



Development and In-Vitro Evaluation of an HPMC-Based Effervescent Gastroretentive Floating Tablet of Zingiber officinale Extract

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Abstract

Background: Gastro retentive floating systems are designed to remain buoyant in gastric fluid and can provide prolonged release from an oral dosage form. Ginger (*Zingiber officinale* Roscoe) contains phenolic constituents, particularly gingerols and shogaols, and has been investigated extensively for its biological and pharmaceutical properties. The present study focused on the formulation and in-vitro evaluation of an effervescent floating tablet containing ginger extract.

Methods: An experimental laboratory-based formulation-development approach was used. Ginger rhizome was subjected to authentication, drying, extraction, phytochemical screening, preformulation evaluation and compatibility assessment. Six trial formulations were developed using hydroxypropyl methylcellulose (HPMC) as a hydrophilic matrix former and sodium bicarbonate/citric acid as an effervescent system. The formulations were evaluated for physical tablet characteristics, floating lag time, total floating time, swelling behavior and in-vitro release. Release data were fitted to zero-order, first-order, Higuchi and Korsmeyer–Peppas models.

Results: The reported extraction yield was 12.50%. Preliminary phytochemical screening indicated phenolic compounds, flavonoids, tannins and terpenoids, with equivocal saponin and negative alkaloid reactions. The powder showed a bulk density of 0.46 g/mL, tapped

density of 0.56 g/mL, Carr's index of 17.86%, Hausner ratio of 1.22 and angle of repose of 29.8°. Across F1–F6, floating lag time ranged from 58 ± 4 to 34 ± 2 s and all formulations reportedly floated for more than 12 h. F5 showed a reported hardness of 6.1 ± 0.2 kg/cm², friability of 0.62%, floating lag time of 35 ± 2 s, 100% swelling at 8 h and 90% release at 12 h. The reported kinetic fitting showed the highest R^2 for the Higuchi model (0.9973).

Conclusion: The findings indicate that the HPMC-based effervescent matrix can serve as a promising platform for developing a ginger-extract floating tablet with prolonged in-vitro buoyancy and controlled release characteristics. Among the developed formulations, F5 exhibited favorable floating behavior, swelling properties and sustained release performance. Further studies are recommended to optimize the formulation and evaluate its long-term stability and in-vivo applicability.

Keywords: Zingiber officinale; ginger extract; gastroretentive drug delivery; floating tablet; HPMC; effervescent system; controlled release; phytochemical screening

Introduction

Oral drug delivery remains an important route because solid dosage forms are convenient to administer, generally acceptable to patients and compatible with established manufacturing processes. Nevertheless, gastrointestinal transit, gastric emptying, luminal conditions and physiological variability can influence the residence time and release of orally administered dosage forms. Gastroretentive drug-delivery systems have therefore been investigated to prolong dosage-form residence in the stomach and to modify release behavior. Floating systems constitute one important gastroretentive approach because a dosage form with sufficiently low apparent density can remain buoyant in gastric fluid (Singh & Kim, 2000; Streubel et al. 2006).

Effervescent floating systems commonly combine a gas-generating component with a hydrophilic polymer. On hydration, sodium bicarbonate reacts with an acidic component to generate carbon dioxide, while a hydrated polymeric matrix can retain gas and contribute to reduced apparent density. The resulting balance among gas generation, polymer hydration, matrix integrity and tablet density influences floating lag time and duration of buoyancy. Reviews of gastroretentive systems emphasize that formulation variables and physiological factors must both be considered when interpreting floating performance (Arora et al. 2005; Pawar et al. 2011).

Ginger (*Zingiber officinale* Roscoe) is a widely used plant belonging to the Zingiberaceae family. Its rhizome contains diverse phytochemical classes, with gingerols and shogaols being particularly important phenolic constituents. Gingerols are characteristic of fresh ginger, whereas dehydration and thermal processing can promote formation of shogaols. Consequently, extraction and processing conditions can affect the chemical profile and reproducibility of ginger preparations (Mao et al. 2019; Maghraby et al. 2023).

The pharmaceutical development of herbal preparations requires particular attention to botanical identity, extraction conditions, chemical consistency and dosage-form performance. A plant extract is not automatically standardized merely because the botanical source has been identified. Marker-based chemical characterization and validated analytical procedures are therefore important when reproducibility and quantitative quality claims are intended (Maghraby et al. 2023).

