numerous beads or pellets that disperse along the gastrointestinal tract, reduce the risk of dose dumping and allow the release barrier to be tailored at the level of each particle[2]. Calcium-mediated ionotropic gelation involves the formation of junction zones between

guluronate-rich regions of neighbouring alginate chains. The resulting hydrogel architecture, conventionally represented by the egg-box model, depends on polymer characteristics and the conditions governing cation availability and gel formation[4]. Magdhut *et al.*[4], showed that floating alginate–gellan gum beads of rabeprazole provide formulation-dependent entrapment and release, confirming the feasibility of this carrier class for the drug.

Drug-layered pellets coated with a release-controlling polymer provide an alternative approach. Eudragit RS100 is an ammonio methacrylate copolymer of low permeability that gives pH-independent, diffusion-controlled release; it is not an enteric polymer. Triethyl citrate is one plasticizer that affects permeability, flexibility, and film formation. Kibria *et al.*[6], demonstrated how the kind and quantity of plasticizer changed the medication release from pellets coated with Eudragit RS 30 D. Recent work on enteric omeprazole pellets and on resin-based rabeprazole carriers has further highlighted the importance of coating composition for this drug class[7,8].

Two independent formulation series were investigated. The alginate series examined the main and interaction effects of polymer and cross-linker concentration on bead attributes. The pellet series assessed triethyl citrate concentration at a fixed target coating weight gain, followed by selection against specified manufacturing and release limits. Subsequent investigations characterized the selected pellets through comparative dissolution, empirical release-model fitting, electron microscopy and storage monitoring.

MATERIALS AND METHODS

Rabeprazole sodium, with an as-supplied assay of 99.4% w/w, was provided by Metrochem API Pvt. Ltd., Hyderabad, India. Eudragit RS100 was provided by Evonik India Pvt. Ltd., Mumbai, India. Both materials were supplied as gift samples. Drug-input quantities and label-claim calculations incorporated correction for the stated API assay.Low-viscosity sodium alginate and 25–30-mesh non-pareil sugar spheres were procured from S D Fine-Chem Ltd., Mumbai, India, and Goa Antibiotics and Pharmaceuticals Ltd., Goa, India, respectively. Calcium chloride dihydrate, lactose monohydrate, polyethylene glycol 4000, triethyl citrate and purified talc were obtained from Dr. Reddy's Laboratories Ltd., India. Other reagents met analytical- or pharmacopoeial-grade specifications, and filtered reverse-osmosis water was used.

Analytical method

Rabeprazole sodium in formulation extracts and dissolution samples was quantified by ultraviolet–visible spectrophotometry (Shimadzu Corporation, Kyoto, Japan) at the wavelength of maximum absorbance in each medium. Samples in acidic medium were analysed within 5 min of withdrawal to minimize degradation. The method was validated according to ICH Q2(R1) for linearity, accuracy (recovery at 80, 100 and 120% of nominal content), repeatability and intermediate precision, specificity against placebo and robustness (±2 nm). Detection and quantification limits were estimated as 3.3σ/S and 10σ/S, respectively, where σ represents response variability and S denotes calibration slope[9].

Experimental design and preparation of alginate beads

The experimental matrix comprised all nine combinations of sodium alginate concentration, X_1, at 2.0, 2.5 and 3.0% w/v, and calcium chloride concentration, X_2, at 1.0, 1.5 and 2.0% w/v. Responses comprised dry-mass recovery, entrapment efficiency, particle diameter, swelling index and cumulative release at 8 h. The analysis evaluated factor main effects and their interaction; response-surface optimization was not undertaken. The drug–alginate dispersion was delivered through a 21-gauge needle attached to a 10 mL syringe into a 250 mL calcium chloride bath. Droplet formation occurred at a needle-to-bath separation of 8–10 cm, with the receiving phase maintained at 25±2°C under agitation at 200 rpm.After a 30 min gelation residence period, the beads were separated by decantation and subjected to two successive rinses, each using 50 mL water. The recovered material was dried at 45°C for 12 h.

