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Research Article

Optimization of HPMC Concentration in *Psidium guajava* Leaf Extract Floating Tablets

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ABSTRACT

Psidium guajava L. leaves have been empirically used in traditional medicine due to their flavonoid content, which exhibits antibacterial and anti-ulcer activities. A floating drug delivery system is intended to prolong gastric residence time and thereby enhance therapeutic effectiveness in the treatment of gastric ulcers. This study aimed to investigate the effect of varying concentrations of hydroxypropyl methylcellulose (HPMC) on the physical characteristics of floating tablets containing *Psidium guajava* leaf extract. The leaf extract, at a dose of 350 mg, was formulated into floating tablets using three HPMC concentrations: 10% (F1), 20% (F2), and 30% (F3). The tablets were evaluated for weight uniformity, hardness, friability, disintegration time, and floating properties. The results showed that all formulations complied with pharmacopeial requirements for weight uniformity, hardness (10-20 kg), friability (<1%), and disintegration time (<60 min). However, formulation F1 exhibited a longer floating lag time of 7200 s and failed to meet the floating ability criterion. Increasing HPMC concentration significantly affected tablet hardness, friability, and floating properties ($p < 0.05$). Formulation F2 demonstrated the most favorable characteristics, with hardness of 10.61 kg, friability of 0.69%, floating lag time of 60 s, and floating duration >12 h. In conclusion, HPMC concentration significantly influenced the physical and floating properties of *Psidium guajava* leaf extract floating tablets, with a 20% HPMC concentration providing the most optimal formulation characteristics.

Keywords: floating tablet; *Psidium guajava* leaf; HPMC; gastric ulcer

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INTRODUCTION

A gastric ulcer is a gastrointestinal disorder characterized by damage to the gastric mucosa, which may result from excessive secretion of gastric acid and pepsin, impaired mucosal defense mechanisms, and infection with *Helicobacter pylori* (Lanas and Chan 2017). Despite advances in pharmacotherapy, the management of gastric ulcers commonly relies on acid-suppressive agents, such as histamine H_2-receptor antagonists, which often require long-term administration. Prolonged use of these drugs may increase the risk of adverse effects, thereby emphasizing the need for safer and more effective therapeutic approaches. Consequently, recent research has increasingly focused on the exploration of herbal-based agents as alternative treatments for gastric ulcers (Prayoga and Aulifa 2024).

Psidium guajava L. leaves are widely used in traditional medicine in Indonesia and have demonstrated considerable potential as an anti-ulcer agent. Guava leaves contain various bioactive compounds, including polyphenols, carotenoids, flavonoids, and tannins, and exhibit multiple pharmacological activities, such as anti-inflammatory, antibacterial, antioxidant, antimutagenic, antihyperglycemic, and antimalarial effects (Huynh et al. 2025). Among these compounds, flavonoids play a crucial role in gastric ulcer prevention and healing due to their ability to enhance gastric mucosal protection (Serafim et al. 2020; Zhang et al. 2020). Previous studies have shown that ethanol extracts of guava leaves significantly reduce gastric acid and pepsin levels and improve gastric mucosal integrity in experimentally induced gastric ulcer models (Huynh et al. 2025). These protective effects are largely attributed to flavonoids, which are believed to promote mucosal repair by increasing prostaglandin synthesis and stimulating mucus production in the gastric wall (Tampubolon et al. 2023; Zhang et al. 2020). In addition, the standardization of plant extracts, such as determining total flavonoid content or specific marker compounds (e.g., quercetin), is considered important to ensure the consistency and reproducibility of their pharmacological effects.

Gastric ulcer is a chronic condition that often requires prolonged therapy; therefore, the development of an appropriate drug delivery system is essential. Conventional tablet formulations frequently necessitate repeated dosing and may lead to fluctuations in drug concentration, potentially reducing therapeutic efficacy (Fatma et al. 2024). Gastroretentive drug delivery systems, particularly floating tablets, offer a promising strategy to overcome these limitations by prolonging gastric residence time, enabling sustained drug release, and reducing dosing frequency and side effects (Khedekar, Sontakke, and Biyani 2025). Floating tablets are designed to remain buoyant in gastric fluid, thereby enhancing drug retention and therapeutic activity in the stomach.

