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Advancing effervescent floating systems: Leveraging multi-layer coatings for enhanced buoyancy and controlled drug release

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ABSTRACT

This study investigated the effectiveness of multi-layer coating techniques in enhancing buoyancy and controlled drug release in effervescent floating systems. By developing a novel multi-layered coated tablet with core effervescent and gas-entrapped layers, we systematically varied the number of spray-coating layers to observe their effects on tablet performance. Increasing the layers reduced the tablet's time to float to 1.25 min. The rapid buoyancy was attributed to the thinner gas-entrapped layers, which enabled faster interactions between the gas-forming agents and the acidic medium. The floating duration remained consistent at over 8 h across all formulations. An increase in coating layers resulted in delayed drug release, controlled via a zero-order and Higuchi model through the gas-entrapped membrane. These findings highlight that multi-layer coating techniques can improve effervescent floating systems for pharmaceutical applications, providing rapid buoyancy and controlled drug release.

Keywords: effervescent floating systems; multi-layer coating technique; buoyancy enhancement; controlled drug release; pharmaceutical formulations

1. INTRODUCTION

The development of effervescent floating drug delivery systems (EFDDS) represents a significant advancement in pharmaceutical sciences. These systems enhance gastric retention and improve drug absorption in the upper gastrointestinal tract, which is essential for medications with specific absorption windows (Das et al., 2021; Huanbutta et al., 2021; Patil et al., 2016; Sriamornsak et al., 2022). The unique characteristics of EFDDS, such as buoyancy and controlled release, play a vital role in increasing drug bioavailability and effectiveness (Das et al., 2021; Sriamornsak et al., 2022). Furthermore, recent advancements in multi-layer coating technologies have enabled more precise control over drug release while maintaining prolonged buoyancy (Amrutkar et al., 2012; Boonyanupap et al., 2022; Kriangkrai et al., 2023; Weiss et al., 2014; Zhang et al., 2012).

Recent studies on multi-layer coating techniques have highlighted their importance in achieving intended therapeutic effects, drawing attention to earlier research in the field (Amrutkar et al., 2012; Dekyndt et al., 2015; Kriangkrai et al., 2014; Zhang et al., 2012). These investigations, each unique in methodology, collectively highlight the practical advantages of multi-

layer coatings in drug delivery. They demonstrate the critical role that both the number of layers and the design of the coating system play in controlling the effervescence and release mechanisms of floating tablets.

Our study explored the impact of multi-layer coating technologies on the buoyancy and drug release characteristics of effervescent floating tablets. By methodically varying the number of spray-coating layers while keeping the overall amount of coating material constant, we aimed to reveal how multi-layer coatings influence the floating behavior and release profiles of these tablets. We hypothesized that an increasing the coating layers would accelerate buoyancy due to intensified interactions between the gas-generating agents and gastric acid. In addition, the research examined how multi-layer coatings contribute to controlled drug release, with a focus on clarifying the diffusion mechanisms across the encapsulated gas barrier. This investigation aimed to advance the development of more efficient and reliable gastroretentive delivery systems, addressing current gaps in pharmaceutical formulations and introducing innovative methods to improve drug absorption, efficacy, and patient adherence.

2. MATERIALS AND METHODS

2.1 Materials

Anhydrous theophylline was sourced from Lianyungang Foreign Trade Corp., Jiangsu, China. Microcrystalline cellulose (Avicel® PH102 from FMC Biopolymer, Cork, Ireland) and lactose monohydrate (Flowlac® 100, from Meggle GmbH, Wasserburg, Germany) were used as the primary excipients for the core tablets. Colloidal silicon dioxide (Aerosil® 200, Degussa AG, Hanau, Germany) and magnesium stearate (from Peter Greven Nederland C.V., Venlo, Netherlands) served as the glidant and lubricant, respectively. The binder for the effervescent layer was hydroxypropyl methylcellulose (HPMC, Anycoat-C® AN15 from Samsung, Korea), plasticized with polyethylene glycol 6000 (PEG 6000 from Fluka Chemie, Switzerland). This layer facilitated the incorporation of sodium bicarbonate ($NaHCO_3$, from Fisher Scientific, UK) as the gas-forming agent. The gas-entrapped membrane consisted of aqueous colloidal polymethacrylate dispersions (Eudragit® RL 30D from Rohm GmbH&Co., Degussa, Germany), plasticized with diethyl phthalate (DEP), a water-insoluble plasticizer obtained from Sigma–Aldrich Chemie GmbH, Steinheim, Germany.