Table 1:3^2 full factorial design for rabeprazole sodium alginate beads (B1–B9).

Formulation	Sodium alginate, X_1 (% w/v)	Calcium chloride, X_2 (% w/v)
B1	2.0 (−1)	1.0 (−1)
B2	2.0 (−1)	1.5 (0)
B3	2.0 (−1)	2.0 (+1)
B4	2.5 (0)	1.0 (−1)
B5	2.5 (0)	1.5 (0)
B6	2.5 (0)	2.0 (+1)
B7	3.0 (+1)	1.0 (−1)
B8	3.0 (+1)	1.5 (0)
B9	3.0 (+1)	2.0 (+1)

Evaluation of alginate beads

Manufacturing recovery was expressed as recovered dry bead mass relative to theoretical dry mass. Entrapment assessment involved comminution of a weighed bead sample, sonication in pH 6.8 phosphate buffer, filtration and measurement at 284 nm. Entrapment efficiency was calculated as the measured drug quantity divided by its theoretical quantity and expressed as a percentage. Individual diameters of 50 beads were determined by calibrated optical microscopy. Gravimetric swelling was assessed after incubating 1.0 g dried beads in 50 mL pH 6.8

phosphate buffer at 37±0.5 ℃ for 2 h. The swelling index was calculated as $100 \times (W_s - Wd)/Wd$, where W_s and Wd denote swollen and initial dry mass, respectively. Beads containing the equivalent of 20 mg rabeprazole sodium were examined in 900 mL pH 6.8 phosphate buffer using USP Apparatus II at 50 rpm and 37±0.5 ℃. Sampling occurred at 1, 2, 4, 6 and 8 h, with replacement of the withdrawn volume and spectrophotometric measurement at 284 nm.

Preparation of drug-layered pellets

The API–lactose mixture was screened through a 90-mesh sieve and blended for 15 min. Powder deposition onto sugar spheres was performed in a conventional coating pan operating at 20–24 rpm, alternating powder application with binder delivery at 2–3 mL/min. Layered cores were dried at 60±2℃ for 5 h and classified using 20/24-mesh sieves.

Table 2:Triethyl citrate levels in the Eudragit RS100 coating of pellet formulations F1–F5.

Formulation	Triethyl citrate (% w/w of Eudragit RS100)	Target coating weight gain (% w/w)
F1	0	8
F2	5	8
F3	10	8
F4	15	8
F5	20	8

Sustained-release coating of pellets

The five coating compositions incorporated triethyl citrate at 0, 5, 10, 15 and 20% relative to Eudragit RS100 mass, corresponding to F1–F5. The coating liquid contained 10% w/w polymer in isopropyl alcohol:acetone (60:40), with purified talc at 50% of polymer mass. Target dry coating weight gain was maintained at 8% w/w across the series. A 300 g charge of layered cores was coated at a pan speed of 20–24 rpm using a 1.0 mm spray nozzle positioned 8–10 cm from the pellet bed. Liquid delivery and atomizing pressure were maintained at 3–5 mL/min and 1.0–1.5 bar, respectively. Inlet air temperature was 40–45 ℃, product temperature was 32–36℃, and coating duration was 90–120 min. Coated pellets were classified using 18/24-mesh sieves, followed by drying at 60℃ for 5 h and a subsequent 1 h curing period at the same temperature.

Evaluation of pellets and selection criteria

Characterization included visual attributes, manufacturing recovery, UV-derived drug content, particle diameter, bulk and tapped densities, compressibility index, Hausner ratio and fixed-funnel angle of repose. Drug content was determined at 284 nm following extraction into pH 6.8 phosphate buffer, while diameter measurements comprised 50 individual pellets. Selection required simultaneous attainment of recovery >85%, measured drug content >95% of label claim, Carr's index ≤15%, acid-stage apparent release ≤10% at 2 h, and cumulative apparent release of 70–80% at 12 h.