Hydroxypropyl methylcellulose (HPMC) is a hydrophilic polymer widely used in floating tablet formulations due to its swelling properties and ability to reduce tablet density below that of gastric fluid. When combined with effervescent agents such as sodium bicarbonate, HPMC facilitates tablet buoyancy and controlled drug release ical factor influencing floating behavior and drug release, since insufficient polymer may result in weak gel formation and poor buoyancy, while excessive polymer can produce a highly viscous matrix that significantly retards drug release. High-viscosity grades, such as HPMC K100M, are particularly suitable for achieving rapid swelling, short floating lag time, and prolonged floating duration (Talaviya et al. 2026). Moreover, HPMC K100M has been reported to provide superior floating performance compared to polymers such as xanthan gum and sodium carboxymethyl cellulose (Andini, Sa'diah, and Puspa 2022). However, studies investigating the application of HPMC in floating tablet formulations containing *Psidium guajava* leaf extract, particularly focusing on the influence of HPMC concentration on floating performance and tablet characteristics, remain limited.

Based on these considerations, further studies are required to optimize floating tablet formulations containing *Psidium guajava* leaf extract. Therefore, this study aimed to evaluate the effect of varying HPMC concentrations on the physical characteristics and floating performance of guava leaf extract floating tablets, in order to identify an optimal formulation that meets pharmacopeial requirements and is suitable for gastric ulcer therapy.

MATERIALS AND METHODS

Material

The primary material used in this study was guava leaf (*Psidium guajava* L.). Other materials included Avicel® pH 102, hydroxypropyl methylcellulose (HPMC) K100M, polyvinylpyrrolidone (PVP) K30, magnesium stearate, sodium bicarbonate, sodium chloride, hydrochloric acid (P), distilled water, and 70% ethanol. All chemicals and solvents used in this study were of analytical grade unless otherwise stated.

Method

Preparation of Guava Leaf Extract

The extraction procedure was initiated using the maceration method. One kilogram of guava leaf simplicia powder was placed into a maceration vessel and immersed in 5 L of 70% ethanol as the extraction solvent. The maceration process was carried out for three days, with manual stirring performed once every 24 h to ensure optimal solvent penetration into the plant material. After maceration, the mixture was filtered to separate the filtrate from the residue. The remaining

residue was subsequently re-macerated twice using the same solvent type and volume to maximize extract recovery. The combined filtrates were then concentrated using a rotary evaporator to obtain a viscous extract. The concentrated extract was further evaporated gradually at room temperature using a fan until a desired consistency was achieved. The final step involved drying the viscous extract using a freeze dryer to obtain a dry guava leaf extract. Upon completion of the extraction process, the percentage yield of the extract was calculated.

$$\text{Extraction yield (\%)} = \frac{\text{Total weight of dried extract (g)}}{\text{Total weight of simplicia powder (g)}} \text{ x } 100\%$$

Preparation of Floating Tablets

Floating tablets containing guava leaf extract were prepared using the wet granulation method. The composition of the floating tablet formulations is presented in Table 1, with each tablet formulated to a total weight of 750 mg. The guava leaf extract was placed in a mortar, followed by the addition of sodium bicarbonate, hydroxypropyl methylcellulose (HPMC), and Avicel® pH 102, and the mixture was blended until homogeneous. Subsequently, polyvinylpyrrolidone (PVP) was added as a binder and mixed thoroughly. A sufficient amount of 70% ethanol was then sprayed onto the mixture to form a cohesive wet granule mass. The wet granules were passed through a 14-mesh sieve to obtain a uniform particle size. The granules were then dried in an oven at 60°C for 2 h. After drying, the granules were blended with magnesium stearate as a lubricant until homogeneous.