2.2 Effervescent floating tablets with multi-layer film coating

2.2.1 Preparation of core tablets

The core tablets were prepared by direct compression using a single punch tableting machine (Model YH06, Yeo Heng Co., Ltd., Thailand), demonstrating the precision and efficiency of modern pharmaceutical equipment. Each tablet contained 20 mg of anhydrous theophylline, along with 140 mg of both Flowlac® 100 and Avicel® PH102. The initial mixing of the core tablet excipients lasted for 10 min, followed by the addition of magnesium stearate (0.5% w/w) and Aerosil® 200 (0.5% w/w) as lubricants and glidants to aid the manufacturing process. After an additional 3 min of mixing, the homogeneous powder was compressed into tablets with a 9.53-mm diameter, biconvex shape, hardness of 9-10 kg, and an average weight of 300 mg.

2.2.2 Preparation of multi-layer floating tablets

To develop the multi-layer floating tablets, the core tablets underwent a sequential coating process, starting with a gas-forming layer followed by a gas-entrapped membrane layer, using a perforated pan coater (NR-COTA18, N.R. Industries Co., Ltd., Bangkok, Thailand). The initial layer was prepared by blending sodium bicarbonate into an HPMC solution, plasticized with PEG 6000 (10% w/w relative to the HPMC's solid content), and applying this mixture to the core tablets. The sodium bicarbonate-to-HPMC ratio was set at 8:2 w/w, aiming for a 12% weight increase from the effervescent layer, with the solid content of the coating solution maintained at 10% w/w. The subsequent gas-entrapped membrane layer involved a colloidal polymer dispersion, plasticized with 20% w/w DEP (based on polymer solids), which was stirred continuously for at least 30 min before application to achieve an additional 10% weight gain. This study explored multi-layer coating techniques by varying the number of spray-coating layers (L1 – L5), while maintaining consistent proportions of coating substances. The compositions of the five coating layers are shown in Table 1, and the number of double layers was assessed in formulations of LS1-4 and L5. Coating parameters were precisely controlled: a batch size of 1 kg, a preheating temperature of 50°C for 10-30 min, inlet and outlet temperatures of 48–50°C and 39–41°C, respectively, an atomizing air pressure of 2.5 bar, and a spray rate of 5–8 mL/min. After coating, the tablets were dried in the chamber for an additional 30 min to ensure evaporation of any residual moisture, optimizing the storage conditions.

2.3 Scanning electron microscopy

The structural details of the multi-layer films on the tablet were examined using scanning electron microscopy (SEM). This analysis utilized a scanning electron microscope (LEO 1455VP, Zeiss, Jena, Germany), to closely observe the cross-sectional morphology of the samples. Prior to examination, samples were carefully mounted onto stages and coated with a thin layer of gold, approximately 90 nm thick, under vacuum conditions. This preparation ensured optimal conductivity and image clarity during the SEM process. Photomicrographs were captured at an acceleration voltage of 15 kV, with magnifications ranging from 100x to 200x, allowing for a thorough visualization of the structural characteristics and layer integrity of the effervescent floating tablets. These images provided essential insights into the effectiveness of the multi-layer coating techniques employed.

2.4 Determination of floating properties

The floating properties of the tablets were evaluated through a detailed process to measure both the time required for the tablets to ascend to the surface and the duration of their buoyancy. This assessment began by determining the "time to float", or the period needed for a tablet to rise from the bottom to the surface of the testing vessel. Following this, the "floating time" was recorded, indicating the length of time a tablet remained afloat on the medium's surface (Kriangkrai et al., 2014). These observations were conducted using a paddle-

equipped apparatus containing 900 mL of 0.1 N HCl, maintained at 37±0.5°C and stirred at 50 rpm to simulate gastric conditions.