***In-vitro* dissolution of pellets and profile comparison**

Sequential-medium testing was conducted using USP Apparatus II at 100 rpm and 37±0.5℃. Pellets were exposed to 900 mL 0.1 N hydrochloric acid for the initial 2 h, followed by testing in 900 mL pH 7.4 phosphate buffer until 12 h. Aliquots were obtained at 2, 4, 6, 8, 10 and 12 h, with volume replacement and measurement at the relevant medium-specific wavelength. The selected pellets, unformulated drug and commercial delayed-release tablet were tested under identical dissolution conditions, with three determinations per preparation. Difference and similarity factors were calculated from the six mean sampling values using the marketed product as reference. These indices were interpreted as descriptive measures of profile separation rather than evidence of pharmaceutical equivalence[10-12].

Release kinetics

The 2–12 h observations were subjected to least-squares linear regression using zero-order, first-order and Higuchi transformations. Regression coefficients and model-specific rate constants were obtained to describe the temporal release pattern. A Korsmeyer–Peppas exponent was not interpreted because the protocol incorporated an initial acid stage and a change of dissolution medium[10,13,14].

Surface morphology and stability study

Particle and surface topography were examined by scanning electron microscopy using a JSM-IT200 instrument operated at 5 kV. The analysis comprised rabeprazole sodium powder and the selected F5 pellet material. F5 pellets packaged in a plastic container were subjected to accelerated exposure at 40±2℃/75±5% relative humidity for six months and long-term exposure at 25±2℃/60±5% relative humidity for twelve months. Appearance, measured drug content and 12 h apparent release were monitored at baseline and at the specified storage intervals[15].

Statistical analysis

Descriptive results are presented as mean±standard deviation for three determinations, except diameter measurements, which comprised 50 particles. Bead responses were evaluated using a two-factor ANOVA incorporating both main effects and their interaction. Pellet responses were evaluated using one-factor ANOVA with Tukey-adjusted comparisons. Statistical significance was assessed at $p < 0.05$.

RESULTS

The absorption maximum shifted from 284 nm in pH 6.8 phosphate buffer to 289 nm in pH 7.4 phosphate buffer and 290 nm in hydrochloric acid. Calibration over 2–12 µg/mL yielded R^2 values of 0.9998, 0.9997 and 0.9996, respectively. Recovery ranged from 99.0 to 100.8%, and repeatability and intermediate-precision relative standard deviations did not exceed 1.2%.

Placebo interference was not detected at 284 nm under the evaluated conditions. The reported detection and quantification limits were 0.20 and 0.62 µg/mL, respectively. These findings do not establish analytical discrimination between intact rabeprazole and its degradation products. The wet beads were Opaque and became opaque and off-white on drying; the beads were spherical, with a smooth to slightly rough surface. As the concentrations of sodium alginate and calcium chloride increased from B1 to B9, yield increased from 82.4±1.2% to 91.0±1.1%, entrapment efficiency from 78.6±1.4% to 91.6±0.7% and mean diameter from 612±18 µm to 758±19 µm, whereas the swelling index decreased from 184±5% to 148±3% (Table 3). Two-way analysis of variance showed significant main effects of both sodium alginate and calcium chloride concentration on all responses (p<0.05), with no significant interaction (p>0.05).

Table 3: Yield, entrapment efficiency, size and swelling of alginate beads B1–B9.