Previous work has also explored gastroretentive delivery of ginger extract. Singh and Kaur (2011), for example, developed floating beads containing ginger extract and investigated their buoyancy and release behavior. Such evidence provides a rationale for examining other gastroretentive platforms, including single-unit floating tablets. The present project addresses the formulation-development interface between ginger extract and an HPMC-based effervescent floating matrix.

The specific objective of the study was to develop and evaluate trial floating tablet formulations containing ginger extract and to compare their physical properties, buoyancy, swelling and in-vitro release characteristics. The study was intended as a formulation-development investigation and not as a clinical efficacy study.

Materials and Methods

Study design

The source project describes an experimental laboratory-based formulation-development design. The workflow comprised authentication and preparation of ginger rhizomes, extraction and concentration, phytochemical screening, standardization, preformulation, excipient compatibility assessment, floating-tablet preparation, physical evaluation, floating and swelling studies, in-vitro release testing, kinetic analysis, formulation selection and stability assessment.

Plant material and materials

The project specifies *Zingiber officinale* Roscoe rhizomes as the plant material and indicates that authentication should be performed by a qualified botanist or recognized herbarium/institution. The listed pharmaceutical excipients were HPMC, sodium bicarbonate, citric acid, microcrystalline cellulose (MCC), magnesium stearate and talc. PVP K30 was listed as a binder if required. A certified [6]-gingerol reference standard was identified for marker analysis. The project also lists analytical balance, sieve set, grinder, hot-air oven, tablet machine, hardness tester, friabilator, thickness gauge, dissolution apparatus, UV spectrophotometer, HPLC system where available, FTIR spectrometer, pH meter and desiccator.

Extraction and preliminary evaluation

The project describes preparation of dried and powdered ginger rhizomes followed by extraction and concentration. A Soxhlet extraction apparatus and rotary evaporator are listed among the proposed equipment. However, the source document does not provide a sufficiently complete, verified record of solvent-to-material ratio, extraction temperature, extraction duration/cycle number, final concentration conditions or authenticated voucher number. These parameters should therefore be inserted from the laboratory notebook before submission.

Extraction yield was calculated as the mass of dried extract divided by the starting mass of ginger powder, multiplied by 100. Preliminary phytochemical screening was reported for phenolic compounds, flavonoids, tannins, terpenoids, saponins and alkaloids.

Preformulation and compatibility assessment

Powder flow properties were evaluated using bulk density, tapped density, Carr's index, Hausner ratio and angle of repose. Compatibility was assessed by FTIR interpretation of ginger extract, HPMC and the physical mixture. The reported interpretation was based on retention of characteristic spectral regions without a clearly new dominant band.

Floating-tablet formulation

The project proposed six trial formulations containing a constant nominal ginger-extract amount of 100 mg/tablet while varying HPMC and effervescent components. The formulation-development matrix is reproduced below because it forms part of the source project; however, it requires verification before use as the definitive manufacturing formula.

Table 1: Formulation Development Matrix for Ginger Extract Effervescent Tablets

Component (mg/tablet)	F1	F2	F3	F4	F5	F6
Ginger extract	100	100	100	100	100	100
HPMC	60	80	100	120	100	100
Sodium bicarbonate	15	15	15	15	20	25
Citric acid	7.5	7.5	7.5	7.5	10	12.5
MCC	198.5	178.5	158.5	138.5	143.5	133
Magnesium stearate	6	6	6	6	6	6
Talc	3	3	3	3	3	3*
Reported total	390	390	390	390	390	390

*The source document displays an anomalous value in the F6 talc cell in one location; 3 mg is shown here as the apparent intended value, but this must be confirmed from the original formulation record. In addition, the arithmetic totals of several reported formulations do not equal 390 mg when the listed components are summed. Therefore, the table is a development matrix rather than a verified manufacturing formula.

Tablet evaluation

The prepared tablets were evaluated for average weight, thickness, hardness and friability. Floating performance was assessed using floating lag time and total floating time. Swelling was reported at 1, 2, 4 and 8 h. The project also describes marker-content estimation and in-vitro release testing, but the analytical conditions required to reproduce the marker assay and dissolution experiment are not fully specified in the available source text.

In-vitro release and kinetic analysis

Cumulative release values were reported at 1, 2, 4, 6, 8, 10 and 12 h for F1–F6. The reported release profiles were fitted to zero-order, first-order, Higuchi and Korsmeyer–Peppas models. The source project reports the coefficient of determination (R^2) for these models.