Additionally, the "floating force" of the tablets was quantified to provide further insight into their buoyancy under simulated physiological conditions. Adapting a method from Strübing et al. (2008), a specially modified apparatus was used to measure the total vertical force exerted on the submerged tablet. In this setup, tablets were placed in a beaker filled with 500 mL of an acidic medium (0.1 N HCl at 37±0.5°C). A probe attached to a sample holder was carefully lowered into the center of this medium, and the floating strength was measured over time using a texture analyzer (TA.XT.plus Texture Analyzer, Stable Micro Systems, England). This comprehensive analysis of floating properties provided valuable data on the buoyancy characteristics of the tablets, shedding light on their potential performance in gastroretentive applications.

Table 1. The compositions of the coating layer of multi-layer coated effervescent floating tablets

Formulation	Coating level (% weight gain)										Tablet scheme
	1 Layer		2 Layers		3 Layers		4 Layers		5 Layers		
	$NaHCO_3$	Eudragit RL30D	$NaHCO_3$	Eudragit RL30D	$NaHCO_3$	Eudragit RL30D	$NaHCO_3$	Eudragit RL30D	$NaHCO_3$	Eudragit RL30D	
L1	12	10	-	-	-	-	-	-	-	-	
L2	6	5	6	5	-	-	-	-	-	-	
L3	4	3.33	4	3.33	4	3.33	-	-	-	-	
L4	3	2.5	3	2.5	3	2.5	3	2.5	-	-	
L5	2.4	2	2.4	2	2.4	2	2.4	2	2.4	2	
LS1	2.4	2	-	-	-	-	-	-	-	-	
LS2	2.4	2	2.4	2	-	-	-	-	-	-	
LS3	2.4	2	2.4	2	2.4	2	-	-	-	-	
LS4	2.4	2	2.4	2	2.4	2	2.4	2	-	-	

Note: ○ = core tablet, blue ● = gas-forming layer, gray ● = gas-entrapped layer

2.5 *In vitro* release study

The *in vitro* drug release from the floating tablets was conducted using a USP dissolution apparatus II, equipped with paddles (Agilent Model 708-DS, Agilent Technologies, Inc., USA). The apparatus was filled with 900 mL of 0.1 N HCl, maintained at 37±0.5°C to simulate gastric conditions (Kriangkrai et al., 2014). Samples were collected at specified intervals to monitor the release of theophylline, and the concentration of theophylline in each sample was accurately quantified using a UV/visible spectrophotometer (UV-1800, Shimadzu, Japan), at a detection wavelength of 270 nm. Each *in vitro* release experiment was performed in triplicate to ensure the reliability and reproducibility of the results.

2.6 Analysis of release data

The drug release mechanism from the effervescent floating tablets in 0.1 N HCl was elucidated through a comprehensive analysis using mathematical models, including zero-order, first-order, and Higuchi equations. The zero-order model (Equation 1) describes drug release systems where the release rate remains constant and independent of drug concentration. The first-order model (Equation 2) applies to situations where the release rate depends on drug concentration, indicating a proportional decrease over time. Higuchi's model (Equation 3) describes release as a function of the square root of time, suggesting a diffusion-controlled process consistent with Fick's laws.

$$C = k_0 t \quad (1)$$

where, k_0 represents the zero-order rate constant, measured in concentration per unit time, and t is time.

$$Log\ C = Log\ C_0 - \frac{kt}{2.303} \quad (2)$$

In this formula, C_0 is the initial drug concentration, and k is the first-order rate constant.

$$Q = k\sqrt{t} \quad (3)$$

For the Higuchi equation, k is a constant that reflects the system's design parameters.

The Korsmeyer-Peppas model (Equation 4) was also applied to further investigate the drug release dynamics from polymeric systems, considering both geometric and structural characteristics of the formulation.

$$M_t / M_\infty = kt^n \quad (4)$$

where M_t / M_∞ signifies the fraction of drug released at time t, k is a constant indicative of the system properties, and n is the release exponent, which indicates the drug release mechanism. Analysis of the release exponent n is confined to the portion of the release profile where $M_t / M_\infty \leq 0.6$ to ensure accuracy (Sriamornsak et al., 2007). An n value of 0.45 denotes Fickian (diffusion-controlled) release, while a value of 0.89 suggests Case II (relaxation-controlled) transport or zero-order release. Values between 0.45 and 0.89 indicate non-Fickian or anomalous transport, reflecting a complex interplay between diffusion and polymer relaxation mechanisms. Super Case II kinetics apply for n values greater than 0.89, emphasizing the intricate dynamics of drug release from cylindrical matrices.