Formulation	Yield (%)	Entrapment efficiency (%)	Bead size (µm)	Swelling index (%)
B1 (2.0:1.0)	82.4±1.2	78.6±1.4	612±18	184±5
B2 (2.0:1.5)	84.1±1.0	81.3±1.2	625±16	176±4
B3 (2.0:2.0)	85.7±1.1	83.7±1.1	641±17	169±5
B4 (2.5:1.0)	86.3±0.9	84.5±1.3	668±19	173±4
B5 (2.5:1.5)	88.2±0.8	87.6±1.0	682±15	166±4
B6 (2.5:2.0)	89.1±0.7	89.2±0.9	698±18	158±5
B7 (3.0:1.0)	88.4±0.9	88.1±1.1	721±20	161±4
B8 (3.0:1.5)	90.2±0.7	90.4±0.8	739±17	154±4
B9 (3.0:2.0)	91.0±1.1	91.6±0.7	758±19	148±3

Table 4: Yield, drug content and size of coated pellets F1–F5.

Formulation	Yield (%)	Drug content (%)	Pellet size (mm)
F1 (0% TEC)	86.4±1.1	94.2±1.3	0.82±0.03
F2 (5% TEC)	88.1±0.9	95.6±1.0	0.84±0.02
F3 (10% TEC)	89.5±1.0	96.8±0.9	0.86±0.02
F4 (15% TEC)	90.7±0.8	97.4±0.8	0.88±0.03
F5 (20% TEC)	92.1±0.7	98.1±0.7	0.90±0.02

Table 5: Flow properties of coated pellets F1–F5.

Formulation	Carr's index	Hausner's ratio	Angle of repose (°)
F1 (0% TEC)	12.9	1.15	29.6±0.8
F2 (5% TEC)	11.4	1.13	28.8±0.7
F3 (10% TEC)	11.3	1.13	28.1±0.6
F4 (15% TEC)	9.9	1.11	27.3±0.7
F5 (20% TEC)	9.7	1.11	26.5±0.6

Cumulative drug release at 8 h decreased from 91.8±1.8% (B1) to 73.5±1.1% (B9) (Figure 1). Formulation B5 (2.5% w/v sodium alginate, 1.5% w/v calcium chloride) showed a yield of 88.2±0.8%, entrapment efficiency of 87.6±1.0%, mean diameter of 682±15 µm, swelling index of 166±4% and 82.4±1.4% release at 8 h, and was considered the most balanced composition of the bead series.

All five coated formulations were spherical and free-flowing, and surface gloss and smoothness improved as the triethyl citrate level increased. From F1 to F5, yield increased from 86.4±1.1% to 92.1±0.7%, drug content from 94.2±1.3% to 98.1±0.7% and mean diameter from 0.82±0.03 mm to 0.90±0.02 mm (Table 4). Carr's index decreased from 12.9% to 9.7%, the Hausner ratio from 1.15 to 1.11 and the angle of repose from 29.6±0.8° to 26.5±0.6°; F4 and F5 fell within the excellent flow category (Table 5). Cumulative release at 12 h decreased progressively with increasing triethyl citrate concentration, being 96.8±1.2%, 92.4±1.1%, 87.6±1.0%, 82.1±1.2% and 76.5±1.0% for F1–F5, respectively (Figure 2A). One-way analysis of var showed a significant effect of triethyl citrate concentration on yield, drug content and 12 h release (p < 0.001), and Tukey's test showed that F5 differed significantly from F1 and F2 for these responses. F5 was the only formulation that met all the predefined criteria; F4 satisfied the manufacturing criteria but exceeded the upper 12 h release limit of 80%. F5 was therefore selected for further evaluation. Under the two-stage protocol, free rabeprazole sodium released 72.6±1.3% at 2 h and 91.8±1.1% at 4 h. The marketed tablet released only 2.1±0.4% in the acid stage, followed by rapid release (96.4±1.0%) by 4 h after transfer to buffer. In contrast, F5 released 4.8±0.6% in the acid stage and showed gradual, sustained release in the buffer stage, reaching 52.8±1.2% at 8 h and 76.5±1.0% at 12 h (Figure 2B). The f_1 and f_2 values between F5 and the marketed tablet were 49.3 and 16.2, respectively, confirming that the two release profiles were dissimilar (f_1> 15; f_2< 50).