Stability assessment

The project reports stability observations at the initial point and at 1, 2 and 3 months, including tablet weight, friability, floating lag time and release at 12 h. However, the storage temperature, relative humidity, packaging system, number of batches, number of replicates and analytical procedures are not adequately reported in the source text. Accordingly, these data should be treated as provisional until verified against the actual stability protocol and laboratory records.

Data analysis

The study used descriptive comparisons among formulations and release-kinetic fitting. The available source does not provide inferential statistical tests, sample sizes for every response, confidence intervals or p-values. These should not be invented. If raw replicate data are available, the final journal manuscript should report appropriate descriptive statistics and, where justified by the experimental design, inferential testing.

Results

Organoleptic characteristics and extraction yield

The ginger extract was reported as brown to dark brown, characteristically aromatic, pungent and finely textured. The dried extract was described as a dry, free-flowing mass. From 500 g of starting ginger powder, 62.5 g of dried extract were reported, corresponding to an extraction yield of 12.50%.

Table 2: Organoleptic Characteristics and Extraction Yield of Ginger Extract

Parameter	Reported result
Starting ginger powder	500 g
Dried extract	62.5 g
Extraction yield	12.50%
Colour	Brown to dark brown
Odour	Characteristic aromatic
Taste	Pungent
Texture	Fine powder

Note. Yield percentage is calculated based on the starting mass of raw ginger powder.

Preliminary phytochemical screening

Table 3: Preliminary Phytochemical Screening of Ginger Extract

Phytochemical group	Reported result
Phenolic compounds	+
Flavonoids	+
Tannins	+
Terpenoids	+
Saponins	±
Alkaloids	—

Note. + = present; ± = weakly present/trace; — = absent. Qualitative screening indicates chemical presence but does not quantify individual active marker concentrations.

The presence of several phytochemical groups is consistent with the chemically diverse nature of ginger described in the literature. Nevertheless, qualitative phytochemical screening does not establish the concentration of individual active or marker constituents. Quantitative marker analysis would therefore be required for a stronger standardization claim.

Powder-flow properties

Table 4: Powder-Flow Properties of Ginger Extract

Parameter	Reported value
Bulk density	0.46 g/mL
Tapped density	0.56 g/mL
Carr's index	17.86%
Hausner ratio	1.22
Angle of repose	29.8°

Note. Measurements reflect the baseline powder compressibility and flowability evaluated prior to tablet compaction.

The reported flow measurements indicate that the ginger extract possessed measurable compressibility and flow characteristics that were considered during formulation development. Interpretation should remain tied to the specific powder-processing conditions and particle-size distribution used in the experiment.

FTIR compatibility

The ginger extract showed characteristic broad O–H and carbonyl/phenolic spectral regions, while HPMC showed characteristic polymer bands. In the physical mixture, the major characteristic bands were retained without a clearly new dominant band. The project therefore interpreted the spectrum as showing no obvious major interaction between the extract and HPMC under the conditions assessed.

Physical properties of tablets

Table 5: Physical Properties of Trial Formulations F1 Through F6

Formulation	Weight (mg)	Thickness (mm)	Hardness	Friability (%)
F1	398.7 ± 3.1	4.82 ± 0.08	5.4 ± 0.2 kg/cm ²	0.91
F2	400.2 ± 2.7	5.01 ± 0.07	5.7 ± 0.2 kg/cm ²	0.78
F3	399.4 ± 2.5	5.12 ± 0.06	6.0 ± 0.2 kg/cm ²	0.64
F4	401.1 ± 2.8	5.20 ± 0.05	6.2 ± 0.2 kg/cm ²	0.59
F5	400.0 ± 2.4	5.15 ± 0.06	6.1 ± 0.2 kg/cm ²	0.62
F6	399.6 ± 2.2	5.18 ± 0.06	6.3 ± 0.2 kg/cm ²	0.57

Note. Values are expressed as mean ± standard deviation (n = 3).

Reported tablet weights were close to 400 mg, while thickness increased from F1 to F4 and remained similar in F5 and F6. Hardness increased across the formulation series, while friability decreased from 0.91% in F1 to 0.57% in F6.

Floating performance

Table 6: Floating Performance of Trial Formulations F1 Through F6

Formulation	Floating lag time (s)	Total floating time
F1	58 ± 4	>12 h
F2	48 ± 3	>12 h
F3	41 ± 3	>12 h
F4	36 ± 2	>12 h
F5	35 ± 2	>12 h
F6	34 ± 2	>12 h

Note. Values for floating lag time are expressed as mean ± standard deviation.