This analytical approach, which integrates mathematical models, provides a nuanced understanding of drug release kinetics from effervescent floating tablets. To offers insights into the interdependent factors influencing drug delivery and release patterns in a gastric medium.

2.7 Statistical analysis

Statistical analysis was conducted to evaluate the study's findings, using the least squares method for linear fitting and determination coefficients to assess correlation strength. Differences among group means were analyzed using one-way analysis of variance (one-way ANOVA) or independent sample t-tests, with a 95% confidence level (α=0.05) set to determine statistical significance.

3. RESULTS AND DISCUSSION

3.1 Multi-layered coated tablet

The successful development of multi-layered coated tablets using spraying method with a perforated pan coater marks a significant advancement in the formulation of effervescent floating tablets. This innovative approach focused on optimizing the thickness of each coating layer—the gas-forming and the gas-entrapped layers—while maintaining a consistent amount of coating material across all formulations. Specifically, the coating weigh increased by 12% w/w for the gas-forming layer and 10% w/w for the gas-entrapped layer relative to the core tablet weight. The resulting multi-layer films exhibited thicknesses ranging from 147.5 to 162.5 µm.

Figure 1 illustrates the cross-sectional morphology of the multi-layer films across the L1 to L5 formulations. The gas-forming layer appears in light gray with a rough texture, due to the incorporation of sodium bicarbonate within the HPMC matrix. The gas-entrapped layer is shown as a uniform dark gray, composed of Eudragit® RL 30D. Each layer was clearly defined, indicating that the coating solutions for were sufficiently dried, resulting in fully formed, distinct films.

3.2 Effect of multi-layer film coatings

The impact of multi-layer film coatings on effervescent floating tablets was rigorously examined by varying the number of coating layers from 1 to 5 (L1 to L5), while keeping the amount of coating material for both the gas-forming and gas-entrapped layers consistent across all formulations. Key floating properties— time to float, floating duration, and floating force—are detailed in Table 2. This investigation revealed that multi-layer film coatings significantly enhance the tablets' buoyancy, as demonstrated by a significant decrease in the time to float. Tablets with five layers (L5) achieved buoyancy up to 9.64 times faster than those with a single layer (L1), with L5 tablets floating in 1.49±0.57 min compared to 14.37±1.90 min for L1. The addition of layers reduced the thickness of each gas-forming and gas-entrapped layer, accelerating acid solution penetration into the gas-forming layer and facilitating rapid buoyancy. Consistent with previous research, a thinner gas-entrapped layer was associated with reduced time to float (Strübing et al., 2008; Sungthongjeen et al., 2008). Optimal buoyancy within 2 min was achieved with gas-forming layer thickness ranging from 2.4% to 4.0% w/w (L3 – L5). Moreover, all tablet formulations remain buoyant for over 8 h, underscoring the efficacy of multi-layer film coatings in enhancing floating properties.