The release data of F5 at 2–12 h fitted the zero-order model (R^2=0.9934; k_0=7.43% h^{-1}) slightly better than the Higuchi model (R^2=0.9894; k_H=36.48% $h^{-1/2}$) and the first-order model (R^2=0.9830; k_1=0.143 h^{-1}) (Figure 3).

SEM examination of pure rabeprazole sodium revealed predominantly elongated, angular particles with well-defined facets, surface irregularities and adhering smaller particles (Figure 4A and 4B). The regions identified as F5 showed a heterogeneous surface comprising irregular, closely packed structures, with

pronounced roughness and visible fissures and interparticle gaps (Figure 4C and 4D). These fields provide local surface views; they do not establish whole-pellet sphericity or a continuous, defect-free coating. After six months of accelerated storage, measured drug content decreased from 98.1±0.7% to 97.1±0.9%, while 12 h apparent release increased from 76.5±1.0% to 78.0±1.2% (Table 6). Corresponding twelve-month long-term values were 97.2±0.9% and 77.8±1.2%. No macroscopic change in pellet appearance was recorded.

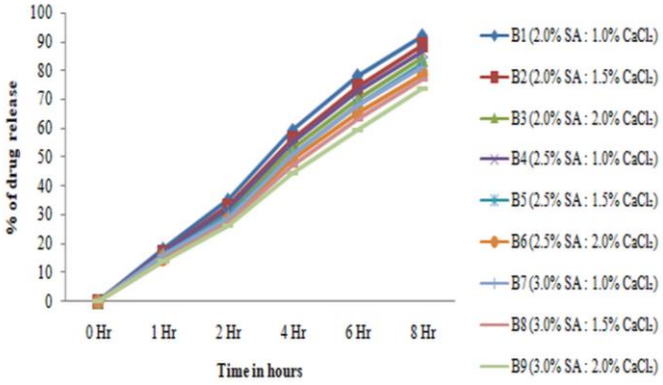


Figure 1: Cumulative *in vitro* release of rabeprazole sodium from alginate bead formulations B1–B9.

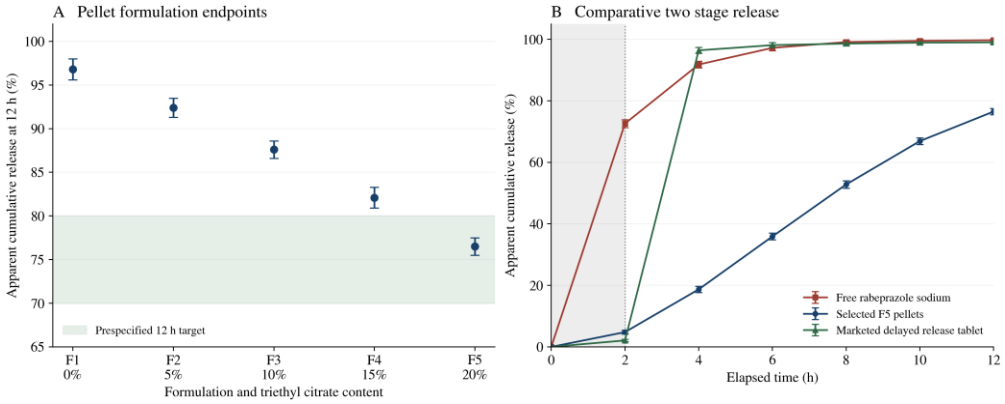


Figure 2: *In vitro* release from coated pellets: (A) cumulative release at 12 h for formulations F1–F5 (shaded band, 70–80% target range); (B) two-stage release profiles of free rabeprazole sodium, selected F5 pellets and the marketed Rablet® 20 tablet.