All six formulations were reported to remain buoyant for more than 12 h. Floating lag time progressively decreased across the formulations, with F6 showing the shortest reported lag time (34 ± 2 s).

Swelling behavior

Table 7: In Vitro Swelling Behavior of Trial Formulations Over Time

Formulation	1 h (%)	2 h (%)	4 h (%)	8 h (%)
F1	42	58	67	71
F2	48	64	75	81
F3	55	73	84	91
F4	61	81	94	102
F5	59	79	92	100
F6	63	84	98	106

Swelling increased with time in all formulations. At 8 h, the reported swelling values ranged from 71% for F1 to 106% for F6. F5 showed 100% swelling at 8 h.

In-vitro release

Table 8: In Vitro Cumulative Drug Release Profiles for Trial Formulations

Time (h)	F1	F2	F3	F4	F5	F6
0	0	0	0	0	0	0
1	24	20	18	15	14	13
2	45	39	35	30	29	26
4	67	59	53	47	46	42
6	79	72	66	59	58	54
8	88	82	76	69	68	63
10	95	91	84	78	78	72
12	98	95	90	86	90	82

The reported release profiles demonstrate a general reduction in release rate as formulation characteristics changed across F1–F6. F1 showed the highest release at each reported time point, reaching 98% at 12 h. F6 showed the lowest release at most time points and reached 82% at 12 h. F5 reached 90% at 12 h.

Release-kinetic analysis

Table 9: Release-Kinetic Modeling of the In Vitro Dissolution Dataset

Model	R ²
Zero-order	0.9744
First-order	0.9529
Higuchi	0.9973
Korsmeyer–Peppas	0.9815

Among the reported models, the Higuchi model produced the highest R² (0.9973), followed by the Korsmeyer–Peppas model (0.9815), zero-order model (0.9744) and first-order model (0.9529). The results therefore indicate that the reported dataset was most closely fitted by the Higuchi model. A definitive mechanistic interpretation would require the underlying release-exponent data and confirmation of the fitting interval.

Selection of the reported optimized formulation

Table 10: Physicochemical and Performance Profile of the Selected Optimized Formulation (F5)

Parameter	F5 reported result
Average tablet weight	400.0 ± 2.4 mg
Thickness	5.15 ± 0.06 mm
Hardness	6.1 ± 0.2 kg/cm ²
Friability	0.62%
Floating lag time	35 ± 2 s
Total floating time	>12 h
Swelling at 8 h	100%
Release at 12 h	90%

The source project identifies F5 as the optimized formulation because it provides a balance among mechanical quality, buoyancy, swelling and controlled release. This selection is retained here as a report of the project's stated optimization decision, not as an independent statistical optimization.

Reported stability observations

Table 11: Preliminary Stability Observations for Formulation F5 Over Three Months

Time	Weight (mg)	Friability (%)	Lag time (s)	Release at 12 h (%)
Initial	400.0	0.62	35	90
1 month	399.7	0.64	36	89
2 months	399.5	0.65	37	89
3 months	399.2	0.67	38	88

Note. Specific environmental storage conditions (temperature and relative humidity parameters) were not completely reported in the source record.

The reported values show only small numerical changes over the three-month period. However, because the project does not fully document storage conditions, replication and analytical procedures, the stability findings should be considered preliminary until verified.

Discussion

The study investigated the feasibility of incorporating ginger extract into an HPMC-based effervescent floating tablet. The rationale is consistent with established gastroretentive drug-delivery principles. Floating systems can be designed to prolong dosage-form residence by reducing apparent density, while hydrophilic polymers can form hydrated matrices that influence water penetration, swelling, erosion and diffusion (Arora et al. 2005; Singh & Kim, 2000; Streubel et al. 2006).

The reported ginger extraction yield was 12.50%. Extraction yield alone, however, is insufficient to establish chemical potency or reproducibility for a complex botanical material. Ginger composition varies with botanical source, processing and extraction conditions, and gingerols can undergo dehydration to form shogaols. Recent reviews emphasize the need for analytical characterization and appropriate standardization when ginger preparations are developed for pharmaceutical or nutraceutical applications (Maghraby et al. 2023).

The preliminary phytochemical profile demonstrated phenolic compounds, flavonoids, tannins and terpenoids. These findings support the presence of broad classes of secondary metabolites but should not be interpreted as proof of therapeutic activity or as a quantitative measure of gingerol content. A validated chromatographic assay for [6]-gingerol and related constituents would strengthen future work.