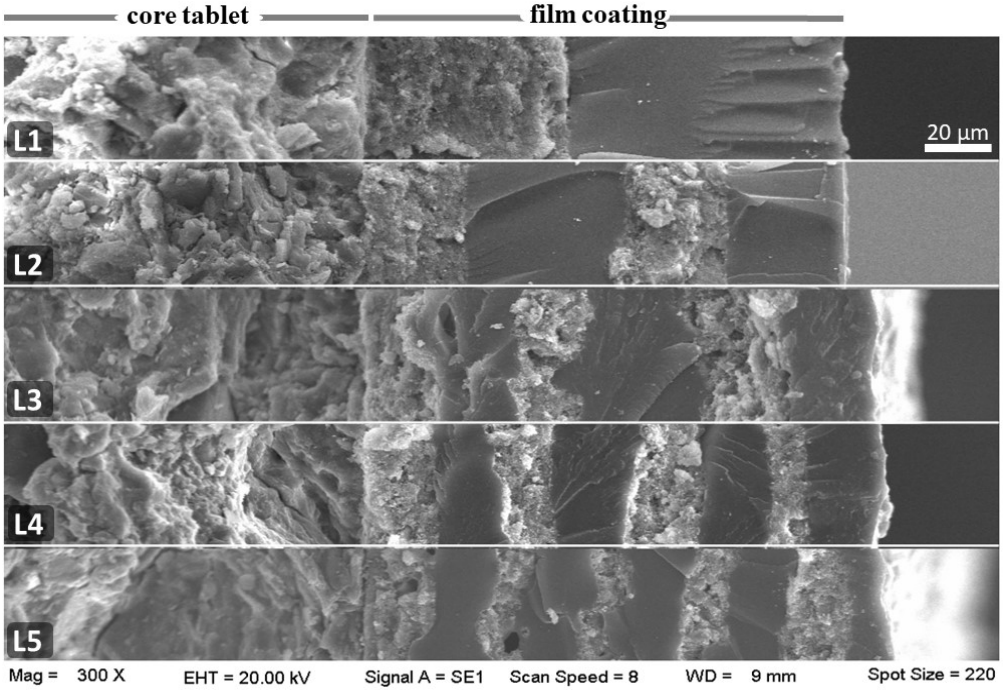

Figure 1. Cross-sectional morphology of multi-layer coated effervescent floating tablets at 300x magnification
Note: The image shows the consistent coating proportions applied to each layer, with 12% w/w for the effervescent (gas-forming) layer and 10% w/w for the gas-entrapped membrane.

Table 2. Floating properties of multi-layer coated effervescent floating tablets

Formulation	Time to float (min±SD)	Floating times (h)	Floating force at 1 h (mN±SD)
L1	14.37±1.90 ^{a}	>8	5.7773±0.64 ^{a}
L2	6.27±1.03 ^{b}	>8	3.9350±0.53 ^{b}
L3	2.07±0.44 ^{c}	>8	3.3213±0.35 ^{c}
L4	2.09±0.09 ^{c}	>8	3.0973±0.51 ^{c}
L5	1.49±0.57 ^{cde}	>8	3.1057±0.40 ^{c}
LS1	1.42±0.09 ^{d}	<1	-
LS2	1.29±0.07 ^{e}	>8	-
LS3	1.29±0.06 ^{e}	>8	-
LS4	1.25±0.09 ^{e}	>8	-

Note: The notation a-e denotes significant differences with a p-value < 0.05.

The assessment of the floating force exerted by the tablets highlighted notable effects based on the multi-layer coatings structure. At the one-hour mark, the L1 formulation demonstrated a higher floating force than formulations L2 – L5. This result is primarily due to L1's single, thicker coating layer, which enhance interaction between the acidic medium and the gas-generating layer, thereby, yielding increased gas production (Sungthongjeen et al., 2008). Additionally, L1's gas-entrapped layer, being the thickest, functions as an effective barrier, retaining gas longer and thus extending buoyancy duration, as shown in Figure 2.

With additional layers, the acidic solution's penetration through each gas-entrapped layer becomes slower, resulting in a staggered gas generation across the gas-forming layers in formulations L3 – L5. This incremental layering also yields thinner gas-trapping layers, enhancing initial buoyancy but, potentially compromise long-term gas retention, indicating potential gas escape from the system. These findings highlight the delicate balance required between layer thickness, gas generation, and retention to optimize the floating performance of effervescent floating tablets.