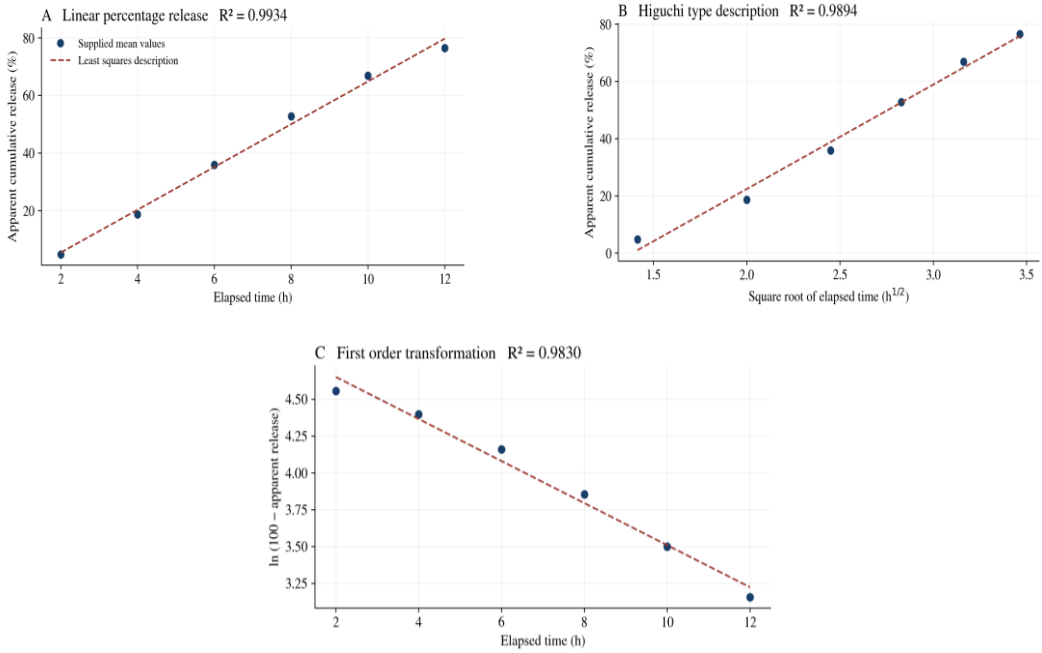


Figure 3: Release-kinetic plots for the selected F5 pellets (2–12 h): (A) zero-order; (B) Higuchi; (C) first-order. Dashed lines represent least-squares linear regression.