Prior to tablet compression, the prepared granules were evaluated for their physical properties, including flow rate and angle of repose, to assess their flowability. Subsequently, the granules were compressed into tablets using a tablet compression machine. During the compression process, the tablet press was operated at a moderate speed to ensure adequate die filling. The resulting tablets were then subjected to further physical evaluation.

Table 1. Formulation of floating tablets containing guava leaf extract

Formula Code	Guava Leaf Extract (mg)	HPMC K100M (%)	Sodium Bicarbonate (%)	Magnesium Stearate (%)	PVP K30 (%)	Avicel® pH 102 (%)
F1	350	10	15	1	5	ad 100
F2	350	20	15	1	5	ad 100
F3	350	30	15	1	5	ad 100

Evaluation of Granules

Flow Rate

The flow properties of the granules were evaluated using a flowability tester. Briefly, 100 g of granules were accurately weighed and transferred into the funnel of the testing apparatus. After loading the granules, the funnel outlet was opened, and the flow time was recorded. The recorded flow time represented the duration required for the entire quantity of granules to pass through the funnel orifice. Granules exhibiting a flow rate of less than 10 g/s were considered to have good flow properties (Hadisoewignyo and Fudholi 2013). The flow rate was calculated using the following equation:

$$\text{Flow rate (g/s)} = \frac{\text{Weight of granules (g)}}{\text{Flow time (s)}}$$

Table 2. Criteria for granule flow properties

Flow Rate (g/s)	Flow Property	Angle of Repose (°)	Flow Property
4-10	Good	<30º	Excellent
1,6-4	Fair	30º - 40º	Good
<1,6	Poor	40º - 50º	Fair
		>50º	Poor

Angle of Repose

Granules that had been subjected to flow rate testing were subsequently used for the determination of the angle of repose. This measurement was performed by allowing the granules to flow freely through a funnel to form a conical heap on a flat surface. The height and diameter of the resulting cone were measured, and the angle of repose was calculated accordingly. Granules were classified as having good flow properties when the angle of repose ranged between 25° and 40° (Hadisoewignyo and Fudholi 2013). Visually, a flatter cone indicated better granule flow characteristics. The angle of repose was calculated using the following equation:

$$\tan\theta = \frac{h}{r}$$

where θ is the angle of repose, his the height of the cone, and ris the radius of the cone.

Evaluation of Tablets

Weight Uniformity Test

The weight uniformity test was performed by individually weighing 20 tablets. The weight of each tablet was recorded, and the average tablet weight was subsequently calculated. For tablets with an average weight exceeding 300 mg, the acceptance criteria specify that no more than two tablets may deviate by more than

±5% from the average weight, and no tablet is permitted to deviate by more than ±10% from the average weight, in accordance with pharmacopeial guidelines (Direktorat Jenderal Pengawasan Obat dan Makanan 1979).

In addition to the standard deviation method, the coefficient of variation (CV) was used as an additional parameter to assess weight uniformity, as reported by Widyaningrum and cited by Monica Graziela (2017). Tablets were considered to have good weight uniformity when the coefficient of variation did not exceed 5%. The coefficient of variation was calculated using the following equation:

$$\text{CV (\%)} = \frac{\text{Standard deviation}}{\text{Mean weight}} \times 100$$

Tablet Hardness Test

The tablet hardness test was conducted by placing one tablet on a hardness tester with the initial scale set to zero. The instrument was then gradually operated until the tablet fractured. The scale reading at the point of tablet breakage was recorded as the tablet hardness, expressed in kilograms (kg). This procedure was repeated five times, and the mean hardness value was calculated. The obtained results were then compared with the specified acceptance range (Bestari, Sulaiman, and Rohman 2016). Floating tablets were considered acceptable when the hardness values ranged between 10 and 20 kg (Fatma et al. 2024).