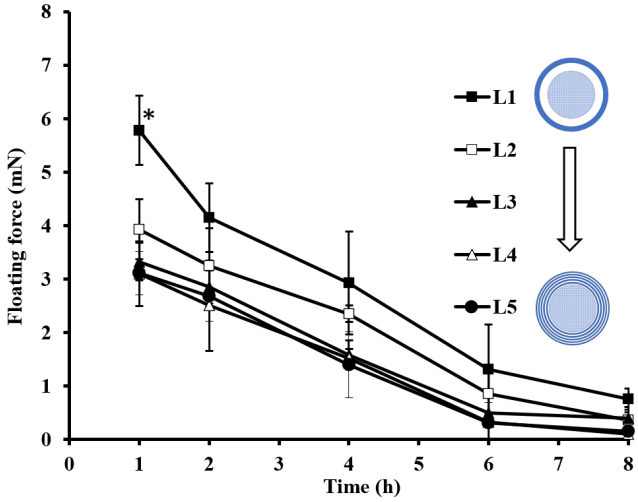

Figure 2. Effect of multi-layer film coatings on the floating force of multi-layer coated effervescent floating tablets (*p<0.05)

Figure 3 illustrates the drug release profiles of multi-layer coated effervescent floating tablets using USP apparatus II. The drug release pattern is divided into three distinct phases. In the first phase, which lasts less than 2 h, a lag time in drug release was observed due to the time required for the solvent to penetrate the system, initiating subsequent gas generation and drug dissolution. During the middle phase, the drug was gradually released, with the concentration in the system nearly depleted after 6 h (Kriangkrai et al., 2014; Weiss et al., 2014). The investigation into drug release from multi-layer coated effervescent floating tablets revealed a significant trend: an incremental decrease in the drug release rate with an increase in the number of layers (L3 – L5), as illustrated in Figure 3. This deceleration in drug release was observed despite the total thickness of the gas-trapping layer remaining constant. Two primary mechanisms were identified as contributing factors to this phenomenon. Firstly, the process of diffusion and partitioning plays a crucial role, as the drug must pass through the solution within the tablet and then cross the gas-trapping film layer before being released into the external environment (Strübing et al., 2008; Sungthongjeen et al., 2008). With each additional layer, these diffusion and partitioning steps were repeated, effectively extending the drug's release duration of the system. This observation aligns with findings from previous research by Dekyndt et al. (2015), which highlighted that increased layering reduces drug release rates by creating obstructed diffusion pathways. Secondly, the presence of gas within each layer introduces an additional barrier to drug release. The inert gas bubbles, which do not facilitate drug movement, mean that with each added layer, the drug is increasingly likely to encounter these gas obstacles, further impeding its release.

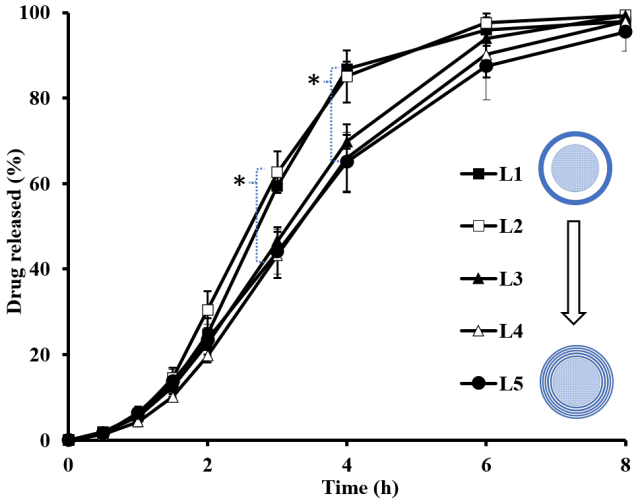

Figure 3. Effect of multi-layer film coatings on the drug release of multi-layer coated effervescent floating tablets (*p-value < 0.05)

3.3 Effect of number of double layers

To elucidate the impact of increasing the number of double layers on effervescent floating tablets, a study was conducted in which the weight gain for both the gas-forming and gas-entrapped layers was set at 2% and 2.4% w/w, respectively. This approach involved sequentially adding additional layers to the tablets, resulting in a series of formulations labeled LS1 to L5, as visually represented in Figure 4. As the number of double layers increased, a corresponding increase in the thickness of the coating layers was observed.