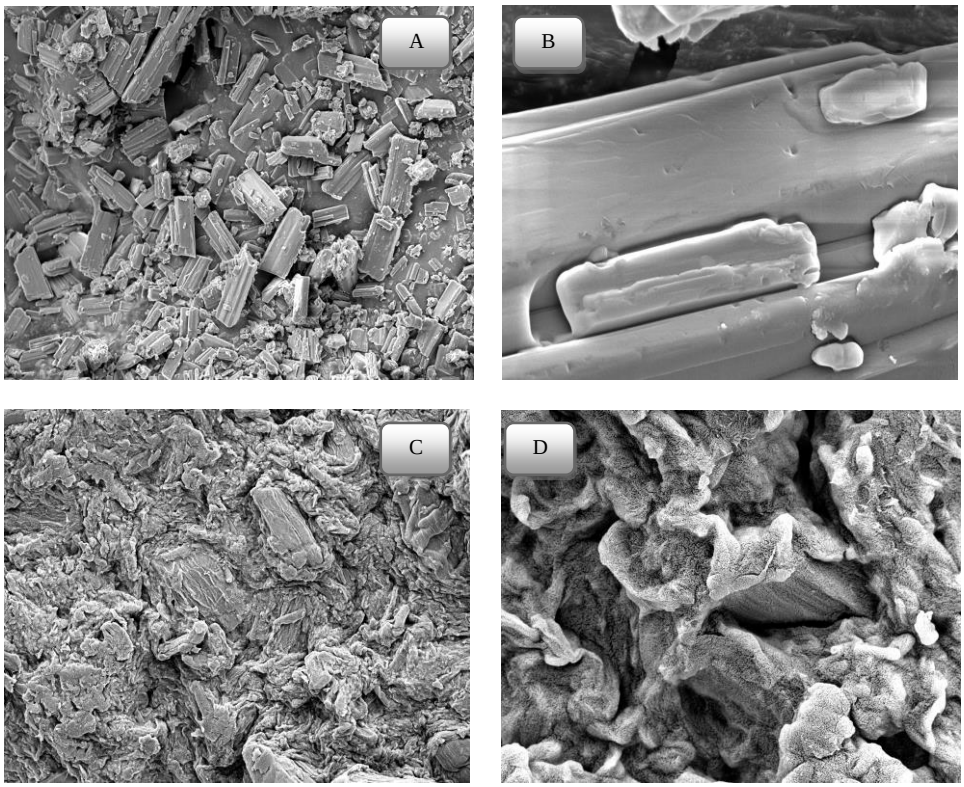


Figure 4: Scanning electron micrographs of pure rabeprazole sodium at (A) low and (B) high magnification, and of the selected F5 pellets at (C) low and (D) high magnification.

DISCUSSION

The ultraviolet method showed linearity, accuracy and precision consistent with the expectations of the ICH validation guidelines, and its limits of quantification were well below the working range used for entrapment, content and dissolution samples[9,16]. The shift in the wavelength of maximum absorbance between pH 6.8 buffer, pH 7.4 buffer and acid reflects the pH-dependent ionization of the benzimidazole chromophore. Because rabeprazole degrades rapidly in acid, acid-stage samples were analysed immediately after withdrawal; nevertheless, the method does not separate the drug from its degradation products, and the acid-stage values for free drug represent total ultraviolet-absorbing species rather than intact rabeprazole. The combination of greater drug retention, lower swelling and slower release at higher formulation-factor levels is compatible with changes in calcium-mediated network formation. Nevertheless, cross-link density, internal porosity and effective diffusivity were not measured, and a denser network remains a mechanistic interpretation rather than a directly demonstrated structural finding[4]. More viscous alginate dispersion resists fragmentation at the needle tip, while a higher calcium concentration accelerates surface gelation; both effects reduce loss of the water-soluble drug during bead formation. The absence of a significant interaction indicates that, over the ranges studied, the two variables act largely additively, which simplifies further refinement of this platform.

Table 6: Stability of the selected F5 pellets under accelerated and long-term storage conditions.

Storage condition	Parameter	Initial	3 months	6 months	9 months	12 months
Accelerated	Drug content (%)	98.1±0.7	97.6±0.8	97.1±0.9	–	–
Accelerated	Release at 12 h (%)	76.5±1.0	77.2±1.1	78.0±1.2	–	–
Long-term	Drug content (%)	98.1±0.7	97.9±0.7	97.7±0.8	97.5±0.8	97.2±0.9
Long-term	Release at 12 h (%)	76.5±1.0	76.8±1.0	77.1±1.1	77.5±1.1	77.8±1.2

The entrapment efficiencies obtained (78.6–91.6%) overlap with, and slightly exceed, the upper part of the range (57–89%) reported by Magdhut *et al.*[4], for floating alginate–gellan gum beads of rabeprazole, which released approximately 69–97% of the drug over 12 h. Similarly, Auriemma *et al.*[17], found that changing the alginate composition of pectin/zinc alginate core-shell beads altered entrapment and release. The present beads released 73.5–91.8% within 8 h; they therefore offer limited prolongation of release, and their composition, intended release duration and dissolution conditions differ from those of the earlier studies, which precludes direct comparison of performance.