Tablet Friability Test

The friability test was performed using 20 tablets with a friability tester. The tablets were initially weighed to obtain the initial weight (W) and subsequently placed into the friability tester. The apparatus was operated at a rotation speed of 25 revolutions per minute (rpm) for 4 minutes, corresponding to a total of 100 rotations. After completion of the test, the tablets were removed, dedusted to eliminate any adhering powder, and reweighed to obtain the final weight (W_1).

The tablets were considered to meet the friability requirement when the percentage of friability was less than 1% (Zhao et al. 2022). The percentage friability was calculated based on the difference between the initial and final weights using the following equation:

$$\text{Friability (\%)} = \frac{W\text{-}W_1}{W} \times 100$$

Disintegration Time Test

The disintegration time test was performed using six tablet samples with a disintegration tester. Each tablet was placed into a beaker of the disintegration tester containing 900 mL of distilled water preheated to 37 °C. The time required for each tablet to completely disintegrate was recorded.

According to standard tablet disintegration criteria, disintegration is considered complete when no residue remains on the screen, except for fragments of coating materials. However, for floating tablets, the disintegration time is required not to exceed 60 minutes (Ansel, Popovich, and Allen Jr 2008).

Floating Ability Test

The floating ability of the tablets was evaluated visually using a glass container filled with 100 mL of simulated gastric fluid (enzyme-free) at pH 1.2. This test involved the observation of the floating lag time, defined as the time required for the tablet to rise to the surface of the medium, and the total floating duration time, defined as the period during which the tablet continuously remained floating on the surface of the medium. The quality of the floating tablet formulation was determined based on its floating performance. A formulation was considered acceptable if it exhibited a floating lag time of less than 60 seconds and a total floating duration time exceeding 12 hours (Fatma et al. 2024; Liu et al. 2019).

The simulated gastric fluid without enzymes (pH 1.2) was prepared by dissolving 2 g of sodium chloride in 7 mL of hydrochloric acid, followed by dilution with distilled water to a final volume of 1000 mL in a volumetric flask. The pH of the medium was re-measured to ensure compliance with the required specification (Direktorat Jenderal Pengawasan Obat dan Makanan 1995).

RESULTS

This study investigated the formulation and evaluation of floating tablets containing guava leaf extract (*Psidium guajava* L.) with varying concentrations of HPMC K100M and their effects on the physical properties of the resulting tablets. Three formulations were prepared using HPMC concentrations of 10% (F1), 20% (F2), and 30% (F3). The extraction process yielded 165 g of dried guava leaf extract from 1 kg of simplicia powder, corresponding to an extraction yield of 16.5%. Floating tablets were successfully prepared using the wet granulation method.

Granule Evaluation Result

The results of granule flow property evaluation are presented in Table 3. Flow rate testing showed that formulations F1 and F2 exhibited good flow properties, with flow rates of 8.3 g/s and 6.2 g/s, respectively. In contrast, formulation F3 showed a lower flow rate of 3.5 g/s, which was categorized as fair.

Angle of repose measurements supported these findings. Formulations F1 and F2 demonstrated angles of repose of 30.11° and 33.42°, respectively, indicating good flow behavior. Formulation F3 exhibited a higher angle of repose (46.93°), suggesting poorer flowability.

Table 3. Flow rate and angle of repose of granules

Formula	Flow Rate (g/s)	Flow Criterion	Angle of Repose (°)	Flow Criterion
F1	8.3	Good	30.11	Good
F2	6.2	Good	33.42	Good
F3	3.5	Fair	46.93	Fair

Tablet Evaluation Results

Weight Uniformity

The weight uniformity test was conducted to ensure consistency in tablet weight among individual dosage units. The results of the weight uniformity test are presented in Table 4. All formulations complied with pharmacopeial requirements for tablets weighing more than 300 mg. None of the tablets deviated beyond the acceptance limits specified for Column A (±5%) and Column B (±10%).