The FTIR interpretation did not show an obvious new dominant band in the physical mixture. This observation is consistent with the absence of a readily apparent major interaction under the conditions evaluated. FTIR compatibility alone, however, cannot establish complete chemical compatibility or stability; complementary analytical and stability studies may be necessary.

The physical tablet results show that all formulations achieved measurable mechanical strength and relatively low reported friability. The progressive increase in hardness and decrease in friability across the series are compatible with the formulation changes reported

in the project. Mechanical quality must nevertheless be interpreted together with buoyancy because excessive compaction can alter porosity and hydration behavior.

The floating results are a prominent feature of the formulation. All six formulations reportedly floated for more than 12 h, while lag time decreased from 58 ± 4 s in F1 to 34 ± 2 s in F6. This pattern is consistent with the role of the effervescent system in generating carbon dioxide and the role of the hydrated HPMC matrix in retaining gas. Similar principles have been described in the gastroretentive literature (Pawar et al. 2011; Kotreka & Adeyeye, 2011).

Swelling increased with time in every formulation. F6 showed the highest 8-h swelling value (106%), whereas F1 showed the lowest (71%). The release profiles broadly moved in the opposite direction: F1 released 98% by 12 h, whereas F6 released 82%. This inverse relationship is consistent with the expected role of polymer hydration and matrix formation as a diffusional barrier, although the precise mechanism cannot be established from the reported data alone.

The reported Higuchi R^2 of 0.9973 was higher than the R^2 values for the other models. Higuchi-type behavior is commonly associated with diffusion-controlled release from matrix systems. Nevertheless, R^2 alone should not be used to claim a definitive mechanism, particularly for swelling, eroding polymer matrices. Model assumptions, fitting intervals and release-exponent information should be considered together.

F5 was selected in the project as the optimized formulation. Its reported profile— 35 ± 2 s floating lag time, more than 12 h buoyancy, 0.62% friability, 100% swelling at 8 h and 90% release at 12 h—represents a compromise between rapid flotation and moderated release. Importantly, F6 had a shorter lag time and lower 12-h release, illustrating why optimization should consider multiple quality attributes rather than a single response.

The concept also has precedent in ginger gastroretentive research. Singh and Kaur (2011) developed ginger-extract floating beads and reported prolonged in-vitro release, demonstrating the broader feasibility of gastroretentive delivery for ginger preparations. The present tablet-based approach differs in dosage-form architecture and therefore contributes formulation-development information rather than duplicating the earlier multiparticulate system.

The major limitation is the level of methodological and data verification available in the source project. The document itself states that some reported values are examples of expected data presentation and not substitutes for actual laboratory observations. In addition, the formulation-composition table contains arithmetic inconsistencies. For an international journal submission, these discrepancies must be resolved using raw laboratory records, batch manufacturing sheets, analytical worksheets and instrument-generated data. The study should also avoid claiming actual human gastric retention because in-vitro buoyancy does not reproduce gastric motility, fed/fasted state, viscosity and other physiological variables (Parikh & Amin, 2008).

Conclusion

The project demonstrates a rational formulation-development approach for a ginger-extract gastroretentive floating tablet using an HPMC-based effervescent matrix. The reported data show that the six trial formulations achieved prolonged in-vitro buoyancy, measurable swelling and controlled release over 12 h. F5 was identified in the project as the optimized formulation based on a balance of mechanical properties, buoyancy and release. The reported kinetic analysis showed the highest R^2 for the Higuchi model.

The findings support further development of ginger-extract floating tablets as a pharmaceutical formulation platform. However, the present manuscript should be regarded as a publication draft pending verification of the experimental dataset and completion of missing methodological details. In particular, definitive claims concerning chemical standardization, stability, in-vivo gastric retention or therapeutic efficacy should not be made without corresponding validated evidence.

Limitations and Future Research

Future work should include validated HPLC analysis of [6]-gingerol and related constituents; systematic optimization using factorial or response-surface methodology; evaluation of different HPMC viscosity grades; control of tablet porosity and compression force; biorelevant dissolution testing where justified; investigation of extract-batch variability; appropriately designed long-term and accelerated stability studies; scale-up reproducibility; and, where scientifically justified and ethically approved, in-vivo gastric-retention studies. These priorities are consistent with the needs of reproducible herbal pharmaceutical development and gastroretentive dosage-form evaluation.

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