In the pellet series, increasing triethyl citrate from 0 to 20% w/w of polymer reduced the 12 h release from 96.8% to 76.5%, while also improving yield, drug content and flow. This trend agrees with the finding of Kibria *et al.*[6], that the amount of triethyl citrate influenced the release of diclofenac sodium from Eudragit RS 30 D-coated pellets. Eudragit RS100 films are rigid and brittle without plasticizer; an adequate plasticizer level lowers the minimum film-forming

temperature and promotes coalescence of the polymer into a continuous film with fewer micro-defects, which provides a more effective diffusion barrier. The improved surface gloss observed with increasing triethyl citrate is consistent with this interpretation. Kaffash *et al.*[18], similarly showed that thermal treatment altered drug release from alginate–Eudragit RS matrix pellets of 5-aminosalicylic acid, indicating that the processing history of Eudragit RS influences its barrier properties; in the present study, all coated batches were cured under identical conditions.

The F5 pellets released only 4.8% of the drug in the acid stage, followed by near-linear release over 2–12 h. The good fit to the zero-order model, with a slightly lower fit to the Higuchi model, is consistent with membrane-controlled diffusion of drug through an intact polymer coat from a reservoir-type pellet. The marked difference between F5 and the marketed tablet (f_2=16.2) is an expected consequence of their different designs: the marketed product is an enteric delayed-release tablet that releases its dose rapidly once the coat dissolves, whereas F5 is a sustained-release system. The comparison was therefore made to characterize the release profiles, not to establish equivalence.[12] Because Eudragit RS100 is not an enteric polymer, the low acid-stage release of F5 does not by itself guarantee chemical protection of rabeprazole in the stomach. Current rabeprazole and omeprazole products rely on enteric coats, seal coats and alkaline stabilizers for this purpose: Lee *et al.*[3], used a magnesium oxide-stabilized core with a seal coat and enteric coat for dexrabeprazole tablets, Rouaz-El-Hajoui *et al.*[7], found that enteric layer weight gain was the only significant factor for the gastro-resistance of omeprazole pellets, and Liu *et al.*[8], protected rabeprazole sodium loaded onto an anion exchange resin with a Eudragit L100 coat. An enteric over-coat applied to F5 pellets is therefore a logical next step towards a delayed- and sustained-release rabeprazole multiparticulate system.

During storage, the drug content and 12 h release of F5 changed by less than two percentage points under both accelerated and long-term conditions, and the appearance of the pellets was unchanged, indicating satisfactory physical stability of the coated system under ICH conditions[15]. The slight upward drift in 12 h release should be monitored in longer studies, and impurity profiling by a stability-indicating chromatographic method is required to confirm chemical stability.

Limitations of the study

This study was limited to *in vitro* evaluation, and the pharmacokinetic and pharmacodynamic performance of the formulations was not assessed. Drug quantification was performed by ultraviolet spectrophotometry, which does not distinguish rabeprazole from its degradation products; a stability-indicating high-performance liquid chromatographic method would strengthen the acid-stage, release and stability data. The bead and pellet platforms were tested under different dissolution conditions and therefore cannot be ranked against each other.

CONCLUSIONS

This investigation identified formulation-dependent changes in the performance of two rabeprazole sodium multiparticulate platforms. Alginate and calcium chloride concentrations influenced bead recovery, entrapment, dimensions, swelling and release, whereas triethyl citrate concentration influenced the performance of Eudragit RS100-coated pellets. F5 satisfied the stated selection limits and exhibited a UV-derived apparent release of 76.5% at 12 h, with limited changes in the monitored storage endpoints. These findings support continued development, with emphasis on intact-drug quantification, verification of gastric protection and reproducibility across independently manufactured batches.

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AUTHOR'S CONTRIBUTION

Madhankumar S: methodology, investigation, data curation, formal analysis, writing original draft. **Mariyappan G:** conceptualization, methodology, supervision, writing, review and editing. **Karthi J:** supervision, project administration, writing, review and editing. **Murugan P:** resources, technical support, writing, review and editing. Final manuscript was checked and approved by all authors.

DATA AVAILABILITY

The related author can provide the empirical data supporting the study's conclusions upon request.

CONFLICT OF INTEREST

There are no conflicts of interest in regard to this project.

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