Table 4. Weight uniformity test results

Formula	Column A (±5%) (mg)	Column B (±10%) (mg)	Acceptance Criteria
F1	695.87–769.13	659.25–805.75	Complied
F2	711.08–785.93	673.65–823.35	Complied
F3	648.85–717.15	614.71–751.30	Complied

Tablet Hardness

Tablet hardness testing was performed to evaluate the mechanical strength of the tablets. The hardness values of all formulations are shown in Table 5. The average hardness values of F1, F2, and F3 were within the acceptable range for floating tablets (10–20 kg).

Table 5. Tablet hardness test results

Tablet	F1 (kg)	F2 (kg)	F3 (kg)
1	10.41	10.74	10.93
2	10.24	10.70	11.97
3	10.07	10.59	10.89
4	10.01	10.50	11.35
5	10.18	10.53	10.82
Mean	10.18	10.61	11.19
Requirement	10–20	10–20	10–20

Friability

The friability test results are summarized in Table 6. All formulations showed friability values below 1%, indicating acceptable resistance to abrasion and mechanical stress.

Table 6. Friability test results

Formula	Initial Weight (g)	Final Weight (g)	Friability (%)	Requirement (<1%)
F1	14.5	14.4	0.68	Complied
F2	14.4	14.3	0.69	Complied
F3	13.1	13.0	0.76	Complied

Disintegration Time

The disintegration times of the floating tablets are presented in Table 7. All formulations complied with the requirement that floating tablets should not disintegrate within 60 minutes.

Table 7. Disintegration time test results

Tablet	F1 (min)	F2 (min)	F3 (min)
1	53	55	56
2	54	56	56
3	54	57	57
4	55	57	58
5	55	58	58
6	55	58	60
Mean	54.33	56.83	57.50
Requirement	<60	<60	<60

Floating Ability

Floating lag time (FLT) and floating duration time (FDT) results are presented in Table 8. Formulation F1 did not meet the floating requirements, whereas F2 and F3 satisfied both FLT and FDT criteria.

Table 8. Floating ability test results

Formula	FLT (s)	FDT (h)	FLT (<60 s)	FDT (>12 h)
F1	7200	8	Not complied	Not complied
F2	60	>12	Complied	Complied
F3	54	>12	Complied	Complied

DISCUSSION

Flow rate is defined as the time required for a certain amount of granules to pass through the orifice of a funnel. Good flow properties are characterized by a high flow rate. An optimal flow rate is crucial in the tablet compression process, as it ensures a constant and uniform filling of granules into the die cavity. This consistency minimizes the formation of voids or pores within the tablet, thereby ensuring high tablet weight uniformity (Rahma et al. 2024).

In addition, flow properties can also be evaluated by measuring the angle of repose, which is determined based on the angle formed between the height of the granule cone and the radius of its base. Granule flowability is considered to

improve as the cone becomes flatter, indicating a smaller angle of inclination (Sharma et al. 2021). The results of granule evaluation are presented in Table 3. The flow rate and angle of repose test results indicate that formulations F1 and F2 met the criteria for good flow properties, whereas F3 did not meet the criteria due to poor flowability. This condition is attributed to the higher concentration of HPMC in F3 compared to F1 and F2. The hygroscopic nature of HPMC increases electrostatic forces and friction between HPMC particles and the funnel surface, thereby reducing granule flowability (Sharma et al. 2021). Nevertheless, the tablets produced from formulation F3 still met the pharmacopeial requirements for weight uniformity, which may be attributed to the controlled compression conditions that allowed sufficient die filling during the tableting process.

The purpose of the weight uniformity test is to ensure that each compressed tablet has a consistent weight. This parameter is essential because it directly affects the uniformity of active pharmaceutical ingredient content in each dosage unit, which ultimately influences the therapeutic effect. One of the key factors affecting tablet weight uniformity is a constant granule flow rate. Granules with good flowability tend to produce tablets with satisfactory weight uniformity (Kudo, Yasuda, and Matsusaka 2020). The results of the tablet weight uniformity test are presented in Table 4. All formulations met the acceptance criteria for weight uniformity. However, formulation F3 exhibited less consistent tablet weights due to its poorer granule flow properties, which were caused by the higher concentration of HPMC. As HPMC is hygroscopic, increasing its concentration adversely affects granule flowability. Poorly flowing granules result in incomplete and inconsistent filling from the hopper into the die cavity, leading to tablets with non-uniform weight.