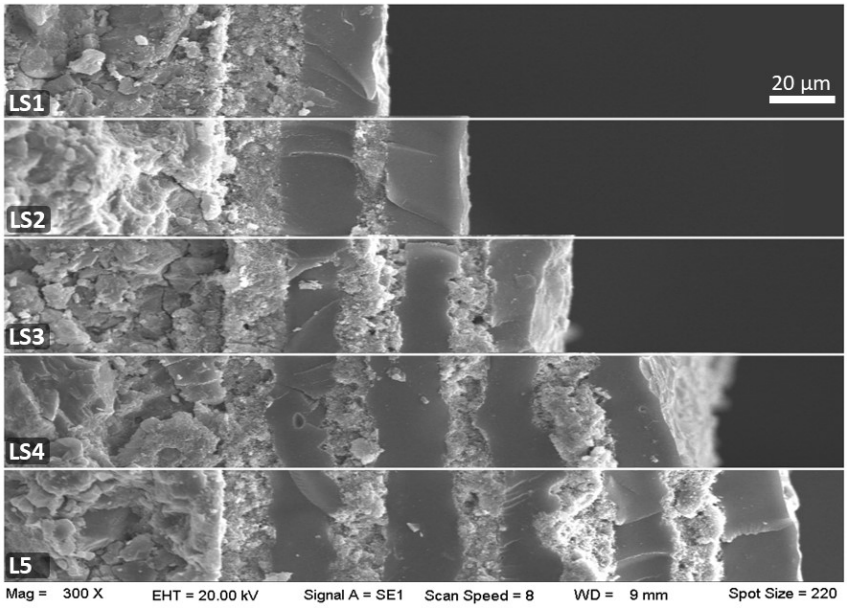

Figure 4. Morphological evolution of multi-layer coated effervescent floating tablets with increasing double layers, viewed at 300x magnification

The investigation into the influence of varying double layers on multi-layer coated effervescent floating tablets, as detailed in Table 2, explored the transition from LS1 to L5 formulations. Interestingly, the study revealed that the time to float was consistent across all five formulations, showing no significant variation. This uniformity in buoyancy onset could be attributed to the consistent thickness of each coating layer, which ensured that the outermost gas-entrapping layers across formulations had similar thicknesses and, consequently, comparable rates of water permeability. Such consistency facilitated the uniform penetration of 0.1 N HCl across formulations, enabling similar rates of reaction with $NaHCO_3$ and the generation of carbon dioxide gas, which is critical for tablet buoyancy. In terms of floating duration, a notable difference was observed with LS1, which had a floating time of less than 1 h, whereas the other formulations remained buoyancy for over 8 h. The shorter floating duration in LS1 was attributed to an inadequate thickness of the gas-entrapped layers, which failed to effectively contain the generated carbon dioxide gas, leading to leakage (Kriangkrai et al., 2014). This leakage reduced the tablet's volume and increased its density, causing it to descend prematurely.

Conversely, the formulations with a greater number of layers exhibited enhanced gas generation capabilities. Despite some carbon dioxide gas escaping from the outer layer, the ongoing permeation of 0.1 N HCl into subsequent layers sustained gas production. This continuous generation of gas, combined with the increased thickness of gas-trapping layers provided by additional coatings, prolonged tablet buoyancy. This nuanced understanding highlights the critical balance between layer thickness, gas generation, and retention, highlighting the complex dynamics that govern the floating efficacy of effervescent floating tablets.

In examining drug release behavior across multi-layer coated effervescent floating tablets, from formulations LS1 to L5, a marked decrease in the drug release rate was observed, as shown in Figure 5. This trend corresponded with the cumulative increase in coating material volume from additional layers. The modulation of drug release was intricately linked to three critical factors. Firstly, the overall thickness of the coating layer significantly influenced the drug's transit out of the tablet, with thicker barriers naturally slowing down the release process, creating successive obstacles that further prolonged drug release. Lastly, the presence of gas within each layer acted as a physical barrier, adding yet another impediment to the drug's pathway to release. These factors underscore the nuanced relationship between the structural attributes of coating layers and the drug release kinetics, emphasizing the pivotal role of precise formulation design in optimizing therapeutic efficacy.