The tablet hardness test was conducted to evaluate the mechanical strength of tablets in withstanding applied pressure. The results of the tablet hardness test are shown in Table 5. Adequate tablet hardness is essential to ensure that tablets can withstand mechanical stress during manufacturing, packaging, distribution, and handling by consumers. The acceptable hardness range for floating tablets is 10–20 kg (Fatma et al. 2024). The hardness test results demonstrated that all formulations exhibited tablet hardness values within the acceptable range for sustained-release tablets. Formulation F3 showed the highest tablet hardness due to the higher concentration of HPMC. An increase in HPMC concentration was positively correlated with increased tablet hardness. This effect is attributed to the role of HPMC as a polymeric matrix capable of providing strong interparticulate binding, thereby enhancing tablet consistency and mechanical strength (Yahya and Abdassah 2019).

Tablet friability indicates the tablet's resistance to surface abrasion and mechanical shock. The acceptable limit for tablet friability is less than 1.0%. The friability test results are presented in Table 6. The results showed that all tested tablet formulations met the monograph requirements, with friability values below

1%. In general, an increase in tablet hardness is positively correlated with a decrease in friability values (Yahya and Abdassah 2019).The role of HPMC as a binding matrix is crucial in minimizing tablet friability. Several studies have reported that higher concentrations of HPMC lead to lower tablet friability (Hadinugroho et al. 2023).

Disintegration time is defined as the time required for a tablet to undergo complete disintegration in an appropriate test medium. Disintegration is characterized by the transformation of the dosage form into a dissolved, dispersed, or softened state. The results of the tablet disintegration time test are detailed in Table 7. The results indicated that all formulations met the acceptance criteria, as none disintegrated in more than 60 minutes. Formulation F3 exhibited the longest disintegration time due to its higher HPMC concentration. Increasing the amount of HPMC prolongs tablet disintegration time, as HPMC effectively retards drug release (Yahya and Abdassah 2019).

HPMC significantly affects tablet disintegration behavior. In the gastrointestinal environment, fluid penetrates the tablet matrix, causing the polymer to swell and form a thick gel layer. This gel layer effectively delays tablet disintegration and prolongs disintegration time (Yahya and Abdassah 2019).

Floating ability is a critical requirement for floating drug delivery systems. The evaluated parameters were floating lag time (FLT) and floating duration time (FDT). Floating lag time is defined as the time required for the tablet to begin floating after being placed in the simulated gastric fluid, whereas floating duration time represents the total period during which the tablet remains buoyant (Khedekar, Sontakke, and Biyani 2025). The results are presented in Table 8.

Formulation F1 did not meet the acceptance criteria, as it exhibited an FLT longer than 60 seconds and an FDT of less than 24 hours. In contrast, formulation F3, containing the highest HPMC concentration, showed the shortest FLT. This behavior is attributed to the rapid swelling of HPMC upon contact with gastric fluid, which facilitates CO_2 entrapment within the matrix and promotes buoyancy. Increasing HPMC concentration also contributes to the formation of a strong gel matrix, thereby extending FDT (Yahya and Abdassah 2019).

CONCLUSIONS

Based on the results of this study, it can be concluded that variations in the concentration of hydroxypropyl methylcellulose (HPMC) significantly influence the physical characteristics and floating behavior of floating tablets containing *Psidium guajava* leaf extract. Increasing the HPMC concentration was shown to shorten the floating lag time, prolong the floating duration, increase tablet hardness, extend disintegration time, and reduce tablet friability. Among the tested formulations, the tablet containing 20% HPMC (F2) exhibited the most

optimal overall characteristics and fulfilled all evaluation parameters, indicating its suitability for the development of floating tablets of *Psidium guajava* leaf extract.

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ETHICAL ISSUES

Not applicable. This study did not involve human participants or experimental animals.

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