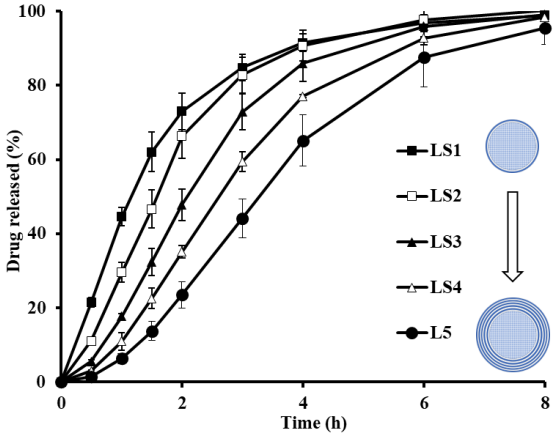

Figure 5. Effect of number of double layers on the drug release of multi-layer coated effervescent floating tablets

3.4 Analysis of release data

In the investigation of theophylline release from multi-layer coated effervescent floating tablets, it was observed that the release kinetics were significantly influenced by both the number of coating layers and the number of double layers. The drug release followed zero-order and Higuchi models, as shown in Table 3, suggesting that release kinetics depended on both the polymeric membrane and matrix diffusion-controlled mechanisms. A previous study reported a zero-order release pattern in effervescent floating tablets (Kriangkrai et al., 2014). However, Sungthongjeen et al. found that the release profile of floating pellets, based on the gas formation technique, was dominated by drug diffusion through the polymer matrix (Higuchi model) from the core pellets (Sungthongjeen et al., 2006). This contrasts with drug diffusion through the polymeric membrane, attributed to the high water permeability of Eudragit® RL membrane. Additionally, the application of the Korsmeyer-Peppas model confirmed complex kinetics, with n values greater than 0.89, indicating Super Case II kinetics. This suggests that a combination of diffusion, swelling, and erosion contributes to the drug release process. As the layer count increased, the release rate diminished, likely due to hindered diffusion across the enhanced barrier. This observation aligns with visual analyses in Figures 3 and 5, indicating that multiple coating layers impact drug release rates. Tadros similarly reported non-Fickian release behavior in floating tablets for ciprofloxacin hydrochloride (Tadros, 2010), with n values ranging from 0.45 to 0.89, suggesting anomalous transport driven by both diffusion and erosion processes. The non-Fickian diffusion approach echoes the findings of Tufail et al. (2024), who reported that the drug release from bilayer floating effervescent tablets was dominated by the higher viscosity of HPMC. This study enhances our understanding of how formulation properties affect release kinetics, offering insights for future drug delivery innovations.

Table 3. Mathematic modeling and drug release kinetics of theophylline from multi-layer coated effervescent floating tablets

Formulation	Correlation coefficient, r^2				Kinetic constant, k (Korsmeyer-Peppas model) (h^{-n})	Diffusional exponent, n (Korsmeyer-Peppas model)
	Zero-order	First-order	Higuchi	Korsmeyer-Peppas		
L1	0.9965	0.9505	0.9927	0.9907	0.0620	1.9623
L2	0.9926	0.9175	0.9985	0.9744	0.0780	1.8014
L3	0.9996	0.9582	0.9935	0.9944	0.0637	1.7631
L4	0.9992	0.9532	0.9928	0.9925	0.0619	1.6050
L5	0.9998	0.9641	0.9942	0.9963	0.0755	1.5787
LS1	0.9757	0.9060	0.9963	0.9875	0.4169	0.8966
LS2	0.9994	0.9403	0.9874	0.9972	0.2818	1.2849
LS3	0.9975	0.9348	0.9980	0.9922	0.1849	1.2902
LS4	0.9954	0.9395	0.9961	0.9939	0.1151	1.5385

4. CONCLUSION

This study highlights significant advancements in EFDDS achieved through multi-layer coating techniques. These techniques enhanced buoyancy and controlled drug release, promising improved bioavailability and efficacy of gastroretentive drug formulations. Tablets with multiple layers floated faster, with five-layer formulations showing the best performance. Thinner layers facilitated quicker interaction with gastric fluids, expediting the floating process while maintaining a consistent buoyancy duration of over 8 h across all formulations. Moreover, an increase in coating layers associated with delayed drug release, following a controlled release pattern consistent with zero-order and Higuchi models. These findings have valuable implications for pharmaceutical sciences, offering new opportunities to optimize EFDDS and improve patient outcomes.

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